BEFORE THE HON'BLE NATIONAL GREEN TRIBUNAL, (SZ), CHENNAI
M.A.No. 03/2021
In
ORIGINAL APPLICATION No. 71/2020 (SZ)

Between:
The Chef Secretary,
Secretary, Hyderabad,
State of Telangana
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Phone No.040-23452620

Applicant
(3rd Respondent)

And
1. Union of India
Rep. by its Secretary,
Union Ministry of Environment, Forest & CC
Indira Paryavaran Bhavan
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1st Respondent
(1st Respondent)

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Hyderabad
Dated: 01.10.2021

Counsel for Applicant

A geotechnical note on the proposed lift at Jonnalaboguda Balancing Reservoir (stage II) under Kalwakurthi Lift Irrigation Scheme, Mahaboobnagar District, Andhra Pradesh.

M. Raju, Geologist (Sr.)
J. Srihari, Geologist (Jr.)
A. Anil Kumar, Asst. Geologist
Geological Survey ofI ndia, Hyderabad.

Introduction

The Kalwakurthi Lift Irrigation Scheme is proposed to provide irrigation and drinking water facility to the chronically drought affected upland areas in Mahaboobnagar District of Andhra Pradesh by lifting water from the River Krishna from the foreshore of the Neelam Sanjeeva Reddy Sagar (Srisailam) Project reservoir. The command area is broadly situated between contours +490 m and +320 m. The Krishna River flows from west to east and the foreshore of the Srisailam reservoir extends to +270 m contour. Therefore, it is the obvious necessity to lift water from the Krishna River to irrigate the command area. The scheme envisages to irrigate 2.5 lakh acres utilising the 25 TMC of water by lifting from the foreshore of the Srisailam reservoir to height of 245 m, in 3 stages of lift using high power pump sets and with 4 balancing reservoirs, connected to each other with deep cut canals tandem with tunnels, as per the procedure adopted in the Alimineti Madhava Reddy Lift irrigation, which is successfully functioning in the Nalgonda district.

Main components of the project are: (i) Stage I lifts water about 96 m from the foreshore of the Srisailam reservoir, feed water to Yellur Balancing Reservoir and Singotam Balancing Reservoir. (ii) Stage II lifts water 79 m to feed into Jonnalaboguda Balancing Reservoir, whose FRL is +407 m and TBL is +410 m and its gross storage 1.79 TMC. (iii) Stage III proposes to lift water 101 m to feed Gudipalligattu Balancing Reservoir. Present study is confined to the proposal of stage II as provided by M/s Navayuga - IVRCL & SEW JV, which is the lift component just before the Jonnalaboguda Balancing Reservoir. The stage II lift predominantly comprises the following.

(i) A 6.6 m finished dia, 4.645 km long, D-shaped, tunnel from R.D. 4.00 to 8.645 km.
(ii) The tunnel joins Surge Pool having its dimensions 20 m wide, 94 m long, 71 m deep from R.D. 8.645 to 8.665 km.
(iii) Followed by 20 m wide, 94 m long, 77 m deep Pump House from R.D. 8.715 to 8.735 km.
(iv) 5 Draft Tube Tunnels connecting Surge Pool and Pump House; 5 Delivery Mains, each have 2.5 m finished dia, 45° inclined tunnels connecting Pump House and Cistern.
(v) Cistern to collect water from Delivery Mains at an elevation of RL +405 m from R.D. 8.930 to 8.960 km.

At the request of the Executive Engineer, M.G.L.I.S.P. Division No.2, I.& C.A.D. Department, Government of Andhra Pradesh, Nagarkurnool, vide his letter No. EE/MGLIP.Dn.2/NKL/DB/D2/294 M, dated 17.11.2005, the item of investigation was taken up by the department and field studies were carried out by authors as detailed below.

M. Raju : 7.12.2005
M. Raju and A. Anil Kumar: 10.2.2006
M. Raju : 20.6.2006
M. Raju and J. Srihari : 23.8.2006 and 24.8.2006.

Sri V. Balachandran, Director, Engineering Geology Division, Geological Survey of India visited the project site on 7th December, 2005, extended his guidance to conduct the studies. The co-operation extended by the authorities of I.& C.A.D. Department and M/s Navayuga - IVRCL & SEW JV in furtherance of field studies is gratefully acknowledged.

Salient Features

Salient features of stage II lift furnished by M/s Navayuga - IVRCL & SEW JV are mentioned below.

Gravity canal from Singotam Balancing Reservoir to Jonnalaboguda Balancing Reservoir from 17.40 to 23.80 km:

Length of canal : 6.40 km
Discharge : 83.19 cumecs
Bed width : 20.10 m
FSD : 4.10 m
Bed fall : 1 in 9,000
Side slopes : ¼:1 (HR)
Velocity : 1.027 m/sec.
'n' : 0.0215

Lift at Jonnalaboguda Balancing Reservoir

CBL at lift point : +328.44 m
Highest level of pumping : +408.75 m
Static head for lifting : +80.3 m
No. of pumps of 25 MW : 4 Nos.
Power utilisation : 193.19 million units
Ayacut : 2,35,000 Acres

Jonnalaboguda Balancing Reservoir

FRL :+407 m
TBL :+410 m
Gross storage at FRL :1.79 TMC
Water spread at FRL : 1254 Acres
Length of earth dam : 1.80 km

Geology

Regional Geology

The area exhibits undulating topography of low lying hillocks and vast stretches of plain country with a few mounds and ridges. Peninsular Gneissic Complex comprising older metamorphics, migmatite, gneisses and younger granites to granite suite of rocks are the predominant rock types present in the area. The granites vary widely in colour, grain size and composition. Granite suite is generally represented by grey granite, hornblende granite alkali feldspar granite, pink granite and granodiorite. The gneisses and granites have been traversed by acid and basic intrusives. The basic intrusives comprise of dykes of pyroxenite, gabbro, dolerite (some of them are porphyritic), whereas, quartz, pegmatite and epidote veins, quartz reefs and granophyre dyke represent acid intrusives. The contact relationship between various types of granites is transitional. It is seen that within very short distances, the granites change in colour and composition resulting in their individual continuity and demarcation difficult. Hence, predominance of the type is taken.

Table-1.

	Cuddapah Super Group	Srisailam Quartzite	
----------Unconformity----------			
	Younger intrusives	Acid intrusives	Granophyre dyke Quartz reef Quartz, pegmatite and epidote veins
		Basic intrusives	Basic intrusives, gabbro, dolerite (at places porphyritic)
Precambrian	Granitic Complex	Medium grained pink granites Coarse grained grey and pink granite alkali feldspar granite Hornblende granite Granodiorite (porphyroblastic at places) Migmatite and banded biotite gneiss	
	Older metamorphics	Banded magnetite quartzite, amphibolite hornblende, biotite schist	

Local Geology

The proposed tunnel alignment has 1 to 2 m thick overburden soil cover with sporadic outcrops of grey to pink coloured granite of Granite Complex of Peninsular Gneissic Complex. Whereas, the proposed surge pool and pump house locations are also covered with scree/overburden soil, underlying that fresh, grey to pink granite is present. The granite is traversed by dolerite dykes and also met with in bore holes drilled at R.D.s 4.70, 8.750 and 9.07 km. The ridge present at the proposed cistern location predominantly consists of quartz reef. It is a linear quartz vein having width 5 to 10 m, extending for length about 2 km, trending in N70° W-S70° E direction with almost vertical dip. The quartz is dull white to brownish white in colour, sheared and un brecciated. The biotite gneiss and granites at places exhibit foliation trending in N30° W-S30° E direction with vertical to sub-vertical dips. The rock formation exhibit joints and prominent sets of joints present are indicated below.

(i) Strike: N20° to 30°W – S20° to 30°E; vertical to sub-vertical dips.
(ii) Strike: N80°W – S80°E; vertical to sub-vertical dips.
(iii) Strike: N50°W – S50°E; vertical to sub-vertical dips.
(iv) Strike: N20°E – S20°W; vertical to sub-vertical dips.
(v) Strike: N60° to 70°E – S60° to 70°W; vertical to sub-vertical dips.

Faulting in the area is represented by displacement of dykes at several places. Major fault directions are NW-SE. Various rock types exposed in the area show evidences of shearing at many places. Shearing is observed in N70°E – S70°W; N70°W – S70°E and N–S directions.

Sub-surface explorations

In order to know sub-surface geological conditions, 8 bore holes were drilled (6 along the proposed tunnel alignment and 2 at the proposed lift complex). The cores obtained from the holes were logged and the detailed geological logs are enclosed (appendix-I). Salient features of the data obtained are given in table-2. The data indicate the presence of overburden soil, thickness vary from 0.75 to 12 m, underlained by 1.00 to 13.50 m tick weathered rock, followed by fresh and hard grey/pink coloured granite with pegmatite intrusion. Dolerite dyke intrusions are also met with in bore holes at R.D. 8.75 and 9.07 km. The surrounding country rock present around dolerite dyke intrusion is closely fractured. The core recoveries are at minimum and RQDs in the portions fall to zero. The rock formation is further fractured along the ridge where quartz reef is met with at R.D. 9.050 km.

Table-2. Salient features of data obtained from bore holes drilled along the proposed tunnel alignment.

B.H.No.	At R.D. in km	Feature	Ground level (+m)	Total depth drilled (m)	Thickness of overburden (m)	Thickness of weathered rock (m)	Depth to fresh rock (m)	Fresh rock level (+m)	Rock type
BH-1	4.70	Tunnel alignment	359.83	50.00	0.75	4.25	5.00	354.83	Grey granite with pegmatite intruded with dolerite dyke.
BH-2	5.30	-do-	355.96	47.28	7.10	4.40	11.50	344.46	Grey/pink granite.
BH-3	5.70	-do-	356.29	50.00	7.90	1.50	9.40	346.89	Pink granite with pegmatite.
BH-4	6.18	-do-	359.185	50.44	4.50	5.50	10.00	349.185	Pink granite, core closely fractured.
BH-5	6.78	-do-	363.78	55.00	6.00	1.00	7.00	356.78	Grey granite with pegmatite
BH-6	7.80	-do-	370.40	68.00	2.50	2.00	4.50	365.90	Pink/grey granite with pegmatite
BH-7	8.75	-do-	382.87	77.40	6.20	12.30	18.50	364.37	Pink granite, with dolerite dyke intrusion. Core closely fractured
BH-8	9.07	Cistern	405.00	92.20	12.00	13.50	25.50	379.50	Grey/pink granite, with dolerite dyke intrusion.

Tunnel

A 6.6 m dia, 4.645 km long, D-shaped, tunnel is proposed from R.D. 4.00 to 8.645 km. The initial portion of the tunnel is aligned in N35°W direction and then takes a kink at an interpolated point R.D. 4.680 km and then runs in N28°E direction. The bed levels of the tunnel are +316.50 m at RD 4.00 km at its entrance portal and +310 m at RD 8.645 km at its exit, the joining point with the surge pool. The ground levels at intake portal of the tunnel +358.55 m and at its exit +378.79 m. The tunnel alignment is covered under 1 to 2 m thick overburden soil with sporadic outcrops of grey to pink coloured granite, granite gneiss of Granite Complex of Peninsular Gneissic Complex. The granites at places exhibit foliation trending in N30°W-S30°E direction with vertical to sub-vertical dips and is traversed by dolerite dykes and pegmatite.

As per the geological mapping carried out along the proposed tunnel alignment and as indicated in the bore holes drilled along the alignment, the minimum rock cover over the tunnel grade is about 30 m in the stream bed at R.D. 5.40 km and maximum rock cover is about 54 m at its joining point with the surge pool chamber at R.D. 8.645 km indicating cover adequacy. Adequate lateral cover is also available all along the proposed length of the tunnel alignment. The tunnel alignment cuts across a stream course between R.D.5.20 to 5.55 km, where 5 to 8 m thick alluvial sand is present as overburden material. The rock cover underlying the stream course is about 30 m. Similarly, the proposed tunnel alignment passes below the existing Mahasamudram irrigation tank between R.D. 6.30 and 6.65 km. The tank bed is covered with thin clay deposit underlying that bed rock granite is present. The rock cover below the tank bed is expected to be 37 m.

As the rock type is fresh and hard, tunnelling in granite is expected to be relatively problem free. By adopting proper excavation procedure, desired profile of tunnel can be achieved. At the intersection of joints, especially at the contact of dyke bodies with granite the rock is expected to be sheared, and possibility of wedge failures, over break is more pronounced. They can be attended to by applying spot rock bolts.

Prominent discontinuities present in the area trend in N30° to 70°W - S30° to 70°E direction and the tunnel alignment cut across the discontinuities. Though the major portion of the tunnel alignment is expected to be dry to wet with some minor dripping of seepage, as some discontinuities are likely to continue connecting the ground water, there is a possibility of heavy seepage in some minor pockets/reaches, especially below the stream bed and Mahasamudram irrigation tank. Such pockets are to be closely monitored at the time of excavation. In case of necessity, provision for pre grouting the periphery of the tunnel may be considered to arrest/minimise the seepage into the tunnel.

At the intake portal of the tunnel, a gate shaft is proposed, which need to be properly placed on suitable foundation and by providing suitable back slopes over the intake portal. The surface drainage to be lined and properly guided into the canal, without effecting the gate shaft and transition of canal to tunnel.

Adit

One adit is also under progress of excavation to approach the main tunnel. The adit has its entrance portal at north of Mahasamudram tank on right side of the tunnel and joins the tunnel at its R.D. 7.45 km. The adit is being excavated in massive granite and the tunnelling medium is found to be very good.

Surge Pool & Pump House Complex

The Construction Agency proposed to have Surge Pool from R.D. 8.645 to 8.665 km and Pump House from R.D. 8.715 to 8.735 km. The proposed surge pool and pump house structures involve formation of deep open chambers, where excavation of vertical walls to the order of about 70 m are to be made. The proposed locations are covered with overburden soil, underlying that fresh grey/pink granite is available. The granite is traversed by pegmatite. A bore hole (BH-7) was drilled at R.D. 8.750 km, nearby the proposed Pump House location. The bore hole is met with dolerite dyke intrusion within the granite bed rock. Probably by the intrusive effect of dyke intrusion, the core is closely fractured and dissected; resulting core recovery and RQD are prominently reduced up to 40 m depth. The RQD further reduced from 66 to 77 m, the last depth drilled. It is inferred that a shear zone passes nearby, which caused deterioration in rock condition. Another bore hole (BH-8) drilled at R.D. 9.07 km also met with a dolerite dyke intrusion. Poor core recoveries and poor RQD values are also consistently noticed in the hole up to 35 m depth. A quartz reef is present in the ridge from R.D. 9.040 to 9.050 km, which affected the rock mass present in close vicinity, fractured and blocky.

As fractured rock and vulnerable features are observed in close vicinity to the proposed Pump House, it is suggested to shift the Surge Pool and Pump House complex about 75 m away from the original proposal to keep the structures in sound rock medium. The newly proposed locations of Surge pool may be from R.D. 8.553 to 8.573 km and Pump House from R.D. 8.623 to 8.643 km. And in such case, the tunnel will be from R.D. 4.00 to 8.553 km, instead of earlier proposal from R.D. 4.00 to 8.645 km.

The newly proposed locations of Surge Pool and Pump House are also covered with overburden soil, underlying that fresh grey/pink granite is available. Though the newly proposed locations are devoid of any borehole data, a Geophysical profile was arranged by the Agency along the alignment, which indicates the presence of continuous massive granite at shallow depth in the area. Deep and vertical cut in bed rock in both the chambers need to be carried out by adopting suitable blasting pattern. In order to prevent slope failures during excavation of deep pits, precaution may be taken by driving rock bolts, applying shotcrete, particularly on the downstream side long wall. Suitable rock bolts driven into the wall, cutting across the joint pattern can strengthen the walls. The exact pattern of rock bolts and their orientation can be worked out on examination of actual cut face of the chambers. A suitable berm is required at the contact of the top overburden soil and the underlying weathered bedrock granite.

Table-3: Rock Mass Rating

S.No.	Parameter	From R.D. 4.05 to 4.60 km; From R.D. 4.70 to 5.20 km; From R.D. 5.55 to 8.645 km;		From R.D. 4.0 to 4.05 km; From R.D. 4.60 to 4.70 km; From R.D. 5.20 to 5.55 km; At R.D. 8.645 km	
		Ranges of values	Rating	Ranges of values	Rating
1	Strength of intact rock material	100 - 250	12	50 - 100	7
2.	RQD	75 - 90	17	<25	3
3.	Spacing of discontinuities	0.6 – 2.0	10	0.06 – 0.2	8
4.	Condition of discontinuities	Very rough	30	Slickensided	10
5.	Ground water condition	Damp	10	Dripping	4
6.	Orientation correction	Very favourable	0	Very favourable	0
7.	RMR	II Good Rock	79	IV Poor Rock	32
8.	Stand up time for 7 m span		About 10 years		Immediate collapse, need supports immediately

Table-4: 'Q' system

S.No.	Parameter	From R.D. 4.05 to 4.60 km; From R.D. 4.70 to 5.20 km; From R.D. 5.55 to 8.645 km;	From R.D. 4.0 to 4.05 km; From R.D. 4.60 to 4.70 km; From R.D. 5.20 to 5.55 km; At R.D. 8.645 km
	Parameter	Rating	Rating
1	RQD	75	10
2.	Jn	9	15
3.	Jr	3	2
4.	Ja	0.75	2
5.	Jw	1	0.66
6.	SRF	1	2.5
7.	Q	33	0.176
8.	ESR	1.6	1.6
9.	Equivalent Dimension=Span/ESR	7/1.6 = 4.375	7/1.6 = 4.375
10.	Tentative support system suggested for 7 m span	Unsupported	Rock bolting, bolt length 2.4 m, bolt spacing 1.5 m + Fibre reinforced shotcrete 10 cm thickness

Q=RQD/Jn x Jr/Ja x Jw/SRF

The proposed location of the chambers is feasible for deep excavation. However, as the orientation of long axis of chambers trending in N60°W direction is almost parallel to the prominent discontinuities present in the area, which are widely spaced, enough care may be taken during excavation bearing this in view. The rock ledge present at the inter space between the two large chambers is proposed to be 50 m, which is about 2 times of the chamber width on either side, and it is considered adequate. Driving rock bolts into the rock ledge from surge pool side and from pump house side will further strengthen the rock ledge.

The proposed delivery mains having 5 inclined shafts of 2.5 m dia each, connecting Pump House and cistern are also suitably located, keeping away from the shear zone, which is met with in bore hole drilled at 8.750 km. Accordingly, the inclined shafts commence from bottom of Pump House from R.D. 8.643 km and touch the ground level at R.D. 8.735 km. From R.D. 8.735 to 8.950 km i.e., up to the proposed Cistern, Delivery Mains run on the ground surface with suitable anchor blocks.

A Cistern is proposed on the ridge present on left flank of the Jonnalaboguda Balancing Reservoir from R.D. 8.950 to 8.980 km at RL +405 m. The cistern is almost located close to the quartz reef and the quartz present there is sheared and fractured. While locating the Cistern, adequate excavation to be made to avoid loose and dislodged rock blocks and to keep the structure on firm rock foundation.

Rock Mass Characterisation

In order to understand the rock mass before excavation of the tunnel and chambers, it is attempted to describe the rock mass likely to be present by adopting standard methodology of Rock Mass Characterisation, such as, 'Q' system (developed by N. Barton and Grimstad) and Rock Mass Rating (developed by Bieniawski). By obtaining information from surface geological mapping and logging of bore holes drilled along the tunnel alignment, a preliminary Rock Mass Characterisation is made. It helps to have a general opinion of rock type and its condition likely to be met with in the excavation to be made. It can be improved and updated on having actual assessment after excavation commenced.

Conclusions

The geotechnical investigations carried out at the proposed lift complex helped to arrive at the following conclusions.

1. The area at the proposed tunnel alignment and the proposed lift complex is geologically mapped and evaluated. 8 bore holes were drilled in the area to understand sub-surface geological condition. Cores obtained were logged for making geotechnical assessment and feasibility of the proposed appurtenant works.

2. Excavation of the proposed tunnel R.D. 4.00 to 8.553 km is feasible. 'Q' values and Rock Mass Ratings are estimated and tentative support requirements are suggested in a few reaches. However, it needs reassessment after actual excavation or while excavation is in progress.

3. The Construction Agency originally proposed to have Surge Pool from R.D. 8.645 to 8.665 km and Pump House from R.D. 8.715 to 8.735 km. Bore holes drilled in the vicinity indicate dolerite dyke intrusion into the granite, causing deterioration of rock condition. As the rock closely fractured, a shear zone is inferred there. As fractured rock and vulnerable features are observed in close vicinity to the proposed Pump House, it is suggested to shift the Surge Pool and Pump House complex about 75 m away from the original proposal to keep the structures in sound rock medium. The newly proposed locations of Surge pool may be from R.D. 8.553 to 8.573 km and Pump House from R.D. 8.623 to 8.643 km. And in such case, the length of tunnel will be from R.D. 4.00 to 8.553 km instead of earlier proposal from R.D. 4.00 to 8.645 km.

4. Excavation of deep pits for the proposed Surge Pool and Pump House is considered feasible in the terrain. Suggested to provide suitable berm at the contact of the overburden soil and bed rock. Also suggested to drive rock bolts into vertical walls, especially into the down stream side wall and to protect the rock ledge in between.

5. The proposed Draft Tube tunnels and inclined Pressure Mains are also considered feasible for their excavation in the terrain.

6. Cistern proposed from R.D. 8.950 to 8.980 km at an elevation of +405 m is feasible. However, the top loose and dislodged rock fragments need to be removed before forming the Cistern on the ground. The ultimate water level in the Cistern has to be taken above FRL of the Jonnalaboguda Balancing Reservoir.

7. Based on surface geological mapping carried out and evaluation of bore hole data, a tentative Rock Mass Characterisation is made for a preliminary assessment. 'Q' values and Rock Mass Ratings are estimated adopting standard techniques. Tentative support requirements are suggested for having prior idea and for safe execution of excavation. However, actual support requirements will be worked out on examination and assessment of actual excavations.

M. Raju

(M. RAJU)
Geologist (Sr.)

Date: 12.03.2013
Inspection Note

Project Title

Construction Stage Engineering Geological Investigations of Surge pool and Pump House (5x30 MW) area of Mahatma Gandhi Kalwakurthi Lift Irrigations Scheme, Stage-II, Mahabubnagar District, Andhra Pradesh (Phase-II)

The Mahatma Gandhi Kalwakurthi Lift Irrigation Scheme (MGKLIS) is being constructed having the three stages (I, II & III) for lifting the Krishna water from Srisailam reservoir (back water) to Gudipallygattu balancing reservoir through channels and tunnels. Navayuga Engineering Company Ltd is constructing MGKLIS package 2 located at Sathapur village, Mahboobnagar District, A.P. MGKLIS-II is being constructed for lifting the water from Singotam balancing reservoir to Jonnalaboguda balancing reservoir. The major components of the project are: one 4.0 km long gravity canal from Singotam balancing reservoir having bed width of 19.15m, one 4.553 km long and 6.85m finished diameter 'D' shaped tunnel, one surge pool (94m long x 40m width x 75m height), 50m long five numbers of draft tube tunnels, one pump house (94m long X 20m width X 78m height) and five numbers, 15m long horizontal & 305m long inclined having 3.0 m finished diameter delivery main tunnels. In between the Surge pool and Pump house 50m wide rock ledge is proposed is the design. So far Navayuga Engineering Company Ltd. has excavated surge pool upto foundation level and pump house upto app. RL 330m. The ground level of surge pool is at RL +382m and the foundation level is at RL +307m while the ground level of pump house is at RL +383m and the foundation level is at RL +305.40m. Three draft tubes have been constructed and two are under excavation. All the four sides of the surge pool and pump house will be lined with 500mm RCC filling from the bed line up to max. surge level and floored with 300mm thick raft foundation to distribute the load as per design specification.

Dr. A.K. Naithani, Senior Scientist, NIRM inspected the site on the request of Navayuga Engineering Company Ltd. The project site was visited on 06.03.2013 and 07.03.2013 regarding the shear zones treatments and lining of surge pool area. The following and other project officials of M/s Navayuga Engineering Company Ltd. and Andhra Pradesh Irrigation and CAD Department were present during the site inspection and the discussions.

NIRM	Navayuga Engineering Company Ltd.	Andhra Pradesh Irrigation and CAD Department
Dr. A.K. Naithani Project Leader, EGD	Mr. G. Shashidhar Reddy, AGM	Mr. S. Suresh, Executive Engineer
	Mr. Kashi Govinda Rao, Senior Project Manager	Mr. K. Sanjeeva Rao, Deputy Executive Engineer
	Mr. Raja Mani, Deputy Project Manager	Mr. P.V. Nagender, Deputy Executive Engineer
	Mr. Vinod Kumar, Assistant Project Manager	
	Mr. P. Sobhan Babu, Site Engineer	

The following decisions were taken after the discussions at the site:

1. Regarding the treatment of thick shear zones special bolting system was suggested at the site to the Contractor Engineers. First the gauge should be cleaned out to the desired extent, then this dental excavation should be backfilled with concrete (M>25) and finally rock bolt installed across the shear zone. The concrete should be allowed to cure for 10-12 days before installation of rock bolt. The length of rock bolt will be varying from 5 to 7 m as per the site condition. The other support system should be as per approved design.
2. In the surge pool area for south, east and west walls concrete lining can be done from the foundation level to the max. Surge Level + 5 m i.e. +340 level in steps i.e. following the cut slope and the remaining portion from +340 to ground level 100 mm shotcreting to be done.
3. For north wall stability has to be checked by the designer, because after excavation the width of rock ledge is less than 20m, particularly towards western side. The reinforced lining will be stitched with the insitu rockmass by 3m long, 20mm dia grouted rock bolts at a spacing of 1.5 mts c/c.
4. Controlled blasting should be adopted for rock excavation at the ultimate walls of the project to minimize deterioration of the rock mass and loose rock mass should be removed by mechanical excavator.

Dr. Ajay Kumar Naithani
Head, Engineering Geology Department
National Institute of Rock Mechanics
Ministry of Mines, Govt. of India
P.O. Champion Reefs
Kolar Gold Field – 563 117, Karnataka

Ref. NIRM/EGD/MGKLIS-II/2013/06 Dated: 14.05.2013

Note on geotechnical assessment of the foundation of surge pool – MGKLIS-II

Project Title - Construction Stage Engineering Geological Investigations of Surge pool and Pump House (5x30 MW) area of Mahatma Gandhi Kalwakurthi Lift Irrigations Scheme, Stage-II, Mahabubnagar District, Andhra Pradesh (Phase-II)

By
A.K. Naithani and L.G. Singh
National Institute of Rock Mechanics, Kolar Gold Fields, Karnataka

1. INTRODUCTION

The Mahatma Gandhi Kalwakurthi Lift Irrigation Scheme (MGKLIS) is being constructed having the three stages (I, II & III) for lifting the Krishna water from Srisailam reservoir (back water) to Gudipallygattu balancing reservoir through channels and tunnels. M/s Navayuga Engineering Company Ltd (NECL) is constructing MGKLIS package 2 located at Sathapur village, Mahboobnagar District, A.P. MGKLIS-II is being constructed for lifting the water from Singotam balancing reservoir to Jonnalaboguda balancing reservoir.

The major components of the project are: one 4.0 km long gravity canal from Singotam balancing reservoir having bed width of 19.15m, one 4.553 km long and 6.85m finished diameter 'D' shaped tunnel, one surge pool (94m long x 40m width x 75m height), 50m long five numbers of draft tube tunnels, one pump house (94m long X 20m width X 78m height) and five numbers, 15m long horizontal & 305m long inclined having 3.0 m finished diameter delivery main tunnels. In between the surge pool and pump house 50m wide rock ledge is proposed is the design.

So far Navayuga Engineering Company Ltd has excavated surge pool up to foundation level and pump house up to app. RL 330m. The ground level of surge pool is at RL +382m and the foundation level is at RL +307m while the ground level of pump house is at RL +383m and the foundation level is at RL +305.40m. Three draft tubes have been constructed and two are under excavation. All the four sides of the surge pool and pump house will be lined with 500mm RCC filling from the bed line up to max. surge level and floored with 300mm thick raft foundation to distribute the load as per design specification.

This note pertains to large scale engineering geological mapping on 1:200 scale of foundation strata at foundation level of surge pool of MGKLIS-II. The objective of this study is to advise suitable engineering measures for the treatment of foundation of surge pool based on detailed engineering geological investigations. The report pertaining to Construction Stage Engineering Geological Investigations of Surge pool and Pump House (5x30 MW) area of Mahatma Gandhi Kalwakurthi Lift Irrigations Scheme, Stage-II, Mahabubnagar District, Andhra Pradesh was submitted by National Institute of Rock Mechanics (NIRM) to Navayuga Engineering Company Ltd in March 2012, containing the large scale geological mapping on 1:200 scale of excavated walls of surge pool and pump house and rock ledge between surge pool and pump of MGKLIS-II. In the present study, detailed engineering geological mapping on 1:200 scale in the foundation of surge pool has been carried out using the Total Station and a total area of approximately 3,600 sq.m. has been mapped (Drawing Nos. NIRM/MGKLIS-II/EG-13-01/01).

2. METHODOLOGY

Grids were prepared for mapping the surge pool floor area. The size of the grid is 2 m X 2 m, which was decided based on the mapping accuracy and resolution required for such investigations. Grids for mapping were marked on the floor by NECL surveyor using elevation & chainages provided by them. Detailed examination of rock types in each grid was carried out which includes mineralogical composition, texture, classification and nomenclature and degree/grade of weathering. Fracture filling that have taken place in the study site were examined and recorded. The attitude and structure of the rocks, fractures and joint pattern present in the floor was determined for mapping. ISRM (1978), classifications for weathered rock mass was used to characterize the rock mass into different grade (Table-1). The assessment of RMR (Bieniawski, 1989) for granites rock masses, based on the rock joints and their nature and laboratory test data has been attempted.

Table 1: Description of Weathering Grade (ISRM, 1978)

Term	Description	Grade
Fresh	No visible sign of rock material weathering; perhaps slight discolouration on major discontinuity surfaces.	I
Slightly weathered	Discolouration indicates weathering of rock material and discontinuity surfaces. All the rock material may be discoloured by weathering and may be somewhat weaker externally than in its fresh condition.	II
Moderately weathered	Less than half of the rock material is decomposed and / or disintegrated to a soil. Fresh or discoloured rock is present either as a continuous framework or as core stones.	III
Highly	More than half of the rock material is decomposed and / or disintegrated to a soil.	IV

weathered	Fresh or discoloured rock is present either as a discontinuous framework or as core stones.	
Completely weathered	All rock material is decomposed and / or disintegrated to soil. The original mass structure is largely intact.	V
Residual soil	All rock material is converted to soil. The mass structure and material fabric are destroyed. There is a large change in volume, but the soil has not been significantly transported.	VI

3. ENGINEERING GEOLOGICAL & GEOTECHNICAL ASSESSMENTS OF FOUNDATION

Foundation floor geological mapping of the important structures is essential to provide permanent data input for geological interpretations during construction and also it forms valuable documentation for post-construction stage. For very important structures like deep surge pool and pump house of lift irrigation, the foundation strata have to be well studied and documented for credible geologic interpretations. Rock is usually recognized as the best foundation material. However, design engineers should be aware of the dangers associated with heterogeneity and unfavourable rock conditions since over-stressing a rock foundation may result in large differential settlements or perhaps sudden failure.

In order to evaluate the design basis foundation parameters for surge pool of MGKLIS-II, engineering geological mapping (on 1:200 scale) was carried out by NIRM Geologists. All the discontinuities in the rock mass of foundation of surge pool with the zone of influence of the foundation has been identified and mapped. The primary purpose of the mapping is to provide a permanent record of conditions during the excavation. Mapping will be used to assess the requirement of any ground improvement. This permanent foundation record will assist in making better interpretation of post-construction foundation instrumentation data.

The floor of surge pool was examined on a grid to grid basis; the size of the grid is 2 m X 2 m. All the lithological and structural features were observed and mapped using Total Station surveying equipment and shown in the final foundation grade geological plan map. Classification of rock mass using Rock Mass Rating (RMR) of Bieniawski (1989) has been attempted and based on investigations recommendations for the treatment of foundation are given.

3.1 Geological and Structural Assessment – Floor of Surge Pool

The foundation of surge pool will be resting as per design on a raft of 300 mm thick at about 75.0 m below the existing ground level for functional requirement. The design ground level is

at RL +307.00 but in some areas it is excavated up to an average RL +306.34 and the over excavation is varying from 0.100m to 1.141m because of presence of unfavourable discontinuities, shear zones and blasting. On the basis of surface geological mapping the excavated surface is acceptable for foundation because the rock mass is competent. Total 3600 sq.m excavated foundation area of surge pool floor has been geologically mapped. Geological foundation mapping was done after the excavation and before first pore of concrete. 2 m x 2 m grids were used for mapping of the floor. Based on the field observations and evidences, it is found that the entire floor area consists of coarse grained, hard and jointed pink granites. Total fifteen shear zones are mapped. The width of the shear zones are varying from 0.1 cm to 40 cm cm. No displacement has been recorded along shear zones. No evidences of faulting are observed on the surface of floor area. The structural features observed during the mapping indicated the need for consolidation grouting so that the entire floor are function as single rock mass.

Pink granites are coarse grained, hard and jointed and shows phenocryst of alkali feldspar and quartz. Main minerals composition is alkali feldspars, quartz, mica and amphiboles. Five prominent joints set are developed and along the joint plane clay filling/coating was also recorded. Joints are irregular in pattern. Granites are generally fresh to moderately weathered (WI–WIII). At the foundation level granites are traversed by dolerite dykes (feature D1, D2 & D3 marked in Drawing No NIRM/MGKLIS-II/EG-13-01/01). Dolerite dykes are fine grained and greenish-black in colour. The width of the dykes varies from 40cm to 200cm and their strike length is more than 100 m in excavated part of surge pool. Dykes are generally sheared and in D1 and D3 clay gouge was observed. Plagioclase and clinopyroxene (augite / titanaugite) are the main minerals occurring in ophitic to sub-ophitic textures in dolerite. Quartz, epidote and opaques occur as accessories. Amphibole, biotite, sericite occur as alteration products. Dykes are generally moderately to highly weathered (WIII – WIV).

The rock mass is characterized by prominent five number of joint sets, which are continuous and persistent, slightly rough to smooth with unaltered joint walls. Staining has been recorded along the joint surfaces where the joints are tight and where opening is up to 20.0 mm, soft clay mineral and crushed material filling has been recorded. In general, the rock mass is characterized by dry condition or minor inflow i.e. < 5.0 l/min. Crack/fractures developed due

to excavation / blasting were also recorded during geological mapping. Some of the cracks are tight while some are open with size of the opening varying from 1 mm to 4 mm. Hairline cracks developed due to excavation work were also recorded. The prominent joints recorded in the coarse grained granite at the foundation of surge pool are given in Table 2.

Plate 1. Cleaning the foundation level of Surge Pool

Plate 2. Marking of grids on the foundation level

Plate 3. Collection of engineering geological data from the foundation of surge pool

Plate 4. Highly jointed area marked as feature A in the Drawing No. NIRM/MGKLIS-II/EG1301/01

Table 2: Prominent joints developed in coarse grained granite at the foundation of surge pool

Joint No	Dip Direction	Dip Amount	Spacing (cm)	Persistence (m)	Roughness	Aperture (mm)	Infilling (mm)	Groundwater Condition	Remarks
1	320	30-40	-	25	Slightly rough to smooth	Up to 70	Clay	Damp	Shear zone (SH-15)
2	290	Vertical	7-70	10	Slightly rough	Tight to 1	Nil	Damp	Joint plane is fresh
3	290	Vertical	20-30	7	Slightly rough	Tight to 1	Nil	Damp	Joint plane is stained
4	320	Vertical	28-50	7	Slightly rough	Tight	Nil	Damp	Joint plane is fresh
5	320	Vertical	28-50	7	Slightly rough	Tight	Nil	Damp	Joint plane is fresh
6	040-070	35-40	7-80	8	Slightly rough	Tight to 2	Nil	Damp	Joint plane is stained
7	070	35-40	7-80	8	Slightly rough	Tight to 2	Nil	Damp	Joint plane is stained
8	055	50	25	15	Slightly rough	Tight to 2	Nil	Damp	Joint plane is stained
9	300	Vertical	25	15	Slightly rough	Tight	Nil	Damp	Joint plane is fresh
10	060	55	25	15	Slightly rough	Tight	Nil	Damp	Joint plane is fresh
11	240	Vertical	-	10	Slightly rough	Tight	Nil	Damp	Joint plane is fresh

12	130	35	100	10	Slightly rough	Tight	Nil	Damp	Joint plane is fresh
13	305	48	10-80	25	Slightly rough	Tight to 1	Nil	Damp	Joint plane is stained
14	295	Vertical	30-70	15	Slightly rough	Tight	Nil	Damp	Joint plane is fresh
15	065	25-30	50-60	20	Slightly rough	Tight	Nil	Damp	Joint plane is fresh
16	270	Vertical	-	8	Slightly rough	Tight to 2	Nil	Damp	Joint plane is stained
16a	350	70-75	-	8	Slightly rough	Tight to 2	Nil	Damp	Joint plane is stained
17	020	60-70	25-30	17	Slightly rough	Tight to 2	Nil	Damp	Joint plane is stained
18	290	Vertical	-	24	Slightly rough to smooth	Tight to 2	Clay	Damp	Slightly weathered
19	020-060	50-60	10-20	15	Slightly rough	Tight	Nil	Damp	Joint plane is fresh
20	260	60	30	20	Slightly rough to smooth	40	Clay	Damp	Shear zone (SH-14)
21	260	50-55	-	23	Slightly rough to smooth	300 to 400	Clay	Damp	Shear zone (SH-13)
22	210	Vertical	-	32	Slightly rough	20	Crushed rock material	Damp	Joint plane is fresh
23	290	50	20-40	5	Slightly rough	Tight	Nil	Damp	Joint plane is fresh
24	290	Vertical	7-10	24	Slightly rough	Tight	Nil	Damp	Joint plane is fresh
25	100	40-60	10-20	30	Slightly rough	Tight	Nil	Damp	Joint plane is fresh
26	060	50-60	10-20	11	Slightly rough	Tight to 2	Nil	Damp	Joint plane is stained
27	255	Vertical	10-20	15	Slightly rough	Tight	Nil	Damp	Joint plane is fresh
28	290	Vertical	10-100	10	Slightly rough	Tight	Nil	Damp	Joint plane is fresh
29	290	Vertical	10-100	10	Slightly rough	Tight	Nil	Damp	Joint plane is fresh
30	220	70	15-60	20	Slightly rough	Tight	Nil	Damp	Joint plane is fresh
30a	310	Vertical	15-60	20	Slightly rough	Tight	Nil	Damp	Joint plane is fresh
31	045	50	16-70	20	Slightly rough	Tight to 1	Nil	Damp	Joint plane is stained
32	290	Vertical	10-50	11	Slightly rough	Tight to 1	Nil	Damp	Joint plane is stained
32a	020	80-85	10-50	11	Slightly rough	Tight to 1	Nil	Damp	Joint plane is stained
33	010	70-80	10-30	24	Slightly rough	Tight to 1	Nil	Damp	Joint plane is stained
35	010	40-50	20-30	13	Slightly rough	Tight to 1	Nil	Damp	Joint plane is stained
36	260	60	10-100	12	Slightly rough	Tight to 1	Nil	Damp	Joint plane is stained
37	020	Vertical	-	8	Slightly rough	Tight to 1	Nil	Damp	Joint plane is stained
38	325	20-25	80-100	14	Slightly rough	Tight to 1	Nil	Damp	Joint plane is stained
39	310	70-75	30-40	15	Slightly rough	Tight to 1	Nil	Damp	Joint plane is stained
40	310	45-60	-	22	Slightly rough	Tight to 1	Nil	Damp	Joint plane is stained
42	230-265	60-70	-	84	Smooth	300 to 1500	Clay	Damp	Dolerite dyke (D1) sheared with clay gauge, moderately to highly weathered
43	050	80-85	7-30	10	Slightly rough	Tight to 1	Nil	Damp	Joint plane is stained
44	040	70-80	7-30	8	Slightly rough	Tight to 1	Nil	Damp	Joint plane is stained
45	310	Vertical	7-40	20	Slightly rough	Tight to 1	Nil	Damp	Joint plane is stained
46	300	Vertical	7-35	15	Slightly rough	Tight to 1	Nil	Damp	Joint plane is stained
47	020	80	16-35	12	Slightly rough	Tight to 1	Nil	Damp	Joint plane is stained
47a	200	60-70	16-35	12	Slightly rough	Tight to 1	Nil	Damp	Joint plane is stained
48	020	75	10-40	20	Slightly rough	Tight to 1	Nil	Damp	Joint plane is stained
49	035	85	20-50	20	Slightly rough	Tight to 1	Nil	Damp	Joint plane is stained
50	170	65-70	40-50	18	Slightly rough	Tight	Nil	Damp	Joint plane is fresh
51	255	Vertical	-	20	Smooth	50	Clay	Damp	Shear zone (SH-12)

52	325	30-50	100	12	Slightly rough	Tight	Nil	Damp	Joint plane is fresh
53	260	Vertical	20-40	20	Slightly rough	Tight	Nil	Damp	Joint plane is fresh
54	335	20-30	100	14	Slightly rough	Tight to 1	Nil	Damp	Joint plane is stained
55	70-80	30-35	150	7	Slightly rough	Tight to 1	Nil	Damp	Joint plane is stained
56	310	70-75	-	15	Slightly rough	Tight to 1	Nil	Damp	Joint plane is stained
57	090	45-50	20-40	22	Slightly rough	Tight to 1	Nil	Damp	Joint plane is stained
58	200	80-85	20-70	15	Slightly rough	Tight	Nil	Damp	Joint plane is fresh
59	005	40-50	20-60	22	Slightly rough	Tight to 1	Nil	Damp	Joint plane is stained
60	200	80	10-30	12	Slightly rough	Tight to 1	Nil	Damp	Joint plane is stained
60a	010	80	10-30	11	Slightly rough	Tight to 1	Nil	Damp	Joint plane is stained
61	205	65	10-60	25	Slightly rough	Tight	Nil	Damp	Joint plane is fresh
62	005	70-80	20-50	18	Slightly rough	Tight	Nil	Damp	Joint plane is fresh
62a	215	80-85	20-50	17	Slightly rough	Tight	Nil	Damp	Joint plane is fresh
63	090	40	80	12	Slightly rough	Tight	Nil	Damp	Joint plane is fresh
64	130	30	-	7	Smooth	2mm	Clay	Damp	Shear zone (SH-11)
65	120-130	40	60	8	Slightly rough	Tight to 1	Nil	Damp	Joint plane is stained
66	080	35	-	20	Smooth	Tight to1	Clay	Damp	Slightly to moderately weathered
67	010	20	10-40	22	Slightly rough	Tight	Nil	Damp	Joint plane is fresh
68	235	45	-	4	Smooth	3	Crushed rock filling	Damp	Fresh to slightly weathered
69	260	65-70	-	13	Slightly rough	Tight	Nil	Damp	Joint plane is fresh
73	270	80-85	-	24	Smooth	2000	Crushed material	Damp	Dolerite dyke (D2) sheared and crushed material, moderately to highly weathered
74	040	45	10-30	13	Smooth	1 to 5	Clay	Damp	Minor shear zone (SH-4)
74a	310	Vertical	10-30	12	Smooth	1 to 5	Clay	Damp	Minor shear zone (SH-4)
75	010	80-85	10-15	30	Smooth	1 to 3	Clay	Damp	Minor shear zone (SH-2)
76	170	40-50	10-40	9	Slightly rough	Tight to 1	Nil	Damp	Joint plane is stained
77	220	65-70	100	25	Smooth	3 to 7	Clay	Damp	Minor shear zone (SH-6)
78	050	60-70	10-15	24	Smooth	3 to 7	Clay	Damp	Minor shear zone (SH-7)
79	310	Vertical	-	16	Smooth	300 to 400	Clay	Damp	Dolerite dyke (D3) sheared with clay gauge, moderately to highly weathered
80	310	Vertical	-	8	Smooth	200 to 300	Clay	Damp	Shear zone (SH-10)
80a	310	Vertical	-	11	Smooth	200 to 300	Clay	Damp	Shear zone (SH-09)
81	270	60-65	10-100	25	Smooth	2 to 4	Clay	Damp	Shear zone (SH-08)
82	310	45-50	40-60	34	Smooth	2 to 4	Clay	Damp	Shear zone (SH-01)
83	310	40-80	-	11	Smooth	2 to 4	Clay	Damp	Shear zone (SH-03)
84	300	60	50-80	7	Slightly rough	1 to 2	Nil	Damp	Joint plane is stained
85	215	65	10-30	7	Slightly rough	1 to 2	Nil	Damp	Joint plane is stained
86	305	65	100	14	Slightly rough	1 to 2	Nil	Damp	Joint plane is stained
87	310	Vertical	10-30	25	Slightly rough	Tight	Nil	Damp	Joint plane is fresh
87a	210	80	10-30	25	Slightly rough to smooth	1 to 2	Clay	Damp	Slightly weathered
88	210	45-60	10-40	7	Slightly rough	1 to 2	Nil	Damp	Joint plane is stained
89	110	45	100	14	Slightly rough to smooth	1 to 2	Clay	Damp	Slightly weathered
90	270	Vertical	-	18	Slightly rough	1 to 2	Nil	Damp	Joint plane is stained
91	170	30-70	10-35	13	Smooth	4 to 6	Clay	Damp	Shear zone (SH-05)
92	020	80-85	10-30	20	Slightly rough	1 to 2	Nil	Damp	Joint plane is stained
93	025	65	10-30	30	Slightly rough	Tight to 1	Nil	Damp	Joint plane is stained
94	010	65	10-30	22	Slightly rough	Tight to 1	Nil	Damp	Joint plane is stained
95	035	60-65	10-40	34	Slightly rough	Tight to 1	Nil	Damp	Joint plane is stained
96	025	75	-	23	Slightly rough	Tight to 1	Nil	Damp	Joint plane is fresh
97	010	60	-	12	Slightly rough	1 to 2	Nil	Damp	Joint plane is stained
98	010	65	-	10	Slightly rough	Tight to 1	Nil	Damp	Joint plane is stained
99	110	30-55	100	12	Slightly rough	1 to 2	Nil	Damp	Joint plane is stained
100	080	45	-	9	Slightly rough	Tight to 1	Nil	Damp	Joint plane is fresh
101	310	55	30	12	Slightly rough	1 to 2	Nil	Damp	Joint plane is stained
102	295	55	100	18	Slightly rough	Tight to 1	Nil	Damp	Joint plane is stained

103	300	50	50-100	22	Slightly rough	Tight to 1	Nil	Damp	Joint plane is fresh
104	310	60-80	100	25	Slightly rough	Tight to 1	Nil	Damp	Joint plane is stained
105	325	30-55	100	22	Slightly rough	Tight to 1	Nil	Damp	Joint plane is stained
106	330	30-45	-	15	Slightly rough	Tight to 1	Nil	Damp	Joint plane is stained
107	325	40	-	14	Slightly rough	Tight to 1	Nil	Damp	Joint plane is stained
108	100	45	-	18	Slightly rough	Tight	Nil	Damp	Joint plane is fresh
109	100	45	-	8	Slightly rough	Tight	Nil	Damp	Joint plane is fresh
110	025	20	100	10	Slightly rough	Tight to 1	Nil	Damp	Joint plane is fresh

3.2 Geological Plan – Floor of Surge Pool

Based on the engineering geological mapping carried out at the foundation of surge pool, and the details collected including lithology and joint patterns measured in the field, the geological map was compiled on scale of 1:200, and it has been appended to this note as Drawing No NIRM/MGKLIS-II/EG-13-01/01.

3.3 Evaluation of Safe Bearing Capacity

Safe Bearing Pressure is an important factor for the design of foundation for large engineering structures. The ultimate bearing capacity (q.ult) is defined as average load per unit area required to produce failure by rupture of a supporting rock mass. The bearing capacity in jointed rock masses can be estimated by Rock Types, Rock Mass Rating (RMR), Uniaxial Compressive Strength (UCS), Point Load Strength, Rock Quality Designations (RQD), Pressure Meter Test and Plate Load Test (IS:12070–1987, Peck et.al., 1974). The methods based on the Rock Type and Rock Mass Rating (RMR) are used to evaluate the bearing capacity foundation parameters for the foundation of surge pool. For this the average Rock Mass Rating (RMR) is taken for the estimation of Safe Bearing Pressure using the procedure given in IS Code : 12070 – 1987.

Based on Rock Mass Classification: The rock type is coarse grained granite, which is a 'crystalline bedrock, including granite'; therefore

Rock Type (Material)	=	Granite
Net safe bearing pressure (q_{ns})	**=**	**1000 t/m^2**
Correction factor (for rock mass with continuous joints with aperture up to 5 mm and clay filled)	=	0.50
Allowable bearing pressure (q_{allow})	=	q_{ns} * correction factor
	=	1000 * 0.50 t/m^2
	=	500.0 t/m^2

Based on Rock Mass Rating, (RMR):

Average RMR	=	47.4
Classification of rock mass	=	Class III
Description of rock mass	=	Fair
Net safe bearing pressure (q_{ns})	**=**	**194.45 t/m^2**
Correction factor (for rock mass with continuous joints with aperture up to 5 mm and clay filled)	=	0.50
Allowable bearing pressure (q_{allow})	=	q_{ns} * correction factor
	=	194.45 * 0.50
	=	**97.225 t/m^2**

The safe bearing pressure and allowable bearing pressure calculated from the above two methods viz. by rock characteristic and RMR method are summarized in table 3 for the surge pool.

Table 3 : Safe bearing pressure and allowable bearing pressure for surge pool foundation

Sl. No.	Method	Safe Bearing Pressure, t/m^2	Allowable Bearing Pressure, t/m^2
01	Base on rock characteristic	1000.0	500.0
02	Based on Rock Mass Rating	194.45	97.225

It is recommended to adopt the allowable pressure value obtained from RMR, that is 97.225 t/m^2 for the design of foundation on this stratum for surge pool.

3.4 Geotechnical Assessment - Floor of Surge Pool

The floor area of the surge pool is falling under weathering grade 1 to 2 (WI - WIII). The grade of the rock mass as evaluated from the UCS and conditions of discontinuities has RMR values are varying from 37 to 63 and fall under poor to good rock. Randomly 20 samples were selected from the foundation of surge pool for the unconfined compressive strength and test results are summarized in Table 4. The uniaxial compressive strength test is primarily an index test for strength classification of rock materials. Tests were conducted at site and specimens were tested at a moisture content close to field conditions. Locations of samples are shown in Drawing No NIRM/MGKLIS-II/EG-13-01/01.

Table 4 : Uniaxial compressive strength of rock from foundation level of surge pool

Sr. No	Sample No.	Rock Type	Load (N)	Cross Sectional Area (mm^2)	Uniaxial Compressive Strength (UCS) (MPa)		RMR	
					Value	Class (ISRM, 1978)	Value	Class
1	UCS-1	Coarse Pink Granite	750000	3600	208.33	Very High Strength	57	III
2	UCS-2	Coarse Pink Granite	750000	3600	208.33	Very High Strength	63	II
3	UCS-3	Coarse Pink Granite	800000	3600	222.22	Very High Strength	43	III
4	UCS-4	Coarse Pink Granite	1000000	4900	204.08	Very High Strength	47	III
5	UCS-5	Coarse Pink Granite	900000	4900	183.67	Very High Strength	54	III
6	UCS-6	Coarse Pink Granite	700000	3600	194.44	Very High Strength	58	III
7	UCS-7	Coarse Pink Granite	850000	3600	236.11	Very High Strength	42	III
8	UCS-8	Coarse Pink Granite	900000	3600	250.00	Very High Strength	47	III
9	UCS-9	Coarse Pink Granite	900000	4900	183.67	Very High Strength	59	III
10	UCS-10	Coarse Pink Granite	900000	4900	183.67	Very High Strength	52	III
11	UCS-11	Coarse Pink Granite	850000	3600	236.11	Very High Strength	40	IV
12	UCS-12	Coarse Pink Granite	1050000	3600	291.67	Extremely High Strength	41	III
13	UCS-13	Coarse Pink Granite	900000	3600	250.00	Very High Strength	47	III
14	UCS-14	Coarse Pink Granite	750000	3600	208.33	Very High Strength	50	III
15	UCS-15	Coarse Pink Granite	900000	3600	250.00	Very High Strength	37	IV
16	UCS-16	Coarse Pink Granite	800000	3600	222.22	Very High Strength	47	III
17	UCS-17	Coarse Pink Granite	750000	3600	208.33	Very High Strength	38	IV
18	UCS-18	Coarse Pink Granite	900000	4900	183.67	Very High Strength	38	IV
19	UCS-19	Coarse Pink Granite	650000	4900	132.65	Very High Strength	38	IV
20	UCS-20	Coarse Pink Granite	750000	4900	153.06	Extremely High Strength	50	III

4. Recommendations – Floor of Surge Pool

Based on above studies, the following recommendations have been made:

a. Based on the field observations and evidences, it is observed that area in the floor of surge pool site is characterized by coarse grained, hard and jointed pink granite (containing alkali feldspars, quartz, mica and amphibole) traversed by dolerite dykes. Depth persistence and lateral prevalence of bed rock was established. The floor region is fresh to moderately weathered (W-I to W-III) but prominent vertical/inclined joints are present.

b. The test results and field observations indicate that the rock mass is quite competent and acceptable for the foundation of the surge pool. The grade of the rock mass as evaluated from the condition of discontinuities and UCS, has RMR values varying from 37 to 63 and falls under poor to good rock mass.

c. The basic requirements of a foundation are firstly, it should behave as a homogeneous / monolith, secondly, it should be free from differential settlement & sliding and thirdly,

if the structure has to retain water above/behind it, the foundation should be watertight. The foundation of the surge pool has to be made massive and requires varied treatments on all the three counts to achieve the objective.

d. The rocks exposed at the foundation grade of the surge pool are jointed pink granite interspersed with sheared dolerite dykes. Shear zones having the varying thickness are mapped which are having differential mechanical behavior due to varying physical properties leading to differential settlement. In order to overcome the problem of differential settlement shear zones treatment plan is given in Table 5.

Table 5 : Treatment plan for shear zones at the foundation level of Surge Pool

Shear Zone	Thickness	Recommended Excavation Depth	Treatment Plan
D1	Up to 2.0 m	2.8 m	Dolerite dyke is sheared having clay gauge, should be excavated up to 2.8 m depth by mechanical breakers and backfilled with concrete (M≥25) up to the foundation level after systematic cleaning, washing and jetting to make the rock mass monolithic. The concrete should be allowed to cure for 10-12 days before rock bolting. The length of rock bolt will be varying from 4 to 5 m as per the site condition.
D2	Up to 2.0 m	2.0 m	Dolerite dyke is crushed and sheared, should be excavated up to 2.0 m depth by mechanical breakers and backfilled with concrete (M≥25) up to the foundation level. The concrete should be allowed to cure for 10-12 days before rock bolting. The length of rock bolt will be varying from 4 to 5 m as per the site condition.
D3	Up to 0.40 m	1.6 m	Dolerite dyke is sheared having clay gauge, should be excavated up to 1.6 m depth by mechanical breakers and backfilled with concrete (M≥25) up to the foundation level.
SH-9, SH-10, SH-13	30.00 to 40.00 cm	0.80 m	Shear zones area should be excavated up to 0.80 m depth by mechanical breakers and backfilled with concrete (M≥25) up to the foundation level.
SH-15	Up to 7.00 cm	0.25 m	Shear zone having clay gauge should be excavated up to 0.25 m depth by mechanical breakers and backfilled with concrete (M≥25) up to the foundation level.
SH-1, SH-2, SH-3, SH-4, SH-5, SH-6, SH-7, SH-8, SH-11, SH-12, SH-14	Up to 4.00 cm	0.10 m	Shear zones having clay gauge should be excavated up to 0.10 m depth by mechanical breakers and backfilled with concrete (M≥25) up to the foundation level.

e. The structural features observed during the mapping indicated that the consolidation grouting up to 6.0 m should be done in the foundation of surge pool using primary, secondary and tertiary holes so that the entire floor area functions as a single rock mass.

The pressure and proportion of grout mixes to be used for injection shall be based on water pressure test and the results of trial grouting operation. Special care to be taken to consolidate rock mass along the weak zones / shear zones. The holes which absorb water greater than 3 lugeons, shall invariable be grouted. (1 Lugeon is water loss of 1 lit/m/min at a pressure of 10 kg/sq.cm.). Recommended BIS codes for the grouting are IS-6066 and IS-5529 Part-2.

f. The grout holes shall be laid out in line with secondary holes staggered with reference to the primary holes on the adjacent lines. Spacing between holes initially shall be 5 m centre to centre. After completing the grouting through these primary holes intermediate holes will be taken in between primary holes. The number of holes for further grouting (tertiary grouting – which will be determined based on results of drilling and grouting of intermediate holes) will be such that a continuous consolidated area of satisfactory water tightness is achieved.

g. It is recommended to complete blasting before taking up grouting operation. If blasting after grouting is unavoidable, through testing and regrouting is essential after blasting.

h. Plain Cement Concrete (PCC) of M15 grade lining up to the design foundation level (i.e. RL+307.00 m) should be done before 300 mm thick raft foundation. This has to be checked by the designer.

i. During the foundation treatment, it should be ensured that area is free from water and Contractor shall take all necessary precautions and measures to exclude ground water and water from other sources such as underground streams, aquifers, springs, artisans, precipitation or infiltration from the surface flows etc. so as to enable the works to be carried out in dry condition in accordance with the construction schedule.

j. On the floor detached rock-masses are laying in scattered form, which need to be removed before any protective measure is applied.

References:

Naithani, A.K., Singh, L.G and Rawat, D.S., 2012, Report on Construction stage engineering geological investigations of surge pool and pump house (5 x 30 MW) area of Mahatma Gandhi Kalwakurthi Lift Irrigation Scheme – II, Mahaboobnagar District, Andhra Pradesh. National Institute of Rock Mechanics Report No. EG-11-04, 50p.

Bieniawski, Z.T. 1989. Engineering rock mass classification. John Willey & Sons, New York, 251 p.

IS : 12070- 1987. Indian Standard - Code of practice for design and construction of shallow foundations on rocks, 13p.

ISRM, 1978. Suggested methods for the quantitative description of discontinuities in rock mass. International Journal Rock Mech. Sci. & Geomech. (Abstract), Pergamon, v. 15(6), pp. 319-368.

Peck, R.B., Hanson, W.E. and Thornburn T.H., 1974. Foundation Engineering, Wiley Publ., New York, 514p.

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Ref. NIRM/EGD/MGKLIS-II/2014/03 Dated: 26.03.2014

Note on Geotechnical Assessment of the Foundation of Pump House – Pump Units 4 & 5 – MGKLIS-II

Project Title - Construction Stage Engineering Geological Investigations of Surge pool and Pump House (5x30 MW) area of Mahatma Gandhi Kalwakurthi Lift Irrigations Scheme, Stage-II, Mahabubnagar District, Andhra Pradesh (Phase-II)

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The objective of this study is to advise suitable engineering measures for the treatment of foundation of pump house based on detailed engineering geological investigations. To achieve this objective, large scale engineering geological mapping on 1:200 scale of foundation strata at foundation level of pump house of MGKLIS-II has been carried out. In order to evaluate the foundation design parameters for pump house of MGKLIS-II, engineering geological mapping (on 1:200 scale) was carried out by NIRM Geologists. All the discontinuities with in the zone of influence of the pump house foundation have been identified and mapped. The recommendations made pertain to the foundation of pump house Units-4 and 5.

On the basis of surface geological mapping, the excavated surface is acceptable for foundation because the rock mass is competent. Based on the field observations and evidences, it is found that the entire floor area consists of coarse grained, hard and jointed pink granites. The floor region is fresh to moderately weathered (W-I to W-III) but prominent vertical/inclined joints are present. Total four shear zones are mapped. The width of the shear zones vary from 10 cm to 100 cm. No displacement has been recorded along the shear zones. No evidence of faulting is observed on the surface of the floor area. The structural features observed during the mapping indicated the need for consolidation grouting so that the entire floor area functions as a single rock mass.

Based on the engineering geological mapping carried out at the foundation of pump house Units 4 & 5, and the details collected including lithology and joint patterns measured in the field, the geological maps were compiled on scale of 1:200, and appended to this note as Drawing Nos. NIRM/MGKLIS-II/EG-13-01/09 & NIRM/MGKLIS-II/EG-13-01/10.

The structural features observed during the mapping indicated that consolidation grouting should be done up to 6.0 m in the foundation of pump house using primary, secondary and tertiary holes so that the entire floor area functions as a single rock mass. The pressure and proportion of grout mixes to be used for injection shall be based on water pressure test and the results of trial grouting operation. Special care should be taken to consolidate the rock mass along the weak zones / shear zones. The grouting should be carried out after laying first stage concrete and surrounding blasting.

(Dr. L.G. Singh)

(Dr. A.K. Naithani)

REPORT NO 2 ON CONSTRUCTION STAGE ENGINEERING GEOLOGICAL INVESTIGATIONS OF SURGE POOL AND PUMP HOUSE (5 x 30 MW) AREA OF MAHATMA GANDHI KALWAKURTHI LIFT IRRIGATION SCHEME–II, MAHABOOBNAGAR DISTRICT, TELANGANA STATE

1. INTRODUCTION

Upland areas of Mahaboobnagar District, Telangana State are drought prone, so lift irrigation scheme was felt by the planner. The Telangana Government has decided to construct the irrigation pump house projects to cater the needs of irrigation in the drought prone upland areas of Mahaboobnagar District. The Mahatma Gandhi Kalwakurthi Lift Irrigation Scheme (MGKLIS) is being constructed in three stages (I, II and III) for lifting the Krishna water from Srisailam reservoir (back water) to Gudipallygattu balancing reservoir through channels and tunnels. The project envisage to irrigate about 3,40,000 acres of uplands in Mahaboobnagar District. Telangana Irrigation & Cad Department, who is the owner of the project, has awarded the package for the constructing of 'Mahatma Gandhi Kalwakurthi Lift Irrigation Scheme-II' located at Sathapur village, Mahaboobnagar District to M/s Navayuga Engineering Company Ltd. (NECL), Hyderabad. MGKLIS-II is being constructed for lifting the water from Singotam balancing reservoir to Jonnalaboguda balancing reservoir. The FRL of the Singotam and Jonnalaboguda balancing reservoirs are +334.680 m and +407.000 m respectively. The capacity of Singotam and Jonnalaboguda balancing reservoirs are 0.55 TMC and 2.14 TMC. The major components of the project are: one 4.0 km long gravity canal from Singotam balancing reservoir having bed width of 19.15 m, one 4.553 km long and 6.85 m finished diameter 'D' shaped tunnel, one surge pool (94 m long x 40 m width x 75 m height), five numbers, 50 m long draft tube tunnels, one pump house (94 m long x 20 m width x 78 m height) and five numbers, 15 m long horizontal and 305 m long inclined having 3.0 m finished diameter delivery main tunnels. Delivery main tunnels are inclined at 45°. Lift height is 86 m and five numbers of pump are being installed in the pump house cavity having 30 MW capacity each. Design discharge of pumps will be 113.2 Cumec. In between the surge pool and pump house 50 m wide rock ledge is proposed in the design.

Engineering geological investigations for the surge pool and pump house area are carried out by National Institute of Rock Mechanics (NIRM) from September 2011 to July 2014. Report No 1 pertains to "Construction Stage Engineering Geological Investigations of Surge Pool and

Pump House area of Mahatma Gandhi Kalwakurthi Lift Irrigation Scheme-II, Mahaboobnagar District" has been submitted to NECL in March 2012 (Naithani et al., 2012). Report No 1 contains the engineering geological assessment of excavated vertical walls of surge pool and pump house and rock ledge existing between pump house and surge pool. During the first phase of the project, excavation was not done up to the design foundation levels of the surge pool and pump house and the annexure building area, so the project was extended. The excavation was delayed by more than 36 months because of the controlled blasting and very unfavourable geological discontinuities in the surge pool and pump house areas. Rock on all the sides of the surge pool and pump house was partly slided, due to presence of unfavourable discontinuities and shear zones. Now NECL has completed the excavation with great difficulty and with control blasting.

This report is containing large scale geological maps on 1:200 scale of floors of surge pool and pump house, north wall of surge pool, all the four vertical walls of surge pool, rock ledge, foundation of service bay and annexure part-A and Part-B. The ground level of surge pool is at RL +382 m and the foundation level is at RL +307 m while the ground level of pump house is at RL +383 m and the foundation level is at RL +304 m. All the four sides of the surge pool and pump house are being lined with 500 mm RCC filling from the bed line and floored with 500 mm thick raft foundation to distribute the load as per design specification. During the second phase investigations, notes on geotechnical assessment of the different components i.e. concurrently with the excavations were submitted to the M/s NECL and are appended to this report as Annexure-I, II, III, IV, V and VI. Details of the Annexure are given in Table 1.

Table 1: Details of the annexure submitted to NECL

Annexure No	Description
I	Field note regarding the shear zones treatment and lining of surge pool area.
II	Note on geotechnical assessment of the foundation of surge pool.
III	Note on geotechnical assessment of the north wall of surge pool and rock ledge
IV	Geotechnical note on the treatment of cracks of the north and south wall of pump house
V	Note on geotechnical assessment of the foundation of pump house – pump units 4 and 5.
VI	Note on geotechnical assessment of foundation of pump house, annexure building and service bay columns.

2. PROJECT LOCATION

Mahatma Gandhi Kalwakurthi Lift Irrigation Scheme (MGKLIS)-II is being constructed near village Sathapur, Mahaboobnagar District of Telangana State, located 195 km away from

Hyderabad city. The biggest town in this area is Nagarkurnool, which is 45 km away from the project site. The approximate latitude and longitude of the surge pool and pump house (rock ledge) are: 16°15'12.6" and 78°18'56.8" respectively. The ground elevation of this area varies from RL +382 m to RL +387 m.

3. METHODOLOGY

Geological mapping on 1:200 scale of the pump house and surge pool walls was carried out by NIRM Geologists by using the Crain and traverse method, while the foundations were mapped using the Total Station. Grids for mapping were marked on the walls and floors by client surveyor using elevations and chainages provided by client. Detailed examination of rock types in each grid was carried out which includes mineralogical composition, texture, classification and nomenclature and degree/grade of weathering. Fracture filling that have taken place in the study site were examined and recorded. The attitude and structure of the rocks, fractures and joint pattern present in the walls were determined for mapping. ISRM (1978), classifications for weathered mass was used to characterize the rock mass into different grade (Table 2). The assessment of Tunnelling Quality Index 'Q' (Barton et al. 1974, 1980) for the granite rock masses of walls of surge pool and pump house has been done based on the rock joint characteristics, while for the granite rock masses of rock ledge between surge pool and pump house, floors of pump house, surge pool, service bay and annexure part-A and part-B the assessment of RMR (Bieniawski, 1989), has been attempted.

Table 2: Description of weathering grade (ISRM, 1978)

Term	Description	Grade
Fresh	No visible sign of rock material weathering; perhaps slight discolouration on major discontinuity surfaces.	I
Slightly weathered	Discolouration surfaces. All the rock material may be discoloured by weathering and may be somewhat weaker externally than in its fresh condition.	II
Moderately weathered	Less than half of the rock material is decomposed and / or disintegrated to a soil. Fresh or discoloured rock is present either as a continuous framework or as corestones.	III
Highly weathered	More than half of the rock material is decomposed and / or disintegrated to a soil. Fresh or discoloured rock is present either as a continuous framework or as corestones.	IV
Completely weathered	All rock material is decomposed and / or disintegrated to soil. The original mass structure is largely intact.	V
Residual soil	All rock material is converted to soil. The mass structure and material fabric are destroyed. There is a large change in volume, but the soil has not been significantly transported.	VI

The objective of this study was to advise suitable measures for stabilization all the sides of pump house and north wall of surge pool and to advise suitable engineering measures for the treatment of foundations of surge pool, pump house, service bay, annexure part-A and annexure part-B of MGKLIS –II based on detailed engineering geological investigations.

4. GEOLOGY OF THE MGKLIS-II PROJECT SITE AND AREA AROUND

The project site is located in the Mahboobnagar District of Telangana State. It forms a part of the Peninsular Shield of the Indian Sub-continent and physiographically fall under the north-western plateau and plains forming the Telangana region (Ramam and Murty, 2012). The MGKLIS–II form a part of Eastern Block of Dharwar Craton mainly comprised of Archaean granites which are intruded by mafic dykes age ranging from Archaean to Upper Proterozoic (Sharma et al., 2008). Granites and gneisses are exposed in and around the project site over a large area. These formations are traversed by several dolerite dyke, quartz-pegmatite-aplite veins trending in different directions. The granites of the project area are jointed in nature. In the western region, approximately 60 km from the project site, a part of Gadwal schist belt is exposed, which extend as a linear in NW-SE direction, includes metabasalt, amphibolite, felsic meta-volcanics, meta acid fuff, volcanic agglomerate and minor portion of Banded Iron Formation (GSI, 2001; Ramam and Murty, 2012). Cuddapah Supergroup of Upper Proterozoic rocks is overlying the granites, gneisses and schists of Archaean age towards southern and eastern direction (approximately 17.0 km and 38.0 km respectively) from the project site. Diamond occurrences are known in the southern part in Quaternary gravels of Krishna River (Geological Quadrangle Maps GSI, 1995).

The different units of the Peninsular Gneissic Complex of Telangana State are grouped into three discrete units on the basis of composition, structure and mutual relations viz. i) gneissic rocks, ii) hornblende-bearing granitoids and iii) younger granites (Late Archaean to Proterozoic) (Raman and Murty, 2012). The younger granites are believed to be a manifestation of reworking and reactivation of older gneisses. The K-rich, grey and pink granites of this area have generally been correlated with the Closepet Granite of Karnataka. Granites of this variety occur as discrete plutons within the Peninsular Gneiss and intrudes the greenstones. They are usually described as Younger Granites, because they constitute the youngest plutonic activity in

the craton. Rapakivi and proto-orbicular structures are reported at places in the coarse-grained pink granites.

Younger granites occur as isolated plutons, stocks, bosses, parallel bands emplaced along major lineaments and as narrow bands and veins. Minor bodies and veins are omnipresent in the form of injections into the component units of Peninsular Gneiss and schists. In some areas, Younger Granites attain batholithic dimensions in which the older granitoids occur as xenoliths and enclaves. Granites of this group, in general, form high hills and prominent topographical highs in an otherwise flat or gentle undulating country underlain by gneissic rocks and schists. The inselbergs, nubbins, corestone, pedestal rocks, whaleback, castle kopples and such other landforms characterize this granite. The denudational landforms result due to long period of sub-aerial denudation leading to erosional landforms.

Gneisses of Telangana State have deformational history documenting three phases of folding (Ramam and Murty, 2012; Geological Quadrangle Maps GSI, 1995). Later these are intruded by different types of younger granites (Reddy and Rao, 1991). The dominant structural trend is along NW-SE direction and at places it is N-S, mainly defined by the regional orientation of the belt. Many shears, fractures and faults have affected the terrain controlled the invasion of quartz, pegmatite, apatite and basic dykes along NW-SE, NNW-SSE, WNW-ESE, N-S, NNE-SSW and ENE-WSW directions (Sridhar et al., 2004; Nagarajan and Roy, 1991; Ramam and Murty, 2012). The reactivation is seen especially in WNW-ESE trending features associated with basic dykes and quartz reefs exhibit intense fractures and shears (Sridhar et al., 2004). The study on relationship of intersection of main fracture systems and their trend helped in understanding the relative age of intersection. The chronological order of trends of fracture systems reported to be NW-SE, N-S and ENE-WSW directions (Nagarajan and Roy, 1991).

The regional study of Mahaboobnagar District area based on geology, photogeology and Landsat imageries (Project Vasundhara, 1994), identified NE-SW, NW-SE, WNW-ESE, NNE-SSW and nearly N-S trending lineaments and major faults trending in NW-SE, WNW-ESE, nearly E-W directions in the eastern and southeastern part of the area. No major lineament or fault is passing through the surge pool and pump house area of MGKLIS-II project site.

Pink and grey granites are exposed in the MGKLIS –II project site. Head race tunnel was excavated through fresh and hard grey (porphyritic) granites with medium to coarse grained feldspars, traversed by dolerite dykes and pegmatite veins, while surge pool, pump house, draft tubes, delivery mains and cistern were excavated through pink granites, traversed by dolerite dykes. Pink granites are coarse grained, hard and jointed and shows phenocryst of alkali feldspar and quartz. Main minerals composition is alkali feldspars, quartz, mica and amphiboles. Three to five prominent joints set are developed and along the joint plane clay coating/filling was also recorded. Joints are irregular in pattern. Grey granites are medium to coarse grained, light colour, hard and jointed. Main minerals composition is feldspars, quartz, mica and amphiboles. Three to four prominent joints set are developed and along the joint plane clay coating are also present. Joints are irregular in pattern. Pink and grey granites are generally fresh to slightly weathered (WI–WII). Dolerite dykes are fine grained and greenish-black in colour. The width of the dykes varies from 30 cm to >100 cm and their strike length is more than 50 m in excavated part of surge pool and pump house. Dykes are generally sheared along the contact at the surge pool and pump house area. Plagioclase and clinopyroxene (augite / titanaugite) are the main minerals occurring in ophitic to sub-ophitic textures in dolerite. Quartz, epidote and opaques occur as accessories. Amphibole, biotite, sericite occur as alteration products. In a regional perspective E-W trending dykes show greater degree of alteration and are relatively older as established from intersecting features. Sulphide disseminations are reported in some dykes. Dykes are generally moderately to highly weathered (WIII – WIV).

Generalised geology map of the project and area around has been complied from the Geological Survey of India (2001) map and appended in Report No 1 as Drawing No. NIRM/MGKLIS-II/EG-11-04/01.

5. ENGINEERING GEOLOGICAL ASSESSMENT OF THE FOUNDATION OF PUMP HOUSE

Foundation floor geological mapping of the important structures is essential to provide permanent data input for geological interpretations during construction and also it forms valuable documentation for post-construction stage. For very important structures like deep surge pool and pump house of lift irrigation, the foundation strata have to be well studied and documented for credible geologic interpretations. Rock is usually recognized as the best

foundation material. However, design engineers should be aware of the dangers associated with heterogeneity and unfavourable rock conditions since over-stressing a rock foundation may result in large differential settlements or perhaps sudden failure.

In order to evaluate the design basis foundation parameters for pump house of MGKLIS-II, engineering geological mapping (on 1:200 scale) was carried out by NIRM Geologists. All the discontinuities in the rock mass of foundation of pump house with the zone of influence of the foundation has been identified and mapped. The primary purpose of the mapping is to provide a permanent record of conditions during the excavation. Mapping will be used to assess the requirement of any ground improvement. This permanent foundation record will assist in making better interpretation of post-construction foundation instrumentation data.

The floor of pump house was examined on a grid to grid basis; the size of the grid is 2 m x 2 m. All the lithological and structural features were observed and mapped using Total Station surveying equipment and shown in the final foundation grade geological plan map. Classification of rock mass using Rock Mass Rating (RMR) of Bieniawski (1989) has been attempted and based on investigations recommendations for the treatment of foundation is given.

5.1 Geological and Structural Assessment – Floor of Pump House

The foundation of pump house will be resting as per design on a raft of 300 mm thick at about 76.0 m below the existing ground level for functional requirement. The design foundation level is at RL +305.40 but in some areas it is excavated up to an average RL +303 and the over excavation was varying from 0.10 m to 2.4 m because of presence of unfavourable discontinuities, and shear zones. Total 1880 sq m excavated foundation area of pump house floor has been geologically mapped. Geological foundation mapping was done after the excavation and before first pore of concrete (Fig. 1 and 2). Based on the field observations and evidences, it is found that the entire floor area consists of coarse grained, hard and jointed pink granite (Fig. 3 and 4). Total five shear zones are mapped. The width of the shear zones are varying from 1 cm to 80 cm. No displacement has been recorded along shear zones. No evidences of faulting are observed on the surface of floor area. On the basis of surface geological mapping the excavated surface is acceptable for foundation because the rock mass is

competent. The structural features observed during the mapping indicated the need for consolidation grouting, so that the entire floor is function as single rock mass.

Fig. 1. Pump house area, viewing towards western direction

Fig. 2. Pump house area, viewing towards eastern direction

Pink granites are coarse grained, hard and jointed and shows phenocryst of alkali feldspar and quartz. Main minerals composition is alkali feldspars, quartz, mica and amphiboles. Five prominent joints set are developed and along the joint plane clay filling/coating was also recorded. Joints are irregular in pattern. Granites are generally fresh to moderately weathered (WI–WIII). At the foundation level granites are traversed by dolerite dyke (feature D1 marked in Drawing No NIRM/MGKLIS-II/EG-13-01/04). Dolerite dykes are fine grained and greenish-black in colour. The width of the dyke is up to 100 cm and strike length is more than 100 m in excavated part of pump house. Dyke is generally sheared and in D1 clay gouge was observed. Plagioclase and clinopyroxene (augite / titanaugite) are the main minerals occurring in ophitic to sub-ophitic textures in dolerite. Quartz, epidote and opaques occur as accessories. Amphibole, biotite, sericite occur as alteration products. Dyke is generally highly weathered (WIV) as per the weathering grade.

Fig. 3. Coarse grained granite exposed at the foundation of pump house

Fig. 4. Cleaning the foundation of pump area-4 before engineering geological mapping

The rock mass is characterized by prominent five number of joint sets, which are continuous and persistent, slightly rough to smooth with unaltered joint walls. Staining has been recorded

along the joint surfaces where the joints are tight and where opening is up to 50.0 mm, soft clay mineral and crushed material filling has been recorded. In general, the rock mass was characterized by dry condition or minor inflow i.e. < 5.0 l/min. Crack/fractures developed due to excavation / blasting were also recorded during geological mapping. Some of the cracks are tight while some are open with size of the opening varying from 1 mm to 5 mm. Hairline cracks developed due to excavation work were also recorded. The prominent joints recorded in the coarse grained granite at the foundation of pump house are given in Table 3.

Table 3: Prominent joints developed in coarse grained granite at the foundation of pump house

Joint Set	Dip Direction	Dip Amount	Spacing (cm)	Persistence (m)	Roughness	Aperture (mm)	Infilling (mm)	Groundwater Condition	Remarks
J1	340-355	60-85	10-50	>20	Slightly rough to smooth	Tight to 50	Nil-Clay	Damp	Joint plane is stained
J2	040-070	70-75	50-100	25	Slightly rough	Tight to 2	Nil-Clay coated	Damp	Joint plane is stained to fresh
J3	230-270	75-80	30-70	20	Slightly rough	Tight to 1	Nil-Clay coated	Damp	Joint plane is stained to fresh
J4	180-220	60-80	50-100	25	Slightly rough	Tight to 2	Nil-Clay coated	Damp	Joint plane is stained to fresh
J5	290-325	70-85	70-100	10	Slightly rough	Tight to 2	Nil-Clay coated		Joint plane is stained to fresh
J6	005	65	30-50	10	Slightly rough	Tight	Nil	Damp	Joint plane is stained
J7	120	80	40-60	5	Slightly rough	Tight	Nil	Damp	Joint plane is stained
J8	040	Vertical	30-80	10	Slightly rough	Tight to 1	Nil	Damp	Joint plane is stained
J9	090	Vertical	-	10	Slightly rough	Tight to 2	Nil	Damp	Joint plane is stained
Note: For vertical joints strike direction is given									

5.2 Geological Map – Floor of Pump House

Based on the engineering geological mapping carried out at the foundation of pump house, and the details collected including lithology and joint patterns measured in the field, the geological map was compiled on scale of 1:200, and it has been appended to this report as Drawing No NIRM/MGKLIS-II/EG-13-01/04.

5.3 Geotechnical Assessment - Floor of Pump House

The floor area of the pump house is falling under weathering grade 1 to 3 (WI - WIII). The grade of the rock mass as evaluated from the conditions of discontinuities has RMR values are varying from 49 to 63 and fall under fair to good rock mass category (Table 4).

Table 4: Rock mass classification using RMR of the foundation of pump house

Block No.	Rock Type	RMR		
		Value	Class	Description
1	Coarse Pink Granite	52	Class-III	Fair
2	Coarse Pink Granite	49	Class-III	Fair
3	Coarse Pink Granite	57	Class-III	Fair
4	Coarse Pink Granite	57	Class-III	Fair
5	Coarse Pink Granite	57	Class-III	Fair
6	Coarse Pink Granite	57	Class-III	Fair
7	Coarse Pink Granite	57	Class-III	Fair
8	Coarse Pink Granite	57	Class-III	Fair
9	Coarse Pink Granite	63	Class-II	Good
10	Coarse Pink Granite	57	Class-III	Fair
11	Coarse Pink Granite	63	Class-II	Good
12	Coarse Pink Granite	61	Class-II	Good
13	Coarse Pink Granite	61	Class-II	Good
14	Coarse Pink Granite	61	Class-II	Good
15	Coarse Pink Granite	52	Class-III	Fair
16	Coarse Pink Granite	57	Class-III	Fair
17	Coarse Pink Granite	57	Class-III	Fair
18	Coarse Pink Granite	52	Class-III	Fair
19	Coarse Pink Granite	52	Class-III	Fair
20	Coarse Pink Granite	57	Class-III	Fair
21	Coarse Pink Granite	49	Class-III	Fair
22	Coarse Pink Granite	49	Class-III	Fair
23	Coarse Pink Granite	57	Class-III	Fair
24	Coarse Pink Granite	63	Class-II	Good
25	Coarse Pink Granite	63	Class-II	Good
26	Coarse Pink Granite	57	Class-III	Fair
27	Coarse Pink Granite	63	Class-II	Good
28	Coarse Pink Granite	63	Class-II	Good
29	Coarse Pink Granite	63	Class-II	Good
30	Coarse Pink Granite	61	Class-II	Good
31	Coarse Pink Granite	57	Class-III	Fair
32	Coarse Pink Granite	52	Class-III	Fair
33	Coarse Pink Granite	57	Class-III	Fair
34	Coarse Pink Granite	61	Class-II	Good
35	Coarse Pink Granite	57	Class-III	Fair
36	Coarse Pink Granite	52	Class-III	Fair
37	Coarse Pink Granite	52	Class-III	Fair

Block No.	Rock Type	RMR		
		Value	Class	Description
38	Coarse Pink Granite	57	Class-III	Fair
39	Coarse Pink Granite	61	Class-II	Good
40	Coarse Pink Granite	57	Class-III	Fair
41	Coarse Pink Granite	49	Class-III	Fair
42	Coarse Pink Granite	52	Class-III	Fair
43	Coarse Pink Granite	61	Class-II	Good
44	Coarse Pink Granite	57	Class-III	Fair
45	Coarse Pink Granite	52	Class-III	Fair
46	Coarse Pink Granite	63	Class-II	Good
47	Coarse Pink Granite	63	Class-II	Good
48	Coarse Pink Granite	63	Class-II	Good
49	Coarse Pink Granite	61	Class-II	Good
50	Coarse Pink Granite	57	Class-III	Fair
51	Coarse Pink Granite	52	Class-III	Fair
52	Coarse Pink Granite	52	Class-III	Fair
53	Coarse Pink Granite	52	Class-III	Fair
54	Coarse Pink Granite	52	Class-III	Fair
55	Coarse Pink Granite	57	Class-III	Fair
56	Coarse Pink Granite	57	Class-III	Fair
57	Coarse Pink Granite	57	Class-III	Fair
58	Coarse Pink Granite	57	Class-III	Fair
59	Coarse Pink Granite	57	Class-III	Fair
60	Coarse Pink Granite	57	Class-III	Fair
61	Coarse Pink Granite	49	Class-III	Fair
62	Coarse Pink Granite	61	Class-II	Good
63	Coarse Pink Granite	57	Class-III	Fair
64	Coarse Pink Granite	57	Class-III	Fair
65	Coarse Pink Granite	57	Class-III	Fair
66	Coarse Pink Granite	57	Class-III	Fair
67	Coarse Pink Granite	57	Class-III	Fair
68	Coarse Pink Granite	52	Class-III	Fair
69	Coarse Pink Granite	52	Class-III	Fair
70	Coarse Pink Granite	52	Class-III	Fair
71	Coarse Pink Granite	57	Class-III	Fair
72	Coarse Pink Granite	57	Class-III	Fair
73	Coarse Pink Granite	57	Class-III	Fair
74	Coarse Pink Granite	57	Class-III	Fair
75	Coarse Pink Granite	61	Class-II	Good
76	Coarse Pink Granite	57	Class-III	Fair

5.4 Inferences and Recommendations – Floor of Pump House

Based on above studies, the following inferences and recommendations are given:

a. Based on the field observations and evidences, it is observed that area in the floor of pump house site is characterized by coarse grained, hard and jointed pink granite (containing alkali feldspars, quartz, mica and amphibole) traversed by dolerite dyke. Depth persistence and lateral prevalence of bed rock was established. The floor region is fresh to moderately weathered (W-I to W-III) but prominent vertical/inclined joints are present.

b. Field observations indicate that the rock mass is quite competent and acceptable for the foundation of the pump house. The grade of the rock mass as evaluated from the condition of discontinuities has RMR values varying from 49 to 63 and falls under fair to good rock mass.

c. The rocks exposed at the foundation grade of the surge pool are jointed pink granite interspersed with sheared dolerite dyke. Shear zones having the varying thickness are mapped which are having differential mechanical behavior due to varying physical properties leading to differential settlement. In order to overcome the problem of differential settlement shear zones treatment plan is given in Table 5.

Table 5: Treatment plan for shear zones at the foundation level of pump house

Shear Zone	Thickness	Recommended Excavation Depth	Treatment Plan
D1	Up to 1.0 m	1.5 m	Dolerite dyke is crushed and sheared, should be excavated up to 1.5 m depth by mechanical breakers and backfilled with concrete (M≥25) up to the foundation level after systematic cleaning, washing and jetting to make the rock mass monolithic. The concrete should be allowed to cure for 10-12 days before rock bolting. The length of rock bolt will be varying from 4 to 5 m as per the site condition.
SH-C, SH-D	20.00 to 30.00 cm	0.60 m	Shear zones area should be excavated up to 0.60 m depth by mechanical breakers and backfilled with concrete (M≥25) up to the foundation level.
SH-B	Up to 15.00 cm	0.50 m	Shear zones area should be excavated up to 0.50 m depth by mechanical breakers and backfilled with concrete (M≥25) up to the foundation level.
SH-A	Up to 10.00 cm	0.30 m	Shear zone having clay gauge should be excavated up to 0.30 m depth by mechanical breakers and backfilled with concrete (M≥25) up to the foundation level.

d. The structural features observed during the mapping indicated that the consolidation grouting up to 6.0 m should be done in the foundation of pump house using primary, secondary and tertiary holes so that the entire floor area functions as a single rock mass. The pressure and proportion of grout mixes to be used for injection shall be based on water pressure test and the results of trial grouting operation. Special care to be taken to consolidate rock mass along the weak zones / shear zones. The holes which absorb water greater than 3 lugeons, shall invariable be grouted. (1 Lugeon is water loss of 1 lit/m/min at a pressure of 10 kg/sq cm). Recommended BIS codes for the grouting are IS-6066 and IS-5529 Part-2.
e. The grout holes shall be laid out in line with secondary holes staggered with reference to the primary holes on the adjacent lines. Spacing between holes initially shall be 5 m centre to centre. After completing the grouting through these primary holes intermediate holes will be taken in between primary holes. The number of holes for further grouting (tertiary grouting – which will be determined based on results of drilling and grouting of intermediate holes) will be such that a continuous consolidated area of satisfactory water tightness is achieved.
f. It is recommended to complete blasting before taking up grouting operation. If blasting after grouting is unavoidable, through testing and regrouting is essential after blasting.
g. Plain Cement Concrete (PCC) of M15 grade lining up to the design foundation level (i.e. RL+305.40 m) should be done before 300 mm thick raft foundation. This has to be checked by the designer.
h. During the foundation treatment, it should be ensured that area is free from water and Contractor shall take all necessary precautions and measures to exclude ground water and water from other sources such as underground streams, aquifers, springs, artesians, precipitation or infiltration from the surface flows etc. so as to enable the works to be carried out in dry condition in accordance with the construction schedule.
i. On the floor detached rock-masses are laying in scattered form, which need to be removed before any protective measure is applied.

6. ENGINEERING GEOLOGICAL ASSESSMENT OF VERTICAL WALLS – PUMP HOUSE

Geological mapping of vertical walls of the important structures is essential to provide data input for geological interpretations during construction and also it forms valuable

documentation for post-construction stage. For important structures like deep surge pool & pump house of lift irrigation, the supporting walls strata have to be well studied and documented for credible geologic interpretations. In order to evaluate the design basis parameters for pump house of MGKLIS-II, engineering geological mapping (on 1:200 scale) of vertical walls were carried out by NIRM Geologists. All the lihtological variance and structural discontinuities in rock mass were identified and mapped by using Total Station survey equipment and shown in the final maps of vertical sides. Classification of rock mass using Tunnelling Quality Index 'Q' of Barton et al. (1974, 1980) has been done. It is observed that the excavation of the pump house pit exposed the top 1 to 2 m thick reddish brown gravely soil, underlained by 3 to 5 m highly weathered and disintegrated granites and the followed by fresh, hard and jointed granites. Based on engineering geological investigations, geotechnical problems were identified and remedial measures are suggested for the vertical walls.

6.1 South Wall of Pump House

The south wall of pump house was excavated from RL +350.00 m to RL +303.00 m. Design bottom level of the wall is at RL +305.40 m. This wall is aligning along the N125°-N305° direction. The average design height of the wall is 45 m from foundation level at RL +305 m to the top of the wall, which is at RL +350 m and the total design length of wall is 94.0 m.

6.1.1 Geological and Structural Assessment of South Wall

Rock type exposed after excavation on the wall section is granite, which is coarse grained, hard and jointed in nature. Its colour varies from pink to grayish and its colour variation is due to varying in the amount of orthoclase. Granite is generally fresh in nature. The rock mass is characterized by prominent five number of joint sets, which are continuous and persistent, smooth–planar to smooth-undulating with unaltered joint walls. Staining has been recorded along the joint surfaces where the joints are tight and where opening is up to 10.0 mm, soft clay mineral and crushed material filling has been recorded. In general, the rock mass was characterized by dry condition or minor inflow i.e. < 5.0 l/min. Crack/fractures developed due to excavation / blasting were also recorded during geological mapping. Some of the cracks are tight while some are open and the size of the opening varying from 1 mm to 10 cm. Hairline cracks developed due to excavation work were also recorded. The details of the joint characteristics of south wall of pump house are given in Table 6.

Table 6: Joint sets developed in granite at the face of south wall of pump house

Joint Set	Dip Direction	Dip Amount	Spacing (cm)	Persistence (m)	Roughness	Aperture (mm)	Infilling (mm)	Groundwater Condition	Remarks
J1	010 - 035	70 - 85	10-50	>20	SP	Tight to 3 mm	Crushed material	Dry	Dipping towards the pump house, unfavourable joint, need to be reinforced
J2	245 - 270	20 - 70	10-100	>20	SP/SU	Tight to 5 mm	Crushed rock material	Dry	Dipping inside of wall i.e. south western direction.
J3	130 - 150	50 - 70	20-60	>20	SP	Tight to 1 mm	Clay coating	Dry	Dipping toward south eastern side of the wall. Need to be reinforced by rock bolting
J4	300 - 330	60 - 75	10-40	>20	SP/SU	Tight to 10 mm	Crushed material along the joint plane	Dry	Dipping towards the north western side of wall.
J5	040 - 060	70 - 85	20-100	2-10	SP	Tight	None	Dry	Dipping towards the pump house i.e. north eastern direction.
J6	160 - 190	80 - 85	20-60	>20	SP	Tight to 1 mm	Clay coating	Dry	Dipping toward south eastern side of the wall. Need to be reinforced by rock bolting
J7	100 - 110	15 - 65	20-60	>20	SP	Tight to 1 mm	Clay coating	Dry	Dipping toward south eastern side of the wall. Need to be reinforced by rock bolting
J8	040°	Vertical	100-200	>20	SP	Tight	None	Dry	Random joint, no displacement has been has been recorded.

An intrusive dolerite dyke (feature dyke-1 in Drawing No NIRM/MGKLIS-II/EG-13-01/05) was mapped on the western side of the south wall (Fig. 5). Dyke is trending in N250° direction with a dip amount of 70°, and a strike length of more than 100 m has been mapped between easting 991 m at RL +335 m and easting 971 m at RL +305 m i.e. bottom of the excavated part. The average width of dyke is 100 cm. The prominent joint sets intersecting the dyke are: N150° (dip direction)/ 50° (dip amount), N190°/85° and N250°/60°. This dolerite dyke is dark gray in colour and sheared.

Shearing was recorded along the joint plane trending in N10° (dip direction)/ 70° (dip amount) direction. This feature was mapped between RL +349 m to RL +317 m on the eastern side of the wall. The average width of shear zone is 20 cm. The prominent joint set intersecting the shear zone are: N260°/65° and N190°/80°.

The rock mass for the south wall of pump house is classified as very poor to poor rock mass (Q 0.18 to 1.25) as per Barton`s classification. The details of the Q values of south wall of pump house are given in Table 7.

Fig. 5. South wall of pump house, sheared dyke-1 is also shown

Table 7: Rock mass classification using 'Q' of the face of south wall of pump house

SE side of South Wall of Pump House				NW side of South Wall of Pump House			
Easting from 1000 to 1047				Easting from 953 to 1000			
Elevation		Q		Elevation		Q	
From	To	Value	Description	From	To	Value	Description
351	340	0.20	Very Poor	352	340	0.18	Very Poor
340	330	0.24	Very Poor	340	330	0.18	Very Poor
330	320	0.43	Very Poor	330	320	0.46	Very Poor
320	310	1.03	Poor	320	310	1.09	Poor
310	305	1.10	Poor	310	305	1.25	Poor

6.1.2 Geological Map - South Wall of Pump House

Based on the engineering geological mapping carried out in the vertical south wall of pump house and the details collected including lithology, joint patterns measured in the field, the geological map was compiled on scale 1:200 has been appended to this report as Drawing No. NIRM/MGKLIS-II/EG-13-01/05.

6.2 West Wall of Pump House

The west wall of pump house was excavated from RL +384.00 m to RL +310.00 m. This wall is aligning along the N035°-N215° direction. The average height of the wall is 74 m from

foundation level at RL +310 m to the top of the wall which is at RL +384 m and the total design length of wall is 20.0 m but over excavation was mapped, which may be due to uncontrolled blasting and unfavourable geological discontinuities.

6.2.1 Geological and Structural Assessment of West Wall

Rock type exposed after excavation on the wall section is granite which is coarse grained, hard and jointed in nature. Its colour varies from pink to grayish and its colour variation is due to varying in the amount of orthoclase (Fig. 6). Granite is generally fresh in nature below RL +348 m. The rock mass is characterized by prominent four number of joint sets, which are continuous and persistent, smooth–planar to smooth-undulating with unaltered joint walls. Staining has been recorded along the joint surfaces where the joints are tight and where opening is up to 10.0 mm, soft clay mineral coating has been recorded. In general, the rock mass is characterized by minor inflow i.e. < 5.0 l/min locally. Crack/fractures developed due to excavation / blasting were also recorded during geological mapping. Some of the cracks are tight while some are open and the size of the opening varying from 1 mm to 2 cm. Hairline cracks developed due to excavation work were also recorded. The details of the joint characteristics of west wall of pump house are given in Table 8. West wall of the pump house was reinforced by shotcrete between elevation RL +349 m and RL +384 m after NIRM suggestion.

Table 8: Joint sets developed in granite at the face of west wall of pump house

Joint Set	Dip Direction	Dip Amount	Spacing (cm)	Persistence (m)	Roughness	Aperture (mm)	Infilling (mm)	Groundwater Condition	Remarks
J1	240 - 250	40 - 60	5-50	>20	SP/SU	Tight to 10 mm	Crushed material along the joint plane	Dry	Dipping inside the wall i.e. southwestern direction.
J2	180	65	30-50	>20	SP	Tight to 3 mm	Crushed material	Dry	Dipping toward the west wall of pump house, not unfavorable.
J3	090	Vertical	20-30	2-5	SP	Tight	None	Dry	Dripping along this joint plane was recorded.
J4	355	20	10-40	>5	SP	Tight	None	Dry	Dipping towards northern side, not unfavorable.
J5	130	Vertical	-	1-2	SP	Tight	None	Dry	Random joint, mainly in the crown portion.

An intrusive dolerite dyke trending in N270° direction with a dip amount of 65°, and a strike length of more than 100 m has been mapped on the southwestern side of the wall, i.e., between northing 8635 m at RL +369 m on the southwestern corner of the wall and northing 8640 m at

RL +383 m on the top of the wall (feature dyke-2 in Drawing No. NIRM/MGKLIS-II/EG-11-04/10). The width of dyke is varying from 50 cm to 100 cm. The prominent joint sets intersecting the dyke are: N345°/75° and 090°/76°. Dolerite is fine grained, jointed, fractured and sheared in nature and dark grey in colour. The contact between granite and dolerite dyke is unweathered to slightly weathered and no failure scar was recorded during the geological mapping. No displacement has been recorded along this feature. This area is shotcreted.

Fig. 7. View of north wall of pump house

Fig. 6. View of west wall of pump house

A shear zone trending in N308° direction with a dip amount of 80°, and a strike length of more than 28 m, was mapped on face of the wall i.e., between northing 8635 m at RL +367 m on the southwestern corner of the wall and northing 8659 m at RL +378 m on the northeastern side of the wall (feature shear zone-1 in Drawing No. NIRM/MGKLIS-II/EG-11-04/10). The prominent joint sets intersecting the shear zone are: N005°/70°, N055°/70° and N090°/55°. No displacement has been recorded along this feature. This area is also shotcreted.

The rock mass for the west wall of pump house is classified as very poor to fair rock mass (Q 0.61 to 5.20) as per Barton`s classification. The details of the Q values of west wall of pump house are given in Table 9.

Table 9: Rock mass classification using 'Q' of the face of west wall of pump house

SW side of West Wall of Pump House				NE side of West Wall of Pump House			
Northing from 8640 to 8650				From 8650 to 8660			
Elevation		Q		Elevation		Q	
From	To	Value	Description	From	To	Value	Description
384	370	0.20	Very Poor	384	370	0.20	Very Poor
370	360	0.40	Very Poor	370	360	0.40	Very Poor
360	350	0.65	Very Poor	360	350	0.61	Very Poor
350	340	1.39	Poor	350	340	0.76	Very Poor
340	330	2.05	Poor	340	330	0.61	Very Poor
330	320	5.12	Fair	330	320	1.63	Poor
320	310	5.20	Fair	320	310	1.72	Poor

6.2.2 Geological Map - West Wall of Pump House

Based on the engineering geological mapping carried out in the west wall of pump house and the details collected including lithology, joint patterns measured in the field, the geological map was compiled on scale 1:200 has been appended to this report as Drawing No. NIRM/MGKLIS-II/EG-13-01/06.

6.3 North Wall of Pump House

The north wall of pump house was excavated from RL +385.00 m to RL +307.00 m. An average 4 m overburden/highly weathered rock portion was removed from the top of the wall. This wall is aligning along the N305°-N125° direction. The average height of the wall will be 74 m from foundation level at RL +307 m to the top of the wall which is at RL +381.00 m and the total design length of wall is 94.0 m. Three berms at RL 350 m, 360 m and 370 m have been constructed after NIRM recommendations.

6.3.1 Geological and Structural Assessment

Rock type exposed after excavation on the wall section is granite, which is coarse grained, hard and jointed in nature. Its colour varies from pink to greyish and its colour variation is due to varying in the amount of orthoclase (Fig. 7). Granite is generally fresh in nature. The rock mass is characterized by prominent six number of joint sets, which are continuous and persistent, slightly rough to smooth with unaltered to slightly altered joint walls. Staining has been

recorded along the joint surfaces where the joints are tight and where opening is up to 3.0 mm, soft clay mineral filling/coating has been recorded. In general, the rock mass is characterized by dry condition or minor inflow i.e. < 5.0 l/min. Crack/fractures developed due to excavation / blasting were also recorded during geological mapping. Some of the cracks are tight while some are open and the size of the opening varying from 1 mm to 6 cm. Hairline cracks developed due to excavation work were also recorded. The details of the joint characteristics of north wall of pump house are given in Table 10. During excavation, slides occurred towards northwestern and central part of the excavated vertical north wall. Rock mass failed was due to structural wedge formation between dyke (N250°/75°) and joint (N200°/75°) and extended 1.5 m to 2.0 m depth in to excavated line of face. The rock ledge portion was removed before the final treatment of this wall. Toppling has been recorded in the central and northeastern portion of the wall along joint set (060°- 090°).

Table 10: Joint sets developed in granite at the face of north wall of pump house

Joint Set	Dip Direction	Dip Amount	Spacing (cm)	Persistence (m)	Roughness	Aperture (mm)	Infilling (mm)	Groundwater Condition	Remarks
J1	180-200	65-75	30-70	>25	Slightly rough to smooth	Tight to 2	Nil-Clay	Dry-Damp	Dipping towards pump house. Very unfavorable from stability point of view.
J2	060-090	60-70	10-300	>25	Slightly rough to smooth	Tight to 1	Nil-Clay coated	Dry-Damp	Dipping inside the slope, very unfavorable from stability point of view.
J3	240-270	50-70	30-100	>25	Slightly rough to smooth	Tight to 3	Nil-Clay coated	Dry-Damp	Dipping towards pump house i.e. west wall side of pump house.
J4	340	60	30-70	>10	Slightly rough	Tight to 2	Nil-Clay coated	Dry-Damp	Dipping inside the wall i.e. towards north-west direction.
J5	090	Vertical	30-50	>10	Slightly rough	Tight to 1	Nil	Damp	Joint plane is stained to fresh
J6	040	Vertical	50	>10	Slightly rough	Tight to 2	Nil-Clay coated	Damp	Joint plane is stained to fresh
J7	130	55	-	>5	Slightly rough	Tight	Nil	Damp	Joint plane is stained

Two intrusive dolerite dykes were mapped on the western and eastern sides of the north wall. Dyke-1 is trending in N250° direction with a dip amount of 75°, and a strike length is more than 100 m has been mapped on the western side of the wall, i.e. between easting 956 m at RL +311 m on the western corner of the wall i.e. bottom of the excavated part and easting 957 m at RL +385 m on the western side i.e. top of the wall (feature dyke-1 in Drawing No NIRM/MGKLIS-II/EG-13-01/07). The width of dyke is varying from 80 cm to 100 cm. The

prominent joint sets intersecting the dyke are: N250° (dip direction)/ 70° (dip amount), N260°/30° and N180°/70°. Dyke-3 is trending in N070° direction with a dip amount of 80°, and a strike length of more than 50 m has been mapped on the eastern side of the wall, i.e. between easting 1016 m at RL +385 m on the top of the wall and easting 1031 at RL +371 m (feature dyke-3 in Drawing No. NIRM/MGKLIS-II/EG-11-04/11). The width of dyke-2 is varying from 100 cm to 120 cm. The prominent joint sets intersecting the dyke-2 are: N060° (dip direction)/ 65° (dip amount), N090°/70°, N250°/75° and N040°/V. Dolerite dykes are fine grained, jointed, fractured and sheared in nature and dark gray in colour. The contact between granites and dolerite dykes are slightly to moderately weathered. Rockfall scar was recorded during the geological mapping along dyke-1 while along dyke-2 no scar was mapped. No displacement has been recorded along these features.

Shear zone was mapped on the face of north wall of pump house. Shear zone is extended from easting 999 m at RL +384 m and easting 1011 m at RL +378 m (feature shear zone-1 in Drawing No. NIRM/MGKLIS-II/EG-11-04/11). This shear zone plane is trending in N190° with a dip amount of 70°. The average width of shear plane is 12 cm. The prominent joint sets intersecting the shear zone are: N250°/45°, N060°/65°, N150°/40° and N310°/55°. No displacement has been recorded along this feature. Concurrently with the excavation up to RL +350 m from the ground level, the wall was shotcreted after NIRM recommendations.

The rock mass for the north wall of pump house is classified as very poor to poor rock mass (Q 0.22 to 2.50) as per Barton`s classification. The details of the Q-values of north wall of pump house are given in Table 11.

Table 11: Rock mass classification using 'Q' of the face of north wall of pump house

NW side of North Wall of Pump House				**SE side of North Wall of Pump House**			
Easting from 953 to 1000				**From 1000 to 1047**			
Elevation		**Q**		**Elevation**		**Q**	
From	**To**	**Value**	**Description**	**From**	**To**	**Value**	**Description**
382	370	0.24	Very Poor	382	370	0.22	Very Poor
370	360	0.30	Very Poor	370	360	0.46	Very Poor
360	350	0.92	Very Poor	360	350	1.63	Poor
350	340	0.98	Very Poor	350	340	2.05	Poor
340	330	0.87	Very Poor	340	330	2.05	Poor
330	320	0.90	Very Poor	330	320	1.63	Poor
320	310	1.32	Poor	320	310	1.87	Poor
310	305	1.87	Poor	310	305	2.50	Poor

6.3.2 Geological Map – North Wall of Pump House

Based on the engineering geological mapping carried out in the north wall of pump house and the details collected including lithology, joint patterns measured in the field, the geological map was compiled on scale 1:200 has been appended to this report as Drawing No NIRM/MGKLIS-II/EG-13-01/07.

6.4 East Wall of Pump House

The east wall of pump house was excavated from RL +349.00 m to RL +302.00 m. This wall is aligning along the N035°-N215° direction. The average height of the wall after total excavation is 47 m from bottom level at RL +302 m to the top of the wall which is at RL+349 m. The total design length of wall is 20.0 m, but over excavation was mapped mainly on the top of the wall is because of geological discontinuities and uncontrolled blasting. From the top elevation of this wall up to ground level i.e. at RL +380 m, ramp is being constructed, which will be the permanent approach during the operation of this project.

6.4.1 Geological and Structural Assessment

Rock type exposed after excavation on the wall section is granite which is coarse grained, hard and jointed in nature. Its colour varies from pink to greyish and its colour variation is due to varying in the amount of orthoclase (Fig. 8). Granite is generally fresh in nature. The rock mass is characterized by prominent four number of joint sets, which are continuous and persistent, slightly rough to smooth with unaltered joint walls. Staining has been recorded along the joint surfaces where the joints are tight and where opening is up to 3.0 mm, soft clay filling/coating has been recorded. In general, the rock mass is characterized by dry condition or minor inflow i.e. < 5.0 l/min. Crack/fractures developed due to excavation / blasting were also recorded during geological mapping. Some of the cracks are tight while some are open and the size of the opening varying from 1 mm to 6 cm. Hairline cracks developed due to excavation work were also recorded. The details of the joint characteristics of east wall of pump house are given in Table 12.

A shear zone-1 (feature SH-1 in Drawing No NIRM/MGKLIS-II/EG-13-01/08) trending in N350° direction with a dip amount of 75°, and a strike length of more than 50 m, has been mapped on face of the wall i.e., between northing 8656 m at RL +302 m on the bottom

excavated portion and northing 8638 m at RL +349 m on the top of the wall. The average width of shear zone is 10 cm. The prominent joint sets intersecting the shear zone are: N 250°/45°, N90°/V, and N180°/40°.

Table 12: Joint sets developed in granite at the face of east wall of pump house

Joint Set	Dip Direction	Dip Amount	Spacing (cm)	Persistence (m)	Roughness	Aperture (mm)	Infilling (mm)	Groundwater Condition	Remarks
J1	250-270	60-70	20-50	>25	Slightly rough to smooth	Tight to 2	Nil-Clay	Dry-Damp	Dipping towards the SE side of pump house area, support is required.
J2	040-070	60-70	50-100	>25	Slightly rough to smooth	Tight to 1	Nil-Clay coated	Dry-Damp	Dipping inside the wall of pump house, not unstable from stability point of view.
J3	350	75	20-50	>25	Slightly rough to smooth	Tight to 3	Nil-Clay coated	Dry-Damp	Dipping towards pump house i.e. west wall of pump house.
J4	300	60	30-70	>10	Slightly rough	Tight to 2	Nil-Clay coated	Dry-Damp	Dipping towards pump house, not favorable, Dripping of water at north east corner of pump house.
J5	090-130	Vertical	30-50	>10	Slightly rough	Tight to 1	Nil	Damp	Joint plane is stained to fresh
J6	200-220	60	50	>10	Slightly rough	Tight to 2	Nil-Clay coated	Damp	Joint plane is stained to fresh
J7	130	55	-	>5	Slightly rough	Tight	Nil	Damp	Joint plane is stained

The rock mass for the east wall of pump house is classified as very poor to poor rock mass (Q 0.18 to 1.09) as per Barton`s classification. The details of the Q values of east wall of pump house are given in Table 13.

Table 13: Rock mass classification using 'Q' of the face of east wall of pump house

NE side of East Wall of Pump House				SW side of East Wall of Pump House			
Northing from 8650 to 8660				From Northing 8640 to 8650			
Elevation		Q		Elevation		Q	
From	To	Value	Description	From	To	Value	Description
349	340	1.16	Poor	349	340	1.24	Poor
340	330	1.38	Poor	340	330	1.16	Poor
330	320	0.87	Very Poor	330	320	1.16	Poor
320	310	3.27	Poor	320	310	3.50	Poor
310	300	3.27	poor	310	300	3.50	Poor

6.4.2 Geological Map – East Wall of Pump House

Based on the engineering geological mapping carried out in the vertical east wall of pump house and the details collected including lithology, joint patterns measured in the field, the geological map was compiled on scale 1:200 has been appended to this report as Drawing No. NIRM/MGKLIS-II/EG-13-01/08.

6.5 Inferences and Recommendations – Walls of Pump House

Based on geological and structural data input, the following inferences and recommendations are given for the south, west, north and east wall of pump house:

a) The stability of the cut slopes/ vertical walls depends upon the geometry, frequency and orientation of joint sets, dip of slope and its plane of weakness. The site condition, particularly the north and south wall of pump house is not favourable for slope stability, mainly along the shear zones, due to their interplay with joint sets forming a wedge. Other major joint sets, dipping inside the wall or towards opposite sides of the wall i.e. those joint sets not dipping towards the pits do not tend to cause unfavourable condition. Generally the rocks are fresh, hard and jointed in nature.

b) The grade of rock mass based on the rock joints characteristics of the walls of pump house, has the Q values varying from 0.18 to 5.20 and fall under the very poor to fair rock mass category.

c) 6.0 m wide ramp with 1 in 10 gradients was constructed from the outer periphery of the pump house/surge pool i.e. outside the final dimensions of the pump house/surge pool has been extended up to south wall of pump house and service bay. This ramp will be the connecting link during the operation phase. This will also function as protective berm for the north wall of surge pool and south wall of pump house.

d) After NIRM recommendations, 3.0 m wide berm at RL +370 m is constructed along the three sides i.e. north, east and west wall of the pump house. Between 1st berm and ground surface i.e. between RL +370 m and RL + 385 m, slope is 1 in 1.7 (60^{o}). After proper scaling, 100 mm thick shotcrete (50 mm shotcrete then wire mesh then 50 mm shotcrete) with chainlink and weep holes was applied all along the face of the excavated surfaces of the pump house from RL +370 m to RL 385 m. Second 3.0 m wide berm is constructed at RL +360 m around three sides of pump house. 1:1.2 (50^{o}) slope was keep between 1st and 2nd berm i.e. between RL +370 m and RL +360 m. Spot rock bolting

and 100 mm thick reinforced shotcrete with chainlink and weep holes are applied in this slope. In case of chainlink of 100 mm with reinforced shotcrete, 50 mm layer shotcrete was first applied then chainlink/wiremesh and again 50 mm layer of shotcrete. The chainlink from the side corners was anchored two feet deep by iron rod. Third 3.0 m wide berm was constructed at RL +350 m for the north side of pump house. 1:1 slope has been provided between 2nd and 3rd berm i.e. between RL +360 m and RL + 350 m. 25 mm dia and 5.0 m length rock bolt with a spacing of 1.0 m c.c. in staggered fashion was applied between RL +360 m to RL +350 m. Additional rock bolts were also provided along the side walls as per the requirement. From ground level i.e. RL +385 m up to RL +381 m overburden and loose material was removed.

e) There in a need to properly scale off the loosened rock fragments from walls of the pump house, which are not shotcreted. The north and south wall of pump house should be properly protected by systematic rock bolting below RL +350 m up to foundation level. For the north and south wall, 25 mm dia and 5.0 m length rock bolt with a spacing of 1.5 m c.c. in staggered fashion is recommended below RL +350 m. 25 mm dia and 5.0 m length rock bolt with a spacing of 2.0 m in staggered fashion is recommended below RL + 360 m for the east and west walls of pump house. Further drainage holes should be provided in to these vertical side walls.
f) Provide 100 mm dia weephole at 4 m c.c. spacing, 1m depth perforated PVC pipe.
g) Chute drains along the berms should be constructed. At every berm, inner slope should be provided with toe drain and connected to the chute drain.
h) Loose, fractured, detached and protruding rock mass in the walls need to be removed before final treatment. It is recommended that all the loose/detached rock blocks may be scaled manually since scaling by machine led to further loosening of the blocks as reported.
i) RCC design lining of 500 mm thick will be done along all side walls of the pump house from foundation up to RL +368 m i.e. the level of five units of pump house. Above this level lining should be done following the cut slope, maintaining the minimum thickness of lining with sufficient anchorage.
j) After providing lining in the area, consolidation grouting (with 2.5 to 3.5 kg/cm^2 pressure) up to maximum 20 m depth should be done from the top surface using primary, secondary and tertiary holes so that the opening created due to blasting are

filled and area functions as monolithic or single rock mass. 6 m spacing for the primary, 3 m for secondary and 1.5 m for tertiary holes, is recommended.

k) On the walls shear zones and dykes are present. Some of the dykes are sheared. The sheared material should be removed by mechanical excavator and the excavated portion should be back filled with concrete.

7. ENGINEERING GEOLOGICAL ASSESSMENT OF THE FOUNDATION OF SERVICE BAY

Service bay area is lying in the eastern side of the pump house and excavated up to an average RL +350 m for the functional requirement. In the design eight columns are provided in the service bay area for the construction of building. From service bay area a 6 m wide ramp with 1 in 10 gradient is constructed up to ground level.

7.1 Geological and Structural Assessment

Rock type exposed after excavation is granite, which is coarse grained, hard and jointed in nature (Fig. 9). Its colour varies from pink to grayish and its colour variation is due to varying in the amount of orthoclase. Granite is generally fresh in nature. The rock mass is characterized by prominent four number of joint sets, which are continuous and persistent, slightly rough to smooth with generally unaltered joint walls. Staining has been recorded along the joint surfaces where the joints are tight and where opening is up to 50.0 mm, soft clay mineral filling/coating has been recorded. In general, the rock mass is characterized by dry condition or minor inflow i.e. < 5.0 l/min. Crack/fractures developed due to excavation / blasting were also recorded during geological mapping. Some of the cracks are tight while some are open and the size of the opening varying from 1 mm to 8 cm. Hairline cracks developed due to excavation work were also recorded. The details of the joint characteristics of service bay portion are given in Table 14.

A shear zone-1 (feature SH-1 in Drawing No NIRM/MGKLIS-II/EG-13-01/11) trending in N10° direction with a dip amount of 60°, and a strike length of more than 50 m, has been mapped on the foundation i.e., between easting 1056 m on the southern excavated portion and northing 8645 m on the eastern side. The average width of shear zone is 20 cm. The prominent joint set intersecting the shear zone are: N 175°/85° and N260°/70°.

Table 14: Joint sets developed in granite at the foundation of service bay

Joint Set	Dip Direction	Dip Amount	Spacing (cm)	Persistence (m)	Roughness	Aperture (mm)	Infilling (mm)	Groundwater Condition	Remarks
J1	010	60	10-50	25	Slightly rough to smooth	Tight to 50	Nil -clay	Damp	Joint plane is stained
J2	350-355	85	10-50	>20	Slightly rough to smooth	Tight to 2	Nil-clay coated	Damp	Joint plane is stained to fresh
J3	035-045	50-65	50-100	25	Slightly rough	Tight to 1	Nil-clay coated	Damp	Joint plane is stained to fresh
J4	250-260	65-70	30-70	20	Slightly rough	Tight to 2	Nil-clay coated	Damp	Joint plane is stained to fresh
J5	040	Vertical	30-80	10	Slightly rough	Tight to 1	Nil	Damp	Joint plane is stained
J6	120	Vertical	50-100	10	Slightly rough	Tight to 2	Nil-clay coated	Damp	Joint plane is stained to fresh
J7	175	85	-	10	Slightly rough	Tight	Nil	Damp	Joint plane is fresh

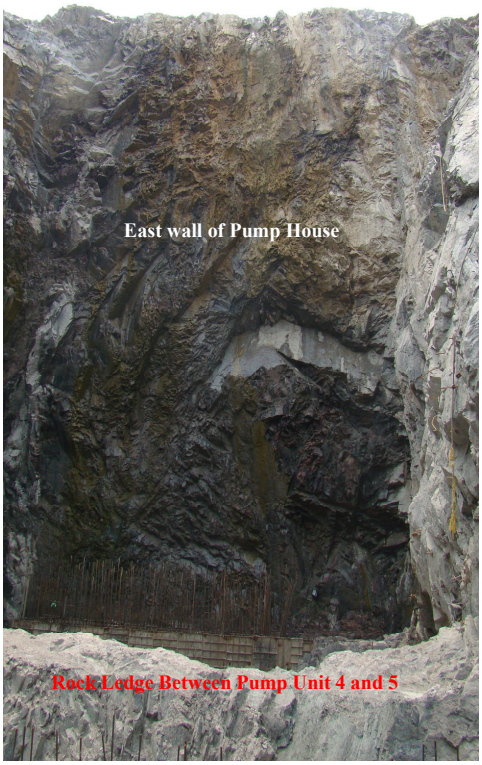

Fig. 8. View of east wall of pump house

Fig. 9. View of foundation of service bay

The rock mass for the foundation of service bay is classified as fair and good rock mass (RMR 52 to 63) as per Bieniawski's classification. The details of the RMR values of foundation of service bay are given in Table 15.

Table 15: Rock mass classification using 'RMR' of the service bay foundation

Block No.	Rock Type	RMR		
		Value	Class	Description
1	Coarse Pink Granite	52	Class-III	Fair
2	Coarse Pink Granite	52	Class-III	Fair
3	Coarse Pink Granite	61	Class-II	Good
4	Coarse Pink Granite	61	Class-II	Good
5	Coarse Pink Granite	61	Class-II	Good
6	Coarse Pink Granite	57	Class-III	Fair
7	Coarse Pink Granite	57	Class-III	Fair
8	Coarse Pink Granite	61	Class-II	Good
9	Coarse Pink Granite	63	Class-II	Good
10	Coarse Pink Granite	61	Class-II	Good
11	Coarse Pink Granite	57	Class-III	Fair
12	Coarse Pink Granite	57	Class-III	Fair
13	Coarse Pink Granite	57	Class-III	Fair
14	Coarse Pink Granite	57	Class-III	Fair
15	Coarse Pink Granite	57	Class-III	Fair
16	Coarse Pink Granite	57	Class-III	Fair
17	Coarse Pink Granite	52	Class-III	Fair
18	Coarse Pink Granite	52	Class-III	Fair
19	Coarse Pink Granite	52	Class-III	Fair
20	Coarse Pink Granite	57	Class-III	Fair

7.2 Geological Map – Foundation of Service Bay

Based on the engineering geological mapping carried out in the foundation of service bay and the details collected including lithology, joint patterns measured in the field, the geological map was compiled on scale 1:200 has been appended to this report as Drawing No. NIRM/MGKLIS-II/EG-13-01/11.

7.3 Inferences and Recommendations for the Foundation of Service Bay

Based on geological and structural data input, the following inferences and recommendations are given for the foundation of service bay:

a) Based on the field observations and evidences, it is observed that floor area of service bay is characterized by coarse grained, hard and jointed pink granite (containing alkali feldspars,

quartz, mica and amphibole) traversed by one shear zone. Depth persistence and lateral prevalence of bed rock was established. The floor region is fresh to slightly weathered (W-I to W-II) but prominent joints are present.

b) Field observations indicate that the rock mass is quite competent and acceptable for the foundation.

c) The grade of rock mass of the foundation of service bay has the RMR values varying from 52 to 63 and fall under fair to good category.

d) There in a need to properly scale off the loosened rock fragments all along the floor of the service bay before the final treatment of foundation.

e) A shear zone-1 (feature SH-1 in Drawing No NIRM/MGKLIS-II/EG-13-01/11) area having clay gauge should be excavated up to 0.50 m depth by mechanical breakers and backfilled with concrete (M≥25) up to the foundation level.

f) After providing lining in the area, consolidation grouting (with 2.5 to 3.5 kg/cm^2 pressure) up to maximum 10 m depth be done from the top surface using primary, secondary and tertiary holes so that the opening created due to blasting are filled and area functions as monolithic or single rock mass. 6 m spacing for the primary, 3 m for secondary and 1.5 m for tertiary holes, is recommended.

g) It is recommended to complete blasting before taking up the grouting operation. If blasting after grouting is unavoidable, through testing and regrouting is essential after blasting.

8. ENGINEERING GEOLOGICAL ASSESSMENT OF THE FOUNDATION OF ANNEXURE PART - A

Annexure Part-A is lying in the southern side of the pump house. Annexure Part-A area is excavated up to an average RL +332 m and six columns for annexure building are provided in the design.

8.1 Geological and Structural Assessment

Rock type exposed after excavation in the foundation of Annexure Part-A is granite, which is coarse grained, hard and jointed in nature (Fig. 10). Its colour varies from pink to grayish and its colour variation is due to varying in the amount of orthoclase. Granite is generally fresh in nature. The rock mass is characterized by prominent four number of joint sets, which are continuous and persistent, slightly rough to smooth with unaltered joint walls (Fig. 11). Staining has been recorded along the joint surfaces where the joints are tight and where

opening is up to 50.0 mm, soft clay mineral and crushed material filling has been recorded. In general, the rock mass is characterized by dry condition or minor inflow i.e. < 5.0 l/min. Crack/fractures developed due to excavation / blasting were also recorded during geological mapping. Some of the cracks are tight while some are open and the size of the opening varying from 1 mm to 8 cm. Hairline cracks developed due to excavation work were also recorded. The details of the joint characteristics of annexure part-A portion are given in Table 16.

Fig. 10. View of foundation of Annexure Part-A

Table 16: Joint sets developed in granite on annexure part-A area

Joint Set	Dip Direction	Dip Amount	Spacing (cm)	Persistence (m)	Roughness	Aperture (mm)	Infilling (mm)	Groundwater Condition	Remarks
J1	175-180	75-80	10-50	25	Slightly rough to smooth	Tight to 50	Nil-Clay	Damp	Joint plane is stained
J2	270-290	70	30-70	>20	Slightly rough to smooth	Tight to 2	Nil-Clay coated	Damp	Joint plane is stained to fresh
J3	065-60	50-65	30-100	10	Slightly rough	Tight to 1	Nil-Clay coated	Damp	Joint plane is stained to fresh
J4	250	Vertical	30-70	10	Slightly rough	Tight to 2	Nil-Clay coated	Damp	Joint plane is stained to fresh
J5	320	75	30-80	>10	Slightly rough	Tight to 1	Nil	Damp	Joint plane is stained
J6	230	75	-	>5	Slightly rough	Tight to 2	Nil-Clay coated	Damp	Joint plane is stained to fresh
J7	190	Vertical	-	>5	Slightly rough	Tight	Nil	Damp	Joint plane is fresh

A shear zone-1 (feature SH-1 in Drawing No NIRM/MGKLIS-II/EG-13-01/12) trending in N190° direction with a dip amount of 80°, and a strike length of more than 25 m, has been

mapped on the foundation i.e., from easting 995 m and northing 8827 m on the eastern side portion to easting 1017 m and northing 8637 m on the western side. The average width of shear zone is 20 cm. The prominent joint sets intersecting the shear zone are: N 065°/60°, N 250°/V and N320°/75°.

Fig. 11. Foundation of Annexure Part-A was cleaned before engineering geological mapping

A shear zone-1 (feature SH-1 in Drawing No NIRM/MGKLIS-II/EG-13-01/12) trending in N190° direction with a dip amount of 80°, and a strike length of more than 25 m, has been mapped on the foundation i.e., from easting 995 m and northing 8827 m on the eastern side portion to easting 1017 m and northing 8637 m on the western side. The average width of shear zone is 20 cm. The prominent joint sets intersecting the shear zone are: N 065°/60°, N 250°/V and N320°/75°.

The rock mass for the foundation of Annexure Part-A is classified as fair rock mass (RMR 49 to 57) as per Bieniawski's classification. The details of the RMR values of foundation of service bay are given in Table 17.

8.2 Geological Map – Foundation of Annexure Part-A

Based on the engineering geological mapping carried out in the foundation of Annexure Part-A and the details collected including lithology, joint patterns measured in the field, the geological

map was compiled on scale 1:200 has been appended to this report as Drawing No. NIRM/MGKLIS-II/EG-13-01/12.

Table 17: Rock mass classification using 'RMR' of the Annexure Part-A

Block No.	Rock Type	RMR		
		Value	Class	Description
1	Coarse Pink Granite	52	Class-III	Fair
2	Coarse Pink Granite	52	Class-III	Fair
3	Coarse Pink Granite	52	Class-III	Fair
4	Coarse Pink Granite	49	Class-III	Fair
5	Coarse Pink Granite	49	Class-III	Fair
6	Coarse Pink Granite	49	Class-III	Fair
7	Coarse Pink Granite	49	Class-III	Fair
8	Coarse Pink Granite	52	Class-III	Fair
9	Coarse Pink Granite	52	Class-III	Fair
10	Coarse Pink Granite	52	Class-III	Fair
11	Coarse Pink Granite	52	Class-III	Fair
12	Coarse Pink Granite	52	Class-III	Fair
13	Coarse Pink Granite	57	Class-III	Fair
14	Coarse Pink Granite	57	Class-III	Fair

8.3 Inferences and Recommendations for the Foundation of Annexure Part-A

Based on geological and structural data input, the following inferences and recommendations are given for the foundation of annexure part-A:

a) Based on the field observations and evidences, it is observed that floor area of annexure part-A is characterized by coarse grained, hard and jointed pink granite traversed by one shear zone. Depth persistence and lateral prevalence of bed rock was established. The floor region is fresh to moderately weathered (W-I to W-III) and prominent inclined/vertical joints are present.

b) The grade of rock mass of the foundation of annexure part-A has the RMR values varying from 49 to 57 and fall under fair rock mass category.

c) There in a need to properly scale off the loosened rock fragments all along the floor of the annexure part-A before the final treatment of foundation.

d) A shear zone-1 (feature SH-1 in Drawing No NIRM/MGKLIS-II/EG-13-01/12) area having clay gauge should be excavated up to 0.50 m depth by mechanical breakers and backfilled with concrete (M≥25) up to the foundation level.

e) After providing lining in the area, consolidation grouting (with 2.5 to 3.5 kg/cm^2 pressure) up to maximum 10 m depth be done from the top surface using primary, secondary and tertiary holes so that the opening created due to blasting are filled and area functions as monolithic or single rock mass. 6 m spacing for the primary, 3 m for secondary and 1.5 m for tertiary holes, is recommended.

f) It is recommended to complete blasting before taking up the grouting operation. If blasting after grouting is unavoidable, through testing and regrouting is essential after blasting.

9. ENGINEERING GEOLOGICAL ASSESSMENT OF THE FOUNDATION OF ANNEXURE PART - B

Annexure Part-B is lying on the southern side of the pump house i.e. towards eastern side of annexure part-A (Fig. 12). Annexure Part-B area is excavated up to an average RL +335 m and three columns for annexure building are provided in the design on this surface.

Fig. 12. View of foundation of Annexure Part-B

9.1 Geological and Structural Assessment

Rock type exposed after excavation in the foundation of Annexure Part-B is granite, which is coarse grained, hard and jointed in nature. Its colour varies from pink to grayish and its colour

variation is due to varying in the amount of orthoclase. Granite is generally fresh in nature. The rock mass is characterized by prominent four number of joint sets, which are continuous and persistent, slightly rough to with unaltered joint walls. Staining has been recorded along the joint surfaces where the joints are tight and where opening is up to 50.0 mm, soft clay mineral and crushed material filling has been recorded. In general, the rock mass is characterized by dry condition or minor inflow i.e. < 5.0 l/min. Crack/fractures developed due to excavation / blasting were also recorded during geological mapping. Some of the cracks are tight while some are open and the size of the opening varying from 1 mm to 6 cm. Hairline cracks developed due to excavation work were also recorded. The details of the joint characteristics of annexure part-A portion are given in Table 18.

Table 18: Joint sets developed in granite on Annexure Part-B area

Joint Set	Dip Direction	Dip Amount	Spacing (cm)	Persistence (m)	Roughness	Aperture (mm)	Infilling (mm)	Groundwater Condition	Remarks
J1	190-200	65-80	10-50	25	Slightly rough to smooth	Tight to 50	Nil-Clay	Damp	Joint plane is stained
J2	240-250	60	30-70	>20	Slightly rough to smooth	Tight to 2	Nil-Clay coated	Damp	Joint plane is stained to fresh
J3	310	65	30-100	10	Slightly rough	Tight to 1	Nil-Clay coated	Damp	Joint plane is stained to fresh
J4	020	80	30-70	10	Slightly rough	Tight to 2	Nil-Clay coated	Damp	Joint plane is stained to fresh
J5	270	Vertical	50	>10	Slightly rough	Tight to 1	Nil	Damp	Joint plane is stained
J6	340	70	-	>10	Slightly rough	Tight to 2	Nil-Clay coated	Damp	Joint plane is stained to fresh
J7	330	Vertical	-	>5	Slightly rough	Tight	Nil	Damp	Joint plane is fresh

The rock mass for the foundation of Annexure Part-B is classified as fair and good rock mass (RMR 52 to 61) as per Bieniawski's classification. The details of the RMR values of foundation of Annexure Part-B are given in Table 19.

9.2 Geological Map – Foundation of Annexure Part-B

Based on the engineering geological mapping carried out in the foundation of Annexure Part-B and the details collected including lithology, joint patterns measured in the field, the geological map was compiled on scale 1:200 has been appended to this report as Drawing No. NIRM/MGKLIS-II/EG-13-01/13.

Table 19: Rock mass classification using 'RMR' of the Annexure Part-B

Block No.	Rock Type	RMR		
		Value	Class	Description
1	Coarse Pink Granite	52	Class-III	Fair
2	Coarse Pink Granite	52	Class-III	Fair
3	Coarse Pink Granite	52	Class-III	Fair
4	Coarse Pink Granite	52	Class-III	Fair
5	Coarse Pink Granite	52	Class-III	Fair
6	Coarse Pink Granite	52	Class-III	Fair
7	Coarse Pink Granite	52	Class-III	Fair
8	Coarse Pink Granite	61	Class-II	Good
9	Coarse Pink Granite	61	Class-II	Good
10	Coarse Pink Granite	61	Class-II	Good

9.3 Inferences and Recommendations for the Foundation of Annexure Part-B

Based on geological and structural data input, the following inferences and recommendations are given for the foundation of annexure part-B:

a) Based on the field observations and evidences, it is observed that floor area of annexure part-B is characterized by coarse grained, hard and jointed pink granite. Depth persistence and lateral prevalence of bed rock was established. The floor region is fresh to moderately weathered (W-I to W-III) and prominent inclined joints are present.

b) The grade of rock mass of the foundation of annexure part-A has the RMR values varying from 52 to 61 and fall under fair and good rock mass category.

c) There in a need to properly scale off the loosened rock fragments all along the floor of the annexure part-B before the final treatment of foundation.

d) After providing lining in the area, consolidation grouting (with 2.5 to 3.5 kg/cm^2 pressure) up to maximum 10 m depth be done from the top surface using primary, secondary and tertiary holes so that the opening created due to blasting are filled and area functions as monolithic or single rock mass. 6 m spacing for the primary, 3 m for secondary and 1.5 m for tertiary holes, is recommended.

e) It is recommended to complete blasting before taking up the grouting operation. If blasting after grouting is unavoidable, through testing and regrouting is essential after blasting.

ACKNOWLEDGEMENTS

We sincerely thanks the Management of Navayuga Engineering Company Limited, Hyderabad for entrusting the engineering geological investigations of surge pool and pump house area of Mahatma Gandhi Kalwakurthi Lift Irrigation Scheme-II to NIRM. We also sincerely acknowledge the support extended by Mr. P.V. Rama Rao, Sr. General Manager and Mr. G. Shashidhar Reddy, General Manager (Project) M/s Navayuga Engineering Company Limited, during the field investigations at the MGKLIS-II site. We also sincerely acknowledge the co-ordination and support rendered by Mr. Kashi Govinda Rao, Project Manager, Mr. P. Sobhan Babu, Site Engineer and Mr. Srikant Reddy, Surveyor of M/s Navayuga Engineering Company Limited.

We sincerely thank Dr. V. Venkateswarlu, Director, NIRM for providing technical guidance, valuable advice during the investigations and for overall supervision. We thank Dr. P.C. Jha, Head, TC & PMD, NIRM, for encouragement throughout the duration of project.

RESTRICTION

This report is classified as confidential and is meant for the internal use of Navayuga Engineering Company Limited to which it is submitted by National Institute of Rock Mechanics (NIRM). This report, in full, or part, can neither be quoted nor published anywhere by anybody other than the investigators. It should not be communicated / circulated to agencies other than the concerned government departments. NIRM reserves the right to publish the results of the present study.

10 REFERENCES

Barton, N., Lien, R. and Lunde, J. 1974. Engineering classification of rock masses for the design of tunnel support. Rock Mechanics, v. 6(4), pp. 189-236.

Barton, N., Loset, F., Lien, R. and Lunde, J. 1980. Application of the Q-system in design decisions concerning dimensions and appropriate support for underground installations. Inter. Conf. on Sub-surface Space, Rock store, Stockholm. Sub-Surface Space, v. 2, pp. 553-561.

Bieniawski, Z.T. 1979. The geomechanics classification in rock engineering application. Proc. 4th International Congress on Rock Mechnacics, ISRM, Montreux, Balkema, Rotterdam, v. 2, 41-48.

Bieniawski, Z.T. 1989. Engineering rock mass classification. John Willey & Sons, New York, 251 p.

Gopal Reddy, T. and Viswanatha Rao, N. 1991. Study of granitic rocks in Gadwal Makhtal area, Mahbubnagar District, Andhra Pradesh. Rec. Geol. Surv. India, v. 124, Part 5, pp. 256-258.

GSI, 2001. Explanatory brochure on Geology and Mineral map of Andra Pradesh. Geological Survey of India.

GSI, 1995. Geological Quadrangle maps of GSI: No. 57E (2004) and 56L (1995) published by Geological Survey of India.

IS 5529 (Part 2). 2006. In-situ permeability test - Part-2 tests in bedrock. Bureau of Indian Standards, 13 p.

IS 6066, 1994. Pressure grouting of rock foundations in river valley projects – recommendations. Bureau of Indian Standards, 16 p.

ISRM, 1978. Suggested methods for the quantitative description of discontinuities in rock mass. International Journal Rock Mech. Sci. & Geomech. (Abstract), Pergamon, v. 15(6), pp. 319-368.

Nagarajan, K. and Roy, M.D. 1991. Geology of Peninsular Gneissic Complex in parts of Mahabubnagar District, Andhra Pradesh, Rec. Geol. Sur. India, v. 124, part 5, pp. 15-17.

Naithani, A.K., Singh, L.G and Rawat, D.S., 2012, Report on Construction stage engineering geological investigations of surge pool and pump house (5 x 30 MW) area of Mahatma Gandhi Kalwakurthi Lift Irrigation Scheme – II, Mahaboobnagar District, Andhra Pradesh. National Institute of Rock Mechanics Report No. EG-11-04, 50 p.

Project Vasundhara, 1994. Geoscientific analysis, database creation and development of GSI for parts of South Indian Peninsular Shield, Special publication, published jointly by AMSE wing, GSI and RRSSC, ISRO.

Ramam, P.K. and V.N. Murty, 2012. Geology of Andhra Pradesh. Geological Society of India, 244 p.

Sharma, Rajendra, Murthy, C.V.V.S., Mishra, V.P., Nagaraju, Gouda, H.C. and Singh, R.K., 2008, Study of structural pattern through aeromagnetic data for mineral prospecting and Kimberlite clan rocks in an area around Mahbubnagar, A.P. Journal Geological Society of India, v. 72, pp. 175-189.

Sridhar, M., Chowdhary, V.S., Nayak, S.S. and Augastine, P. F. 2004. Discovery of Kamberlite pipes in Gadwal area Mahabubnagar District, Jour. Geol. Soc. India, v. 63, No. 1, pp. 95-99.

ANNEXURE - I

Ref. NIRM/EGD/MGKLIS-II/2013/05 **Date: 12.03.2013**

Inspection Note

Project Title

Construction Stage Engineering Geological Investigations of Surge pool and Pump House (5x30 MW) area of Mahatma Gandhi Kalwakurthi Lift Irrigations Scheme, Stage-II, Mahabubnagar District, Andhra Pradesh (Phase-II)

The Mahatma Gandhi Kalwakurthi Lift Irrigation Scheme (MGKLIS) is being constructed having the three stages (I, II & III) for lifting the Krishna water from Srisailam reservoir (back water) to Gudipallygattu balancing reservoir through channels and tunnels. Navayuga Engineering Company Ltd is constructing MGKLIS package 2 located at Sathapur village, Mahboobnagar District, A.P. MGKLIS-II is being constructed for lifting the water from Singotam balancing reservoir to Jonnalaboguda balancing reservoir. The major components of the project are: one 4.0 km long gravity canal from Singotam balancing reservoir having bed width of 19.15 m, one 4.553 km long and 6.85 m finished diameter 'D' shaped tunnel, one surge pool (94m long x 40m width x 75m height), 50m long five numbers of draft tube tunnels, one pump house (94 m long X 20 m width X 78 m height) and five numbers, 15m long horizontal & 305m long inclined having 3.0 m finished diameter delivery main tunnels. In between the Surge pool and Pump house 50m wide rock ledge is proposed is the design. So far Navayuga Engineering Company Ltd. has excavated surge pool upto foundation level and pump house up to app. RL 330 m. The ground level of surge pool is at RL +382 m and the foundation level is at RL +307 m while the ground level of pump house is at RL +383 m and the foundation level is at RL +305.40 m. Three draft tubes have been constructed and two are under excavation. All the four sides of the surge pool and pump house will be lined with 500 mm RCC filling from the bed line up to max. surge level and floored with 300 mm thick raft foundation to distribute the load as per design specification.

Dr. A.K. Naithani, Senior Scientist, NIRM inspected the site on the request of Navayuga Engineering Company Ltd. The project site was visited on 06.03.2013 and 07.03.2013 regarding the shear zones treatments and lining of surge pool area. The following and other project officials of M/s Navayuga Engineering Company Ltd. and Andhra Pradesh Irrigation and CAD Department were present during the site inspection and the discussions.

NIRM	Navayuga Engineering Company Ltd.	Andhra Pradesh Irrigation and CAD Department
Dr. A.K. Naithani Project Leader, EGD	Mr. G. Shashidhar Reddy, AGM	Mr. S. Suresh, Executive Engineer
	Mr. Kashi Govinda Rao, Senior Project Manager	Mr. K. Sanjeeva Rao, Deputy Executive Engineer
	Mr. Raja Mani, Deputy Project Manager	Mr. P.V. Nagender, Deputy Executive Engineer
	Mr. Vinod Kumar, Assistant Project Manager	
	Mr. P. Sobhan Babu, Site Engineer	

The following decisions were taken after the discussions at the site:

1. Regarding the treatment of thick shear zones special bolting system was suggested at the site to the Contractor Engineers. First the gauge should be cleaned out to the desired extent, then this dental excavation should be backfilled with concrete (M>25) and finally rock bolt installed across the shear zone. The concrete should be allowed to cure for 10-12 days before installation of rock bolt. The length of rock bolt will be varying from 5 to 7 m as per the site condition. The other support system should be as per approved design.
2. In the surge pool area for south, east and west walls concrete lining can be done from the foundation level to the max. Surge Level + 5 m i.e. +340 level in steps i.e. following the cut slope and the remaining portion from +340 to ground level 100 mm shotcreting to be done.
3. For north wall stability has to be checked by the designer, because after excavation the width of rock ledge is less than 20m, particularly towards western side. The reinforced lining will be stitched with the insitu rockmass by 3m long, 20mm dia grouted rock bolts at a spacing of 1.5 mts c/c.
4. Controlled blasting should be adopted for rock excavation at the ultimate walls of the project to minimize deterioration of the rock mass and loose rock mass should be removed by mechanical excavator.

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ANNEXURE - II

Ref. NIRM/EGD/MGKLIS-II/2013/06 Dated: 14.05.2013

Note on Geotechnical Assessment of the Foundation of Surge Pool – MGKLIS-II

Project Title - Construction Stage Engineering Geological Investigations of Surge pool and Pump House (5x30 MW) area of Mahatma Gandhi Kalwakurthi Lift Irrigations Scheme, Stage-II, Mahabubnagar District, Andhra Pradesh (Phase-II)

By
A.K. Naithani and L.G. Singh
National Institute of Rock Mechanics, Kolar Gold Fields, Karnataka

1. INTRODUCTION

The Mahatma Gandhi Kalwakurthi Lift Irrigation Scheme (MGKLIS) is being constructed having the three stages (I, II & III) for lifting the Krishna water from Srisailam reservoir (back water) to Gudipallygattu balancing reservoir through channels and tunnels. M/s Navayuga Engineering Company Ltd (NECL) is constructing MGKLIS package 2 located at Sathapur village, Mahboobnagar District, A.P. MGKLIS-II is being constructed for lifting the water from Singotam balancing reservoir to Jonnalaboguda balancing reservoir.

The major components of the project are: one 4.0 km long gravity canal from Singotam balancing reservoir having bed width of 19.15m, one 4.553 km long and 6.85m finished diameter 'D' shaped tunnel, one surge pool (94m long x 40m width x 75m height), 50m long five numbers of draft tube tunnels, one pump house (94m long X 20m width X 78m height) and five numbers, 15m long horizontal & 305m long inclined having 3.0 m finished diameter delivery main tunnels. In between the surge pool and pump house 50m wide rock ledge is proposed is the design.

So far Navayuga Engineering Company Ltd has excavated surge pool up to foundation level and pump house up to app. RL 330m. The ground level of surge pool is at RL +382m and the foundation level is at RL +307m while the ground level of pump house is at RL +383m and the foundation level is at RL +305.40m. Three draft tubes have been constructed and two are under excavation. All the four sides of the surge pool and pump house will be lined with 500mm RCC filling from the bed line up to max. surge level and floored with 300mm thick raft foundation to distribute the load as per design specification.

This note pertains to large scale engineering geological mapping on 1:200 scale of foundation strata at foundation level of surge pool of MGKLIS-II. The objective of this study is to advise suitable engineering measures for the treatment of foundation of surge pool based on detailed engineering geological investigations. The report pertaining to Construction Stage Engineering Geological Investigations of Surge pool and Pump House (5x30 MW) area of Mahatma Gandhi Kalwakurthi Lift Irrigations Scheme, Stage-II, Mahabubnagar District, Andhra Pradesh was submitted by National Institute of Rock Mechanics (NIRM) to Navayuga Engineering Company Ltd in March 2012, containing the large scale geological mapping on 1:200 scale of excavated walls of surge pool and pump house and rock ledge between surge pool and pump of MGKLIS-II. In the present study, detailed engineering geological mapping on 1:200 scale in the foundation of surge pool has been carried out using the Total Station and a total area of approximately 3,600 sq.m. has been mapped (Drawing Nos. NIRM/MGKLIS-II/EG-13-01/01).

2. METHODOLOGY

Grids were prepared for mapping the surge pool floor area. The size of the grid is 2 m X 2 m, which was decided based on the mapping accuracy and resolution required for such investigations. Grids for mapping were marked on the floor by NECL surveyor using elevation & chainages provided by them. Detailed examination of rock types in each grid was carried out which includes mineralogical composition, texture, classification and nomenclature and degree/grade of weathering. Fracture filling that have taken place in the study site were examined and recorded. The attitude and structure of the rocks, fractures and joint pattern present in the floor was determined for mapping. ISRM (1978), classifications for weathered rock mass was used to characterize the rock mass into different grade (Table-1). The assessment of RMR (Bieniawski, 1989) for granites rock masses, based on the rock joints and their nature and laboratory test data has been attempted.

Table 1: Description of Weathering Grade (ISRM, 1978)

Term	Description	Grade
Fresh	No visible sign of rock material weathering; perhaps slight discolouration on major discontinuity surfaces.	I
Slightly weathered	Discolouration indicates weathering of rock material and discontinuity surfaces. All the rock material may be discoloured by weathering and may be somewhat weaker externally than in its fresh condition.	II
Moderately weathered	Less than half of the rock material is decomposed and / or disintegrated to a soil. Fresh or discoloured rock is present either as a continuous framework or as core stones.	III
Highly weathered	More than half of the rock material is decomposed and / or disintegrated to a soil. Fresh or discoloured rock is present either as a discontinuous framework or as core stones.	IV
Completely weathered	All rock material is decomposed and / or disintegrated to soil. The original mass structure is largely intact.	V
Residual soil	All rock material is converted to soil. The mass structure and material fabric are destroyed. There is a large change in volume, but the soil has not been significantly transported.	VI

3. ENGINEERING GEOLOGICAL & GEOTECHNICAL ASSESSMENTS OF FOUNDATION

Foundation floor geological mapping of the important structures is essential to provide permanent data input for geological interpretations during construction and also it forms valuable documentation for post-construction stage. For very important structures like deep surge pool and pump house of lift irrigation, the foundation strata have to be well studied and documented for credible geologic interpretations. Rock is usually recognized as the best foundation material. However, design engineers should be aware of the dangers associated with heterogeneity and unfavourable rock conditions since over-stressing a rock foundation may result in large differential settlements or perhaps sudden failure.

In order to evaluate the design basis foundation parameters for surge pool of MGKLIS-II, engineering geological mapping (on 1:200 scale) was carried out by NIRM Geologists. All the discontinuities in the rock mass of foundation of surge pool with the zone of influence of the foundation has been identified and mapped. The primary purpose of the mapping is to provide a permanent record of conditions during the excavation. Mapping will be used to assess the requirement of any ground improvement. This permanent foundation record will assist in making better interpretation of post-construction foundation instrumentation data.

The floor of surge pool was examined on a grid to grid basis; the size of the grid is 2 m X 2 m. All the lithological and structural features were observed and mapped using Total Station surveying equipment and shown in the final foundation grade geological plan map. Classification of rock mass using Rock Mass Rating (RMR) of Bieniawski (1989) has been attempted and based on investigations recommendations for the treatment of foundation are given.

3.1 Geological and Structural Assessment – Floor of Surge Pool

The foundation of surge pool will be resting as per design on a raft of 300 mm thick at about 75.0 m below the existing ground level for functional requirement. The design ground level is at RL +307.00 but in some areas it is excavated up to an average RL +306.34 and the over excavation is varying from 0.100m to 1.141m because of presence of unfavourable discontinuities, shear zones and blasting. On the basis of surface geological mapping the excavated surface is acceptable for foundation because the rock mass is competent. Total 3600

sq.m excavated foundation area of surge pool floor has been geologically mapped. Geological foundation mapping was done after the excavation and before first pore of concrete. 2 m x 2 m grids were used for mapping of the floor. Based on the field observations and evidences, it is found that the entire floor area consists of coarse grained, hard and jointed pink granites. Total fifteen shear zones are mapped. The width of the shear zones are varying from 0.1 cm to 40 cm cm. No displacement has been recorded along shear zones. No evidences of faulting are observed on the surface of floor area. The structural features observed during the mapping indicated the need for consolidation grouting so that the entire floor are function as single rock mass.

Pink granites are coarse grained, hard and jointed and shows phenocryst of alkali feldspar and quartz. Main minerals composition is alkali feldspars, quartz, mica and amphiboles. Five prominent joints set are developed and along the joint plane clay filling/coating was also recorded. Joints are irregular in pattern. Granites are generally fresh to moderately weathered (WI–WIII). At the foundation level granites are traversed by dolerite dykes (feature D1, D2 & D3 marked in Drawing No NIRM/MGKLIS-II/EG-13-01/01). Dolerite dykes are fine grained and greenish-black in colour. The width of the dykes varies from 40cm to 200cm and their strike length is more than 100 m in excavated part of surge pool. Dykes are generally sheared and in D1 and D3 clay gouge was observed. Plagioclase and clinopyroxene (augite / titanaugite) are the main minerals occurring in ophitic to sub-ophitic textures in dolerite. Quartz, epidote and opaques occur as accessories. Amphibole, biotite, sericite occur as alteration products. Dykes are generally moderately to highly weathered (WIII – WIV).

The rock mass is characterized by prominent five number of joint sets, which are continuous and persistent, slightly rough to smooth with unaltered joint walls. Staining has been recorded along the joint surfaces where the joints are tight and where opening is up to 20.0 mm, soft clay mineral and crushed material filling has been recorded. In general, the rock mass is characterized by dry condition or minor inflow i.e. < 5.0 l/min. Crack/fractures developed due to excavation / blasting were also recorded during geological mapping. Some of the cracks are tight while some are open with size of the opening varying from 1 mm to 4 mm. Hairline cracks developed due to excavation work were also recorded. The prominent joints recorded in the coarse grained granite at the foundation of surge pool are given in Table 2.

Plate 1. Cleaning the foundation level of Surge Pool

Plate 2. Marking of grids on the foundation level

Plate 3. Collection of engineering geological data from the foundation of surge pool

Plate 4. Highly jointed area marked as feature A in the Drawing No. NIRM/MGKLIS-II/EG1301/01

Table 2: Prominent joints developed in coarse grained granite at the foundation of surge pool

Joint No	Dip Direction	Dip Amount	Spacing (cm)	Persistence (m)	Roughness	Aperture (mm)	Infilling (mm)	Groundwater Condition	Remarks
1	320	30-40	-	25	Slightly rough to smooth	Up to 70	Clay	Damp	Shear zone (SH-15)
2	290	Vertical	7-70	10	Slightly rough	Tight to 1	Nil	Damp	Joint plane is fresh
3	290	Vertical	20-30	7	Slightly rough	Tight to 1	Nil	Damp	Joint plane is stained
4	320	Vertical	28-50	7	Slightly rough	Tight	Nil	Damp	Joint plane is fresh
5	320	Vertical	28-50	7	Slightly rough	Tight	Nil	Damp	Joint plane is fresh
6	040-070	35-40	7-80	8	Slightly rough	Tight to 2	Nil	Damp	Joint plane is stained
7	070	35-40	7-80	8	Slightly rough	Tight to 2	Nil	Damp	Joint plane is stained
8	055	50	25	15	Slightly rough	Tight to 2	Nil	Damp	Joint plane is stained
9	300	Vertical	25	15	Slightly rough	Tight	Nil	Damp	Joint plane is fresh
10	060	55	25	15	Slightly rough	Tight	Nil	Damp	Joint plane is fresh
11	240	Vertical	-	10	Slightly rough	Tight	Nil	Damp	Joint plane is fresh
12	130	35	100	10	Slightly rough	Tight	Nil	Damp	Joint plane is fresh
13	305	48	10-80	25	Slightly rough	Tight to 1	Nil	Damp	Joint plane is stained
14	295	Vertical	30-70	15	Slightly rough	Tight	Nil	Damp	Joint plane is fresh
15	065	25-30	50-60	20	Slightly rough	Tight	Nil	Damp	Joint plane is fresh

Joint No	Dip Direction	Dip Amount	Spacing (cm)	Persistence (m)	Roughness	Aperture (mm)	Infilling (mm)	Groundwater Condition	Remarks
16	270	Vertical	-	8	Slightly rough	Tight to 2	Nil	Damp	Joint plane is stained
16a	350	70-75	-	8	Slightly rough	Tight to 2	Nil	Damp	Joint plane is stained
17	020	60-70	25-30	17	Slightly rough	Tight to 2	Nil	Damp	Joint plane is stained
18	290	Vertical	-	24	Slightly rough to smooth	Tight to 2	Clay	Damp	Slightly weathered
19	020-060	50-60	10-20	15	Slightly rough	Tight	Nil	Damp	Joint plane is fresh
20	260	60	30	20	Slightly rough to smooth	40	Clay	Damp	Shear zone (SH-14)
21	260	50-55	-	23	Slightly rough to smooth	300 to 400	Clay	Damp	Shear zone (SH-13)
22	210	Vertical	-	32	Slightly rough	20	Crushed rock material	Damp	Joint plane is fresh
23	290	50	20-40	5	Slightly rough	Tight	Nil	Damp	Joint plane is fresh
24	290	Vertical	7-10	24	Slightly rough	Tight	Nil	Damp	Joint plane is fresh
25	100	40-60	10-20	30	Slightly rough	Tight	Nil	Damp	Joint plane is fresh
26	060	50-60	10-20	11	Slightly rough	Tight to 2	Nil	Damp	Joint plane is stained
27	255	Vertical	10-20	15	Slightly rough	Tight	Nil	Damp	Joint plane is fresh
28	290	Vertical	10-100	10	Slightly rough	Tight	Nil	Damp	Joint plane is fresh
29	290	Vertical	10-100	10	Slightly rough	Tight	Nil	Damp	Joint plane is fresh
30	220	70	15-60	20	Slightly rough	Tight	Nil	Damp	Joint plane is fresh
30a	310	Vertical	15-60	20	Slightly rough	Tight	Nil	Damp	Joint plane is fresh
31	045	50	16-70	20	Slightly rough	Tight to 1	Nil	Damp	Joint plane is stained
32	290	Vertical	10-50	11	Slightly rough	Tight to 1	Nil	Damp	Joint plane is stained
32a	020	80-85	10-50	11	Slightly rough	Tight to 1	Nil	Damp	Joint plane is stained
33	010	70-80	10-30	24	Slightly rough	Tight to 1	Nil	Damp	Joint plane is stained
35	010	40-50	20-30	13	Slightly rough	Tight to 1	Nil	Damp	Joint plane is stained
36	260	60	10-100	12	Slightly rough	Tight to 1	Nil	Damp	Joint plane is stained
37	020	Vertical	-	8	Slightly rough	Tight to 1	Nil	Damp	Joint plane is stained
38	325	20-25	80-100	14	Slightly rough	Tight to 1	Nil	Damp	Joint plane is stained
39	310	70-75	30-40	15	Slightly rough	Tight to 1	Nil	Damp	Joint plane is stained
40	310	45-60	-	22	Slightly rough	Tight to 1	Nil	Damp	Joint plane is stained
42	230-265	60-70	-	84	Smooth	300 to 1500	Clay	Damp	Dolerite dyke (D1) sheared with clay gauge, moderately to highly weathered
43	050	80-85	7-30	10	Slightly rough	Tight to 1	Nil	Damp	Joint plane is stained
44	040	70-80	7-30	8	Slightly rough	Tight to 1	Nil	Damp	Joint plane is stained
45	310	Vertical	7-40	20	Slightly rough	Tight to 1	Nil	Damp	Joint plane is stained
46	300	Vertical	7-35	15	Slightly rough	Tight to 1	Nil	Damp	Joint plane is stained
47	020	80	16-35	12	Slightly rough	Tight to 1	Nil	Damp	Joint plane is stained
47a	200	60-70	16-35	12	Slightly rough	Tight to 1	Nil	Damp	Joint plane is stained
48	020	75	10-40	20	Slightly rough	Tight to 1	Nil	Damp	Joint plane is stained
49	035	85	20-50	20	Slightly rough	Tight to 1	Nil	Damp	Joint plane is stained
50	170	65-70	40-50	18	Slightly rough	Tight	Nil	Damp	Joint plane is fresh
51	255	Vertical	-	20	Smooth	50	Clay	Damp	Shear zone (SH-12)
52	325	30-50	100	12	Slightly rough	Tight	Nil	Damp	Joint plane is fresh
53	260	Vertical	20-40	20	Slightly rough	Tight	Nil	Damp	Joint plane is fresh
54	335	20-30	100	14	Slightly rough	Tight to 1	Nil	Damp	Joint plane is stained
55	70-80	30-35	150	7	Slightly rough	Tight to 1	Nil	Damp	Joint plane is stained

Joint No	Dip Direction	Dip Amount	Spacing (cm)	Persistence (m)	Roughness	Aperture (mm)	Infilling (mm)	Groundwater Condition	Remarks
56	310	70-75	-	15	Slightly rough	Tight to 1	Nil	Damp	Joint plane is stained
57	090	45-50	20-40	22	Slightly rough	Tight to 1	Nil	Damp	Joint plane is stained
58	200	80-85	20-70	15	Slightly rough	Tight	Nil	Damp	Joint plane is fresh
59	005	40-50	20-60	22	Slightly rough	Tight to 1	Nil	Damp	Joint plane is stained
60	200	80	10-30	12	Slightly rough	Tight to 1	Nil	Damp	Joint plane is stained
60a	010	80	10-30	11	Slightly rough	Tight to 1	Nil	Damp	Joint plane is stained
61	205	65	10-60	25	Slightly rough	Tight	Nil	Damp	Joint plane is fresh
62	005	70-80	20-50	18	Slightly rough	Tight	Nil	Damp	Joint plane is fresh
62a	215	80-85	20-50	17	Slightly rough	Tight	Nil	Damp	Joint plane is fresh
63	090	40	80	12	Slightly rough	Tight	Nil	Damp	Joint plane is fresh
64	130	30	-	7	Smooth	2mm	Clay	Damp	Shear zone (SH-11)
65	120-130	40	60	8	Slightly rough	Tight to 1	Nil	Damp	Joint plane is stained
66	080	35	-	20	Smooth	Tight to1	Clay	Damp	Slightly to moderately weathered
67	010	20	10-40	22	Slightly rough	Tight	Nil	Damp	Joint plane is fresh
68	235	45	-	4	Smooth	3	Crushed rock filling	Damp	Fresh to slightly weathered
69	260	65-70	-	13	Slightly rough	Tight	Nil	Damp	Joint plane is fresh
73	270	80-85	-	24	Smooth	2000	Crushed material	Damp	Dolerite dyke (D2) sheared and crushed material, moderately to highly weathered
74	040	45	10-30	13	Smooth	1 to 5	Clay	Damp	Minor shear zone (SH-4)
74a	310	Vertical	10-30	12	Smooth	1 to 5	Clay	Damp	Minor shear zone (SH-4)
75	010	80-85	10-15	30	Smooth	1 to 3	Clay	Damp	Minor shear zone (SH-2)
76	170	40-50	10-40	9	Slightly rough	Tight to 1	Nil	Damp	Joint plane is stained
77	220	65-70	100	25	Smooth	3 to 7	Clay	Damp	Minor shear zone (SH-6)
78	050	60-70	10-15	24	Smooth	3 to 7	Clay	Damp	Minor shear zone (SH-7)
79	310	Vertical	-	16	Smooth	300 to 400	Clay	Damp	Dolerite dyke (D3) sheared with clay gauge, moderately to highly weathered
80	310	Vertical	-	8	Smooth	200 to 300	Clay	Damp	Shear zone (SH-10)
80a	310	Vertical	-	11	Smooth	200 to 300	Clay	Damp	Shear zone (SH-09)
81	270	60-65	10-100	25	Smooth	2 to 4	Clay	Damp	Shear zone (SH-08)
82	310	45-50	40-60	34	Smooth	2 to 4	Clay	Damp	Shear zone (SH-01)
83	310	40-80	-	11	Smooth	2 to 4	Clay	Damp	Shear zone (SH-03)
84	300	60	50-80	7	Slightly rough	1 to 2	Nil	Damp	Joint plane is stained
85	215	65	10-30	7	Slightly rough	1 to 2	Nil	Damp	Joint plane is stained
86	305	65	100	14	Slightly rough	1 to 2	Nil	Damp	Joint plane is stained
87	310	Vertical	10-30	25	Slightly rough	Tight	Nil	Damp	Joint plane is fresh
87a	210	80	10-30	25	Slightly rough to smooth	1 to 2	Clay	Damp	Slightly weathered
88	210	45-60	10-40	7	Slightly rough	1 to 2	Nil	Damp	Joint plane is stained
89	110	45	100	14	Slightly rough to smooth	1 to 2	Clay	Damp	Slightly weathered
90	270	Vertical	-	18	Slightly rough	1 to 2	Nil	Damp	Joint plane is stained
91	170	30-70	10-35	13	Smooth	4 to 6	Clay	Damp	Shear zone (SH-05)
92	020	80-85	10-30	20	Slightly rough	1 to 2	Nil	Damp	Joint plane is stained
93	025	65	10-30	30	Slightly rough	Tight to 1	Nil	Damp	Joint plane is stained
94	010	65	10-30	22	Slightly rough	Tight to 1	Nil	Damp	Joint plane is stained
95	035	60-65	10-40	34	Slightly rough	Tight to 1	Nil	Damp	Joint plane is stained
96	025	75	-	23	Slightly rough	Tight to 1	Nil	Damp	Joint plane is fresh
97	010	60	-	12	Slightly rough	1 to 2	Nil	Damp	Joint plane is stained
98	010	65	-	10	Slightly rough	Tight to 1	Nil	Damp	Joint plane is stained
99	110	30-55	100	12	Slightly rough	1 to 2	Nil	Damp	Joint plane is stained
100	080	45	-	9	Slightly rough	Tight to 1	Nil	Damp	Joint plane is fresh
101	310	55	30	12	Slightly rough	1 to 2	Nil	Damp	Joint plane is stained
102	295	55	100	18	Slightly rough	Tight to 1	Nil	Damp	Joint plane is stained
103	300	50	50-100	22	Slightly rough	Tight to 1	Nil	Damp	Joint plane is fresh
104	310	60-80	100	25	Slightly rough	Tight to 1	Nil	Damp	Joint plane is stained
105	325	30-55	100	22	Slightly rough	Tight to 1	Nil	Damp	Joint plane is stained

Joint No	Dip Direction	Dip Amount	Spacing (cm)	Persistence (m)	Roughness	Aperture (mm)	Infilling (mm)	Groundwater Condition	Remarks
106	330	30-45	-	15	Slightly rough	Tight to 1	Nil	Damp	Joint plane is stained
107	325	40	-	14	Slightly rough	Tight to 1	Nil	Damp	Joint plane is stained
108	100	45	-	18	Slightly rough	Tight	Nil	Damp	Joint plane is fresh
109	100	45	-	8	Slightly rough	Tight	Nil	Damp	Joint plane is fresh
110	025	20	100	10	Slightly rough	Tight to 1	Nil	Damp	Joint plane is fresh

3.2 Geological Plan – Floor of Surge Pool

Based on the engineering geological mapping carried out at the foundation of surge pool, and the details collected including lithology and joint patterns measured in the field, the geological map was compiled on scale of 1:200, and it has been appended to this note as Drawing No NIRM/MGKLIS-II/EG-13-01/01.

3.3 Evaluation of Safe Bearing Capacity

Safe Bearing Pressure is an important factor for the design of foundation for large engineering structures. The ultimate bearing capacity (q.ult) is defined as average load per unit area required to produce failure by rupture of a supporting rock mass. The bearing capacity in jointed rock masses can be estimated by Rock Types, Rock Mass Rating (RMR), Uniaxial Compressive Strength (UCS), Point Load Strength, Rock Quality Designations (RQD), Pressure Meter Test and Plate Load Test (IS:12070–1987, Peck et.al., 1974). The methods based on the Rock Type and Rock Mass Rating (RMR) are used to evaluate the bearing capacity foundation parameters for the foundation of surge pool. For this the average Rock Mass Rating (RMR) is taken for the estimation of Safe Bearing Pressure using the procedure given in IS Code : 12070 – 1987.

Based on Rock Mass Classification: The rock type is coarse grained granite, which is a 'crystalline bedrock, including granite'; therefore

Rock Type (Material)	=	Granite
Net safe bearing pressure (q_{ns})	=	**1000 t/m^2**
Correction factor (for rock mass with continuous joints with aperture up to 5 mm and clay filled)	=	0.50
Allowable bearing pressure (q_{allow})	=	q_{ns} * correction factor
	=	1000 * 0.50 t/m^2
	=	500.0 t/m^2

Based on Rock Mass Rating, (RMR):

Average RMR	=	47.4
Classification of rock mass	=	Class III
Description of rock mass	=	Fair
Net safe bearing pressure (q_{ns})	**=**	**194.45 t/m^2**
Correction factor (for rock mass with continuous joints with aperture up to 5 mm and clay filled)	=	0.50
Allowable bearing pressure (q_{allow})	=	q_{ns} * correction factor
	=	194.45 * 0.50
	=	**97.225 t/m^2**

The safe bearing pressure and allowable bearing pressure calculated from the above two methods viz. by rock characteristic and RMR method are summarized in table 3 for the surge pool.

Table 3 : Safe bearing pressure and allowable bearing pressure for surge pool foundation

Sl. No.	Method	Safe Bearing Pressure, t/m^2	Allowable Bearing Pressure, t/m^2
01	Base on rock characteristic	1000.0	500.0
02	Based on Rock Mass Rating	194.45	97.225

It is recommended to adopt the allowable pressure value obtained from RMR, that is 97.225 t/m^2 for the design of foundation on this stratum for surge pool.

3.4 Geotechnical Assessment - Floor of Surge Pool

The floor area of the surge pool is falling under weathering grade 1 to 3 (WI - WIII). The grade of the rock mass as evaluated from the UCS and conditions of discontinuities has RMR values are varying from 37 to 63 and fall under poor to good rock. Randomly 20 samples were selected from the foundation of surge pool for the unconfined compressive strength and test results are summarized in Table 4. The uniaxial compressive strength test is primarily an index test for strength classification of rock materials. Tests were conducted at site and specimens were tested at a moisture content close to field conditions. Locations of samples are shown in Drawing No NIRM/MGKLIS-II/EG-13-01/01.

Table 4 : Uniaxial compressive strength of rock from foundation level of surge pool

Sr. No	Sample No.	Rock Type	Load (N)	Cross Sectional Area (mm^2)	Uniaxial Compressive Strength (UCS) (MPa)		RMR	
					Value	Class (ISRM, 1978)	Value	Class
1	UCS-1	Coarse Pink Granite	750000	3600	208.33	Very High Strength	57	III
2	UCS-2	Coarse Pink Granite	750000	3600	208.33	Very High Strength	63	II
3	UCS-3	Coarse Pink Granite	800000	3600	222.22	Very High Strength	43	III
4	UCS-4	Coarse Pink Granite	1000000	4900	204.08	Very High Strength	47	III
5	UCS-5	Coarse Pink Granite	900000	4900	183.67	Very High Strength	54	III
6	UCS-6	Coarse Pink Granite	700000	3600	194.44	Very High Strength	58	III
7	UCS-7	Coarse Pink Granite	850000	3600	236.11	Very High Strength	42	III
8	UCS-8	Coarse Pink Granite	900000	3600	250.00	Very High Strength	47	III
9	UCS-9	Coarse Pink Granite	900000	4900	183.67	Very High Strength	59	III
10	UCS-10	Coarse Pink Granite	900000	4900	183.67	Very High Strength	52	III
11	UCS-11	Coarse Pink Granite	850000	3600	236.11	Very High Strength	40	IV
12	UCS-12	Coarse Pink Granite	1050000	3600	291.67	Extremely High Strength	41	III
13	UCS-13	Coarse Pink Granite	900000	3600	250.00	Very High Strength	47	III
14	UCS-14	Coarse Pink Granite	750000	3600	208.33	Very High Strength	50	III
15	UCS-15	Coarse Pink Granite	900000	3600	250.00	Very High Strength	37	IV
16	UCS-16	Coarse Pink Granite	800000	3600	222.22	Very High Strength	47	III
17	UCS-17	Coarse Pink Granite	750000	3600	208.33	Very High Strength	38	IV
18	UCS-18	Coarse Pink Granite	900000	4900	183.67	Very High Strength	38	IV
19	UCS-19	Coarse Pink Granite	650000	4900	132.65	Very High Strength	38	IV
20	UCS-20	Coarse Pink Granite	750000	4900	153.06	Extremely High Strength	50	III

4. Recommendations – Floor of Surge Pool

Based on above studies, the following recommendations have been made:

a. Based on the field observations and evidences, it is observed that area in the floor of surge pool site is characterized by coarse grained, hard and jointed pink granite (containing alkali feldspars, quartz, mica and amphibole) traversed by dolerite dykes. Depth persistence and lateral prevalence of bed rock was established. The floor region is fresh to moderately weathered (W-I to W-III) but prominent vertical/inclined joints are present.

b. The test results and field observations indicate that the rock mass is quite competent and acceptable for the foundation of the surge pool. The grade of the rock mass as evaluated from the condition of discontinuities and UCS, has RMR values varying from 37 to 63 and falls under poor to good rock mass.

c. The basic requirements of a foundation are firstly, it should behave as a homogeneous / monolith, secondly, it should be free from differential settlement & sliding and thirdly, if the structure has to retain water above/behind it, the foundation should be watertight. The foundation of the surge pool has to be made massive and requires varied treatments on all the three counts to achieve the objective.

d. The rocks exposed at the foundation grade of the surge pool are jointed pink granite interspersed with sheared dolerite dykes. Shear zones having the varying thickness are mapped which are having differential mechanical behavior due to varying physical properties leading to differential settlement. In order to overcome the problem of differential settlement shear zones treatment plan is given in Table 5.

Table 5 : Treatment plan for shear zones at the foundation level of Surge Pool

Shear Zone	Thickness	Recommended Excavation Depth	Treatment Plan
D1	Up to 2.0 m	2.8 m	Dolerite dyke is sheared having clay gauge, should be excavated up to 2.8 m depth by mechanical breakers and backfilled with concrete (M≥25) up to the foundation level after systematic cleaning, washing and jetting to make the rock mass monolithic. The concrete should be allowed to cure for 10-12 days before rock bolting. The length of rock bolt will be varying from 4 to 5 m as per the site condition.
D2	Up to 2.0 m	2.0 m	Dolerite dyke is crushed and sheared, should be excavated up to 2.0 m depth by mechanical breakers and backfilled with concrete (M≥25) up to the foundation level. The concrete should be allowed to cure for 10-12 days before rock bolting. The length of rock bolt will be varying from 4 to 5 m as per the site condition.
D3	Up to 0.40 m	1.6 m	Dolerite dyke is sheared having clay gauge, should be excavated up to 1.6 m depth by mechanical breakers and backfilled with concrete (M≥25) up to the foundation level.
SH-9, SH-10, SH-13	30.00 to 40.00 cm	0.80 m	Shear zones area should be excavated up to 0.80 m depth by mechanical breakers and backfilled with concrete (M≥25) up to the foundation level.
SH-15	Up to 7.00 cm	0.25 m	Shear zone having clay gauge should be excavated up to 0.25 m depth by mechanical breakers and backfilled with concrete (M≥25) up to the foundation level.
SH-1, SH-2, SH-3, SH-4, SH-5, SH-6, SH-7, SH-8, SH-11, SH-12, SH-14	Up to 4.00 cm	0.10 m	Shear zones having clay gauge should be excavated up to 0.10 m depth by mechanical breakers and backfilled with concrete (M≥25) up to the foundation level.

e. The structural features observed during the mapping indicated that the consolidation grouting up to 6.0 m should be done in the foundation of surge pool using primary, secondary and tertiary holes so that the entire floor area functions as a single rock mass. The pressure and proportion of grout mixes to be used for injection shall be based on water pressure test and the results of trial grouting operation. Special care to be taken to consolidate rock mass along the weak zones / shear zones. The holes which absorb water greater than 3 lugeons, shall invariable be grouted. (1 Lugeon is water loss of 1 lit/m/min at a pressure of 10 kg/sq.cm.). Recommended BIS codes for the grouting are IS-6066 and IS-5529 Part-2.

f. The grout holes shall be laid out in line with secondary holes staggered with reference to the primary holes on the adjacent lines. Spacing between holes initially shall be 5 m centre to centre. After completing the grouting through these primary holes intermediate holes will be taken in between primary holes. The number of holes for further grouting (tertiary grouting – which will be determined based on results of drilling and grouting of intermediate holes) will be such that a continuous consolidated area of satisfactory water tightness is achieved.

g. It is recommended to complete blasting before taking up grouting operation. If blasting after grouting is unavoidable, through testing and regrouting is essential after blasting.

h. Plain Cement Concrete (PCC) of M15 grade lining up to the design foundation level (i.e. RL+307.00 m) should be done before 300 mm thick raft foundation. This has to be checked by the designer.

i. During the foundation treatment, it should be ensured that area is free from water and Contractor shall take all necessary precautions and measures to exclude ground water and water from other sources such as underground streams, aquifers, springs, artisans, precipitation or infiltration from the surface flows etc. so as to enable the works to be carried out in dry condition in accordance with the construction schedule.

j. On the floor detached rock-masses are laying in scattered form, which need to be removed before any protective measure is applied.

References

Naithani, A.K., Singh, L.G and Rawat, D.S., 2012, Report on Construction stage engineering geological investigations of surge pool and pump house (5 x 30 MW) area of Mahatma Gandhi Kalwakurthi Lift Irrigation Scheme – II, Mahaboobnagar District, Andhra Pradesh. National Institute of Rock Mechanics Report No. EG-11-04, 50p.

Bieniawski, Z.T. 1989. Engineering rock mass classification. John Willey & Sons, New York, 251 p.

IS : 12070- 1987. Indian Standard - Code of practice for design and construction of shallow foundations on rocks, 13p.

ISRM, 1978. Suggested methods for the quantitative description of discontinuities in rock mass. International Journal Rock Mech. Sci. & Geomech. (Abstract), Pergamon, v. 15(6), pp. 319-368.

Peck, R.B., Hanson, W.E. and Thornburn T.H., 1974. Foundation Engineering, Wiley Publ., New York, 514p.

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ANNEXURE - III

Ref. No. NIRM/EGD/MGKLIS-PII/2013/17 Dated: 16.09.2013

Note on Geotechnical Assessment of the North Wall of Surge Pool and Rock Ledge

Project Title : Construction Stage Engineering Geological Investigations of Surge pool and Pump House (5x30 MW) area of Mahatma Gandhi Kalwakurthi Lift Irrigations Scheme, Package-II, Mahabubnagar District, Andhra Pradesh (Phase-II)

By

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1. INTRODUCTION

The Mahatma Gandhi Kalwakurthi Lift Irrigation Scheme (MGKLIS), under construction has three stages (I, II & III) for lifting the Krishna water from Srisailam reservoir (back water) to Gudipallygattu balancing reservoir through channels and tunnels. M/s Navayuga Engineering Company Ltd (NECL) is constructing MGKLIS stage II located at Sathapur village, Mahboobnagar District, A.P. MGKLIS-II is being constructed for lifting the water from Singotam balancing reservoir to Jonnalaboguda balancing reservoir.

The major components of the project are: one 4.0 km long gravity canal from Singotam balancing reservoir having bed width of 19.15m, one 4.553 km long and 6.85m finished diameter 'D' shaped tunnel, one surge pool (94m long x 40m width x 75m height), 50m long five numbers of draft tube tunnels, one pump house (94m long X 20m width X 78m height) and five numbers, 15m long horizontal & 305m long inclined having 3.0 m finished diameter delivery main tunnels. In between the surge pool and pump house 50m wide rock ledge is proposed is the design.

So far Navayuga Engineering Company Ltd has excavated surge pool up to foundation level and pump house up to app. RL 320 m. The ground level of surge pool is at RL +382 m and the foundation level is at RL +307 m while the ground level of pump house is at RL +383 m and the foundation level is at RL +305.40 m. Three draft tubes have been constructed and two are under excavation. All the four sides of the surge pool and pump house will be lined with 500

mm RCC lining from the bed line up to maximum surge level / pump levels and floored with 300mm thick raft foundation to distribute the load as per design specification.

This note pertains to large scale engineering geological mapping on 1:200 scale of excavated north wall of surge pool and rock ledge existing between surge pool and pump house of MGKLIS-PII. The objective of this study is to advise suitable engineering measures for stabilization of excavated north wall and the treatment of foundation of rock ledge based on detailed engineering geological investigations. The report pertaining to "Construction Stage Engineering Geological Investigations of Surge Pool and Pump House (5x30 MW) area of Mahatma Gandhi Kalwakurthi Lift Irrigations Scheme, Stage-II, Mahabubnagar District, Andhra Pradesh" was submitted by National Institute of Rock Mechanics (NIRM) to Navayuga Engineering Company Ltd in March 2012, containing the large scale geological mapping on 1:200 scale of excavated walls of surge pool and pump house and rock ledge between surge pool and pump of MGKLIS-II. In the present study, detailed engineering geological mapping on 1:200 scale in the north wall of surge pool and foundation of rock ledge has been carried out using the Total Station and a total area of approximately 4,100 sq.m. has been mapped (Drawing Nos. NIRM/MGKLIS-II/EG-13-01/02 and NIRM/MGKLIS-II/EG-13-01/03).

2. METHODOLOGY

Grids were prepared for mapping the excavated north wall of surge pool and floor area of rock ledge. The size of the grid is 2 m X 2 m, which was decided based on the mapping accuracy and resolution required for such investigations. Grids for mapping were marked on the floor and wall by NECL surveyor using elevation & chainages provided by them. Detailed examination of rock types in each grid was carried out which included mineralogical composition, texture, classification and nomenclature and degree/grade of weathering. Fracture filling that have taken place in the study site were examined and recorded. The attitude and structure of the rocks, fractures and joint pattern present in the wall and floor was determined for mapping. ISRM (1978) classifications for weathered rock mass was used to characterize the rock mass into different grades (Table-1). The assessment of Tunnelling Quality Index 'Q' (Barton et.al. 1974, 1980) for granite rock masses of north wall, based on the rock joints characteristics of the north wall of surge pool, has been done while the assessment of RMR

(Bieniawski, 1989) for granite rock masses of rock ledge between surge pool and pump house, has been attempted based on the rock joints and their nature.

Table 1: Description of Weathering Grade (ISRM, 1978)

Term	Description	Grade
Fresh	No visible sign of rock material weathering; perhaps slight discolouration on major discontinuity surfaces.	I
Slightly weathered	Discolouration indicates weathering of rock material and discontinuity surfaces. All the rock material may be discoloured by weathering and may be somewhat weaker externally than in its fresh condition.	II
Moderately weathered	Less than half of the rock material is decomposed and / or disintegrated to a soil. Fresh or discoloured rock is present either as a continuous framework or as core stones.	III
Highly weathered	More than half of the rock material is decomposed and / or disintegrated to a soil. Fresh or discoloured rock is present either as a discontinuous framework or as core stones.	IV
Completely weathered	All rock material is decomposed and / or disintegrated to soil. The original mass structure is largely intact.	V
Residual soil	All rock material is converted to soil. The mass structure and material fabric are destroyed. There is a large change in volume, but the soil has not been significantly transported.	VI

3. ENGINEERING GEOLOGICAL & GEOTECHNICAL ASSESSMENTS OF VERTICAL WALL AND ROCK LEDGE

Vertical wall and foundation floor geological mapping of the important structures is essential to provide permanent data input for geological interpretations during construction and also it forms valuable documentation for post-construction stage. For very important structures like deep surge pool and pump house of lift irrigation, the foundation strata have to be studied and documented for credible geologic interpretations. Rock is usually recognized as the best foundation material. However, design engineers should be aware of the dangers associated with heterogeneity and unfavourable rock conditions since over-stressing a rock foundation may result in large differential settlements or perhaps sudden failure.

In order to evaluate the design basis foundation parameters for rock ledge of MGKLIS-PII, engineering geological mapping (on 1:200 scale) was carried out by NIRM Geologists. All the discontinuities in the rock mass of foundation of rock ledge with the zone of influence of the foundation has been identified and mapped. The primary purpose of the mapping is to provide a permanent record of conditions during the excavation. Mapping will be used to assess the

requirement of any ground improvement. This permanent foundation record will assist in making better interpretation of post-construction foundation instrumentation data.

The excavated north wall of surge pool and floor of rock ledge was examined on a grid to grid basis; the size of the grid is 2 m X 2 m. All the lithological and structural features were observed and mapped using Total Station surveying equipment and shown in the final foundation grade geological plan map. Classifications of rock mass using Tunnel Quality Index 'Q' of Barton et.al. 1974 and Rock Mass Rating (RMR) of Bieniawski (1989) have been attempted and based on investigations recommendations for the treatment of north vertical wall of surge pool and foundation of rock ledge are given.

3.1 Engineering Geological Assessment of North Wall – Surge Pool

The north wall of surge pool is excavated from RL +351.00m to design RL +307.00m. This wall is aligning along the N305°-N125°direction. After the final excavation the average height of the wall is 42.0m from foundation level at RL +306.00m to the top of the wall which is at RL +348.00m and the total design length of wall is 94.0m. Over excavation was mapped, which may be due to unfavourable geological discontinuities.

The rock type exposed after excavation on the wall section is granite which is coarse grained, hard and jointed in nature. Its colour varies from pink to greyish and its colour variation is due to varying amount of orthoclase (Plate 1). Granite is generally fresh to moderately weathered. This rock will also be present at the foundation level of pump house. The rock mass is characterized by prominent six number of joint sets, which are continuous and persistent, smooth–planar to smooth-undulating with unaltered to slightly altered joint walls. Staining has been recorded along the joint surfaces where the joints are tight and where opening is up to 3.0 mm, soft clay mineral and crushed material filling has been recorded. In general, the rock mass is characterized by dry condition or minor inflow i.e. < 5.0 l/min. Crack/fractures developed due to excavation / blasting were also recorded during geological mapping. Some of the cracks are tight while some are open and the size of the opening varies from 1 mm to 6 cm. Hairline cracks developed due to excavation work were also recorded. The details of the joint characteristics of north wall of surge pool are given in Table 2. During excavation rock slides occurred towards western part of the surge pool along this excavated vertical wall. Rock mass

failure was due to structural wedge formation between dyke-2 (N240°/65°) & joint (N180°-190°/45°-50°) and extended to 1.5m to 2.0m depth into the excavated line of face.

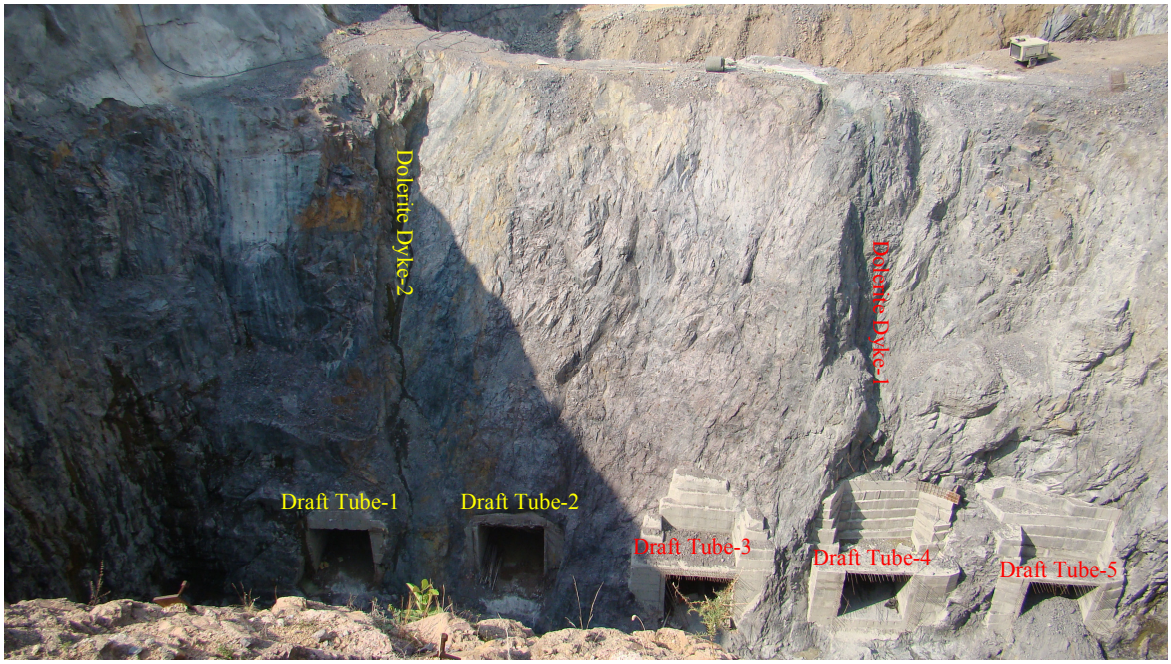

Plate 1: View of north wall of surge pool; rock types are pink and grey granites intruded by dolerite dykes

Table 2: Joint sets developed in granite at the face of north wall of surge pool

1	2	3	4	5	6	7	8	9	10
J1	020 - 040	60 – 70	10 – 50	> 20	SP/SU	Tight	None	Dry	Dipping inside the wall i.e. towards south wall of pump house. Crushed material at the north-east corner.
J2	340 – 351	70	5 – 50	> 20	SP/SU	Tight to 3 mm	Clay coating along the joint plane	Dry	Dipping inside slope i.e. towards western wall.
J3	300 – 325	45 – 80	10 – 100	> 20	SP/SU	Tight to 3 mm	Clay coating along some joint plane	Dry	Dipping towards west wall side.
J4	180 – 190	40 – 60	5 – 40	5 – 10	SU	Tight	None	Dry	Dipping towards surge pool i.e. south-eastern direction.
J5	220 – 230	50 – 75	-	2 – 7	SU	Tight to 2 mm	Clay coating	Dry	Dipping towards surge pool.
J6	240 – 250	60	30 – 100	> 20	SP/SU	Tight	None	Dry	Dipping towards surge pool, dyke is parallel to this joint set. Unfavourable for the stability of wall.
J7	040	Vertical	30 – 100	10	SP	Tight	None	Dry	Vertical joint, mainly in the central portion of the wall.
J8	050 – 070	70	-	5 – 10	SP/SU	Tight to 3 mm	Crushed rock fragments	Dry	Random joint, dipping inside wall i.e. north eastern direction.
J9	100	10	-	50 – 100	SP/SU	Tight to 2 mm	Crushed rock fragments	Dry	Random joint, dipping towards inside the wall i.e. eastern direction
J10	310	Vertical	-	5	SU	Tight	None	Dry	Vertical joint, mainly in the western part of surge pool
1- Joint Sets, 2- Dip Direction, 3- Dip Amount, 4- Spacing (cm), 5- Persistence (m), 6- Roughness, 7- Aperture (mm), 8- Infilling (mm), 9- Groundwater Condition, 10- Remarks ; SP- smooth planar, SU – smooth undulating									

Two intrusive dolerite dykes (features dyke-1 and dyke-2 in Drawing No NIRM/MGKLIS-II/EG-13-03/02) were mapped on the eastern and western sides of the north wall. Dyke-1 is trending in N265° direction with a dip amount of 75°, and a strike length of more than 100m has been mapped on the eastern side of the wall, i.e., between easting 111 at RL +349m on the top of the wall and easting 1017 at RL +307m i.e. bottom of the excavated part. The width of dyke-1 is varying from 0.80m to 2.0m. The prominent joint set intersecting the dyke-1 are: N350° (dip direction)/ 65° (dip amount), N30°/65° and N310°/45°. Dyke-2 is trending in N240° direction with a dip amount of 65°, and a strike length of more than 100m has been mapped on the western side of the wall, i.e. between easting 971 at RL +348m on the top of the wall and easting 973 at RL +307m i.e. bottom of the wall. The width of dyke-2 is varying from 0.70m to 2.0m. The prominent joint set intersecting the dyke-2 are: N055° (dip direction)/ 70° (dip amount), N351°/40° and N020°/55°. Dolerite dykes are fine grained, jointed, fractured and sheared in nature and dark gray in colour. The contact between granite and dolerite dyke are unweathered to slightly weathered and scar was recorded during the geological mapping along dyke-2. No displacement has been recorded along these features.

Three shear zones (feature shear zone-1, shear zone-2 and shear zone-3 in Drawing No NIRM/MGKLIS-II/EG-13-03/02) were mapped on the face of north wall of surge pool. Shear zone-1 trending in N320° direction with a dip amount of 40°, and a strike length of more than 24m, has been mapped between easting 953 at RL +307m at the western side of the wall and easting 972 at RL +318m on the middle of the wall. The average width of shear zone-1 is 7 cm. The prominent joint set intersecting the shear zone-1 are: N240°/65°, N030°/65° and N040°/70°. This shear zone is intersecting dolerite dyke-2 at RL +317m on the eastern side of the wall at easting 972. Shear zone-2 trending in N340° direction with a dip amount of 70°, and a strike length of more than 36m, has been mapped on face of the wall i.e. between easting 1020 at RL +320m at the middle of the wall and easting 1039 at RL +350m on the top of the wall. The width of shear zone-2 is varying between 1 cm and 1.5 cm. The prominent joint set intersecting the shear zone-2 are: N070°/70°, N025°/60°, and N325°/60°. Shear zone-3 trending in N300° direction with a dip amount of 65°, and a strike length of more than 18m, has been mapped on eastern side of the wall i.e. between easting 1038 at RL +327m at the middle of the wall and easting 1046 at RL +340m on the eastern side of the wall. The width of shear zone is

varying between 5 cm and 10 cm. The prominent joint set intersecting the shear zone-3 are: N070°/65°, N025°/60°, and N100°/10°. No displacement has been recorded along these features. Longitudinal sections at different RDs of the north wall of surge pool have been made and details are given in Table 3.

Table 3 : Longitudinal sections at different RDs and at different elevation of the north wall of surge pool

Easting	969	984	1001	1016	1032
Elevation (m)					
+349	-	-	-	-	+15.21 m
+347	+28.45 m	+26.16 m	+24.09 m	+18.68 m	+12.73 m
+342	+19.58 m	+22.49 m	+18.79 m	+16.41 m	+11.07 m
+337	+16.23 m	+19.53 m	+15.53 m	+14.32 m	+8.71 m
+332	+14.52 m	+17.05 m	+12.11 m	+12.18 m	+6.76 m
+327	+12.77 m	+14.17 m	+9.05 m	+7.96 m	+4.70 m
+322	+9.29 m	+8.82 m	+6.47 m	+6.49 m	+4.23 m
+317	+4.17 m	+5.32 m	+3.87 m	+5.23 m	+3.20 m
+312	+2.25 m	+3.61 m	0.0 m	0.0 m	0.0 m
+307	0.0 m	0.0 m	0.0 m	0.0 m	0.0 m
+ Over Excavated and – Under Excavation					

The rock mass is classified as very poor rock mass (Q 0.20 to 0.58) as per Barton`s classification. The details of the Q values of north wall of surge pool are given in Table 4.

Table 4: Rock mass classification using 'Q' of the face of north wall of surge poll

Western Side of North Wall of Surge Pool				Eastern side of North Wall of Surge Pool			
From Easting 953 to 1000				From Easting 1000 to 1047			
Elevation		Q	Description	Elevation		Q	Description
From	To			From	To		
350	340	0.24	Very Poor	350	340	0.26	Very Poor
340	330	0.29	Very Poor	340	330	0.20	Very Poor
330	320	0.35	Very Poor	330	320	0.22	Very Poor
320	310	0.38	Very Poor	320	310	0.40	Very Poor
310	307	0.30	Very Poor	310	307	0.58	Very Poor

Based on the engineering geological mapping carried out in the north wall of surge pool and the details collected including lithology, joint patterns measured in the field, the geological map was compiled on scale 1:200, and has been appended to this note as Drawing No NIRM/MGKLIS-II/EG-13-01/02.

3.2 Engineering Geological Assessment of Rock Ledge

A 50.0m rock ledge has been provided in the design between surge pool and pump house. In the rock ledge at an average RL +309.50m five draft tubes are constructed. A ramp has been constructed commencing from ground level RL +382m from the eastern side and joining the rock ledge at RL +353m, which can be considered as berm-3 for the north wall of surge pool and south wall of pump house. In the design, Annexure Building has been provided on the top of this wall at an average RL +350m. The total design width of the rock ledge is 50.0m but over excavation was mapped, which may be due to unfavourable geological conditions.

Rock type exposed after excavation on the surface of rock ledge is granite which is coarse grained, hard and jointed in nature (Plate 2 & 3). Its colour varies from pink to greyish and its colour variation is due to varying amount of orthoclase. Granite is generally fresh to moderately weathered. This rock will be also present at the foundation level of pump house. The rock mass is characterized by prominent six number of joint sets, which are continuous and persistent, slightly rough to smooth with unaltered joint walls. Staining has been recorded along the joint surfaces where the joints are tight and where opening is up to 5.0 mm, soft clay mineral and crushed material filling has been recorded. In general, the rock mass is characterized by dry condition or minor inflow i.e. < 5.0 l/min. Crack/fractures developed due to excavation / blasting were also recorded during geological mapping. Some of the cracks are tight while some are open, with the size of the opening varying from 1 mm to 6 cm. Hairline cracks developed due to excavation work were also recorded. The details of the joint characteristics of rock ledge portion between pump house and surge pool are given in Table 5.

Two intrusive dolerite dykes (feature dyke-1 and dyke-2 in Drawing No NIRM/MGKLIS-II/EG-13-01/03) were mapped on the rock ledge. Dyke-1 is trending in N265° direction with a dip amount of 75°, and a strike length of more than 18m has been mapped on the top of the rock ledge portion. The width of dyke-1 is varying from 0.80m to 2.0m. The prominent joint set intersecting the dyke-1 are: N340° (dip direction)/ 65° (dip amount), N300°/50° and

N240°/70°. Dyke-2 is trending in N240° direction with a dip amount of 65°, and a strike length of more than 4m has been mapped on the western side top of the wall. The width of dyke-2 is varying from 0.70m to 2.0m. The prominent joint sets intersecting the dyke-2 are: N300° (dip direction)/ 60° (dip amount), N340°/65° and N260°/60°. Dolerite dykes are fine grained, jointed, fractured and sheared in nature and dark gray in colour. The contact between granite and dolerite dyke are slightly weathered. No displacement has been observed along these features. No evidences of faulting are observed on the surface of floor area. The structural features observed during the mapping indicated the need for consolidation grouting so that the entire floor are a functions as a single rock mass.

Plate 2: Fresh and jointed granite at the surface of rock ledge

Plate 3: Slightly weathered and jointed granite at the surface of rock ledge

Table 5: Joint sets developed in granite on rock ledge between surge pool and pump house

1	2	3	4	5	6	7	8	9	10
J1	220 – 250	50 – 70	5 – 70	> 20	Slightly rough to smooth	Tight to 5	Clay	Dry	Joint plane is stained
J2	180 – 195	45 – 85	5 – 40	> 10	Slightly rough to smooth	Tight to 3	Clay	Dry	Joint plane is stained
J3	260 – 275	60 – 85	10 – 30	> 10	Slightly rough to smooth	Tight to 3	Clay	Dry	Joint plane is stained
J4	300 – 315	60 – 70	20 – 70	< 10	Slightly rough	Tight	Nil	Dry	Joint plane is fresh
J5	120	55	30 – 50	7	Slightly rough	Tight	Nil	Dry	Joint plane is fresh
J6	340	65	15 – 50	< 5	Slightly rough	Tight to 2	Nil	Dry	Joint plane is stained

1- Joint Sets, 2- Dip Direction, 3- Dip Amount, 4- Spacing (cm), 5- Persistence (m), 6- Roughness, 7- Aperture (mm), 8- Infilling (mm), 9- Groundwater Condition, 10- Remarks

Four shear zones (features shear zone-1, shear zone-2, shear zone-3 and shear zone-4 in Drawing No NIRM/MGKLIS-II/EG-13-03/03) were mapped on the surface of rock ledge. Shear zone-1 trending in N355° direction with a dip amount of 70°, and a strike length of more than 8m, has been mapped on the middle of the floor. The average width of shear zone is 25 cm. The prominent joint set intersecting the shear zone-1 is N270°/75° and this shear zone is intersecting dolerite dyke-1. Shear zone-2 trending in N190° direction with a dip amount of

70°, and a strike length of more than 17m has been mapped on the western side of the floor. The width of shear zone is varying between 10 cm and 15 cm. The prominent joint set intersecting the shear zone-2 are: N260°/60° and N240°/70°. This shear zone is intersecting dolerite dyke-2. Vertical shear zone-3 trending in N305° direction, and a strike length of more than 16m, has been mapped on western side of the floor. The width of shear zone is varying between 8 cm and 10 cm. The prominent joint set intersecting the shear zone-3 are: N260°/60°, N300°/60°, and N180°/45°. Shear zone-4 trending in N185° direction with a dip amount of 75°, and a strike length of more than 11m, has been mapped on the western side of the floor. The average width of shear zone is 10 cm. The prominent joint set intersecting the shear zone-4 are: N260°/60°, N300°/60°, and N180°/45°. No displacement has been recorded along these features.

The rock mass is classified as poor to good rock mass (RMR 36 to 65) as per Bieniawski classification (1989). The details of the RMR values of rock ledge between surge pool and pump house are given in Table 6.

Table 6: Rock mass classification using 'RMR' of the rock ledge between surge pool and pump house

1	2		3	4	5	6	7	8	9	10
	Easting	Northing								
1	960 – 965	8635 – 8640	4	8	8	20	15	-15	40	Poor
2	960 – 965	8630 – 8635	4	8	8	18	15	-15	38	Poor
3	960 – 965	8625 – 8630	4	8	8	20	15	-15	40	Poor
4	960 – 965	8620 – 8625	4	8	8	16	15	-15	36	Poor
5	965 – 970	8630 – 8635	7	8	8	20	15	-7	51	Fair
6	965 – 970	8625 – 8630	4	8	8	20	15	-15	40	Poor
7	965 – 970	8620 – 8625	4	8	8	18	15	-15	38	Poor
8	965 – 970	8615 – 8620	4	8	8	20	15	-15	40	Poor
9	970 – 975	8625 – 8630	4	8	8	18	15	-15	38	Poor
10	970 – 975	8620 – 8625	7	8	8	20	15	-15	43	Fair
11	975 – 980	8625 – 8630	4	8	8	16	15	-15	36	Poor
12	975 – 980	8620 – 8625	4	8	8	20	15	-15	40	Poor
13	975 – 980	8615 – 8620	4	8	8	18	15	-15	38	Poor
14	980 – 985	8625 – 8630	4	8	8	16	15	-15	36	Poor
15	980 – 985	8620 – 8625	4	8	8	16	15	-15	36	Poor
16	980 – 985	8615 – 8620	4	8	8	16	15	-15	36	Poor
17	985 – 990	8620 – 8625	4	8	8	20	15	-15	40	Poor
18	985 – 990	8615 – 8620	4	8	8	18	15	-15	38	Poor

	2									
19	990 – 995	8620 – 8625	4	8	8	16	15	-7	44	Fair
20	990 – 995	8615 – 8620	4	8	8	17	15	-7	45	Fair
21	995 – 1000	8620 – 8625	4	8	8	20	15	-15	40	Poor
22	995 – 1000	8615 – 8620	4	8	8	16	15	-7	44	Fair
23	1000 – 1005	8620 – 8625	4	8	8	20	15	-15	40	Poor
24	1000 – 1005	8615 – 8620	7	8	8	16	15	-15	39	Poor
25	1000 – 1005	8610 – 8615	4	8	8	16	15	-15	36	Poor
26	1005 – 1010	8620 – 8625	7	13	15	17	15	-2	65	Good
27	1005 – 1010	8615 – 8620	4	8	8	20	15	-15	40	Poor
28	1005 – 1010	8610 – 8615	4	8	8	16	15	-15	36	Poor
29	1010 – 1015	8615 – 8620	4	8	8	17	15	-7	45	Fair
30	1010 – 1015	8610 – 8615	4	8	8	20	15	-15	40	Poor
1- Block No., 2- Coordinate, 3- UCS (Rating), 4- RQD, 5- Spacing of Discontinuity, 6- Condition of Discontinuity, 7- Ground Water, 8- Adjustment Joint Orientation, 9- RMR, 10- Class Description										

Based on the engineering geological mapping carried out in the rock ledge between pump house & surge pool and the details collected including lithology, joint patterns measured in the field, the geological map was compiled on scale 1:200, and it has been appended to this report as Drawing No. NIRM/MGKLIS-II/EG-13-01/03.

4. Conclusions & Recommendations – North Wall of Surge Pool and Floor of Rock Ledge

Based on above studies, the following conclusions and recommendations have been made:

a. The stability of the cut slope/ vertical wall depends upon the geometry, frequency and orientation of joint sets, dip of slope and its plane of weakness. The site condition is not favourable for slope stability, particularly along the shear zone due to its interplay with a joint set forming a wedge. Other major joint sets, dipping inside the wall or towards opposite sides of the wall i.e. those joint sets not dipping towards the pits do not tend to cause unfavourable condition. Generally the rocks are fresh to moderately weathered, hard and jointed in nature. But the top level is fractured/jointed and joints are open, which may require proper treatment by consolidation grouting once the lining of wall is provided.

b. The grade of rock mass based on the rock joints characteristics of the north wall of surge pool, has the Q values varying from 0.20 to 0.58 and fall under ‘very poor’ rock mass category.

c. There is a need to properly scale off the loosened rock fragments all along the north wall of the surge pool and rock ledge surface.

d. The north wall of surge pool should be properly protected by systematic rock bolting below RL +350m up to foundation level. Rock bolts of 25mm dia and 5.0 m length with a spacing of 1.5 m c.c. in staggered fashion is recommended. Driving rock bolts into the rock ledge from the north wall of surge pool and from south wall of pump house will further strengthen the rock ledge. Drainage holes may be provided above surge level in to this vertical side wall.

e. Weep holes of 100 mm dia, at 4m c.c spacing, and 1m depth should be provided with perforated PVC/GI pipe above surge level.

f. 500 mm thick RCC stepped lining should be done from foundation level up to surface level i.e. RL +350 m following the cut slope to avoid overburden, maintaining the minimum thickness of lining with sufficient anchorage. The reinforced lining will be stitched with the insitu rock mass by 3m long, 20mm dia grouted rock bolts at a spacing of 1.5 mts c/c. Consolidation grouting is also recommended.

g. Based on the field observations and evidences, it is observed that area in the floor of rock ledge is characterized by coarse grained, hard and jointed pink to greyish granite traversed by dolerite dykes and shear zones. The floor region is fresh to moderately weathered (W-I to W-III) but prominent inclined joints are present.

h. The grade of rock mass of the rock ledge between surge pool and pump house has RMR values varying from 36 to 65 and fall under poor to good category.

i. On the north wall and rock ledge portion, shear zones and sheared dykes are present. The sheared material should be removed by mechanical excavator and the excavated portion should be back filled with concrete (M≥25) after systematic cleaning, washing and jetting to make the rock mass monolithic.

j. For the treatment of thick shear zones, special bolting system was suggested at the site to the Contractor Engineers. First the gauge should be cleaned out to the desired extent, then the dental excavation should be backfilled with concrete (M≥25) and finally rock bolts should be installed across the shear zone. The concrete should be allowed to cure for 10-12 days before installation of the rock bolts. The length of rock bolts will vary from 5 to 7 m as per the site condition. The other support system should be as per approved design.

k. After providing lining in the north wall of surge pool and south wall of pump house, consolidation grouting (with 2.5 to 3.5 kg/cm2 pressure) up to maximum 20m depth be done in the rock ledge portion using primary, secondary and tertiary holes so that the openings are filled and the area functions as monolithic rock mass. A spacing of 6m for the primary, 3m for secondary and 1.5m for tertiary holes, is recommended. Special care should be taken to consolidate rock mass along the weak zones / shear zones.

l. It is recommended to complete blasting before taking up grouting operation. If blasting after grouting is unavoidable, thorough testing and regrouting is essential after blasting.

References

Barton, N., Lien, R. and Lunde, J. 1974. Engineering classification of rock masses for the design of tunnel support. Rock Mechanics, v. 6(4), pp. 189-236.

Barton, N., Loset, F., Lien, R. and Lunde, J. 1980. Application of the Q-system in design decisions concerning dimensions and appropriate support for underground installations. Inter. Conf. on Sub-surface Space, Rock store, Stockholm. Sub-Surface Space, v. 2, pp. 553-561.

Bieniawski, Z.T. 1989. Engineering rock mass classification. John Willey & Sons, New York, 251 p.

ISRM, 1978. Suggested methods for the quantitative description of discontinuities in rock mass. International Journal Rock Mech. Sci. & Geomech. (Abstract), Pergamon, v. 15(6), pp. 319-368.

Naithani, A.K., Singh, L.G and Rawat, D.S., 2012, Report on Construction stage engineering geological investigations of surge pool and pump house (5 x 30 MW) area of Mahatma Gandhi Kalwakurthi Lift Irrigation Scheme – II, Mahaboobnagar District, Andhra Pradesh. National Institute of Rock Mechanics Report No. EG-11-04, 50 p.

(Dr. L.G. Singh) (Dr. A.K. Naithani)

ANNEXURE – IV

Ref. No. NIRM/EGD/MGKLIS-PII/2013 Dated: 30.12.2013

Geotechnical Note on the Treatment of Cracks of the North and South Wall of Pump House

Project Title : Construction Stage Engineering Geological Investigations of Surge pool and Pump House (5x30 MW) area of Mahatma Gandhi Kalwakurthi Lift Irrigations Scheme, Package-II, Mahabubnagar District, Andhra Pradesh (Phase-II)

By

A.K. Naithani

National Institute of Rock Mechanics, Ministry of Mines, Govt. of India, Kolar Gold Fields Karnataka

The Mahatma Gandhi Kalwakurthi Lift Irrigation Scheme (MGKLIS), under construction has three stages (I, II & III) for lifting the Krishna water from Srisailam reservoir (back water) to Gudipallygattu balancing reservoir through channels and tunnels. M/s Navayuga Engineering Company Ltd (NECL) is constructing MGKLIS Stage-II located at Sathapur village, Mahboobnagar District, A.P. MGKLIS-II is being constructed for lifting the water from Singotam balancing reservoir to Jonnalaboguda balancing reservoir.

The major components of the project are: one 4.0 km long gravity canal from Singotam balancing reservoir having bed width of 19.15m, one 4.553 km long and 6.85m finished diameter 'D' shaped tunnel, one surge pool (94m long x 40m width x 75m height), 50m long five numbers of draft tube tunnels, one pump house (94m long X 20m width X 78m height) and five numbers, 15m long horizontal & 305m long inclined having 3.0 m finished diameter delivery main tunnels. In between the surge pool and pump house 50m wide rock ledge is proposed is the design.

So far Navayuga Engineering Company Ltd has excavated surge pool up to foundation level and pump house up to app. RL 310m. The ground level of surge pool is at RL +382m and the foundation level is at RL +307m while the ground level of pump house is at RL +383m and the foundation level is at RL +305.40m. All the five draft tubes have been constructed. All the four sides of the surge pool are being lined with 500mm RCC lining from the bed line up to

maximum surge level / pump levels and floored with 300mm thick raft foundation to distribute the load as per design specification.

During the excavation of pump house one crack each on the north (on 3rd berm at EL 350) and south walls (on rock ledge) of pump house was reported. These cracks are parallel to the excavated faces. Crack on the north wall of pump house was grouted by the site engineers. Dr. A.K. Naithani, Senior Scientist, NIRM visited the site on the request of Navayuga Engineering Company Ltd. The project site was visited on 17.12.2013 and 18.12.2013 regarding these cracks treatments and for making a ramp from the eastern side to the pump house. The following and other project officials of M/s Navayuga Engineering Company Ltd. were present during the site visit and the discussions.

NIRM	Navayuga Engineering Company Ltd.
Dr. A.K. Naithani Project Leader & Coordinator, EGD	Mr. G. Shashidhar Reddy, AGM
	Mr. Kashi Govinda Rao, Senior Project Manager
	Mr. Vinod Kumar, Assistant Project Manager
	Mr. P. Sobhan Babu, Site Engineer

The following decisions were taken after the discussions at the site:

1. On the western side of the north wall of pump house, dripping / flowing condition was observed. This water is percolating into the crack, which is very dangerous for the stability point of view. This should be channelized and properly treated.
2. The crack area was divided into three zones (A – B – A') and same was marked on the site. For A and A' zones, rock bolts of 32 mm dia and 7.0 m length with a spacing of 1.0 m c.c. and inclined to 30^{o} from horizontal in two rows from the face in staggered fashion is recommended. For B zone, rock bolts of 32 mm dia and 7.0 m length with a spacing of 0.75 m c.c. and inclined to 30^{o} from the berm in staggered fashion is recommended. Execution of rock bolts was explained at site to the Engineers.
3. In the bottom potion of this crack effected area near to delivery mains 1 & 2, spot rock bolting of 32 mm dia and 7.0 m length in staggered fashion is recommended.
4. In the north wall of pump house many rock bolts are detached / not intact, they should be replaced. Major contact zones, as explained at site, should be stitched with rock bolts

of 25 mm dia and 5.0 m length. Stitching should be done 1 m away from the contact plane.

5. Immediately lining should be completed for the north wall of surge pool.
6. The procedure which was followed for the opening of draft tube nos. 4 & 5 from the surge pool side should be followed for the opening of delivery mains from the pump house side.
7. For the treatment of crack on the south wall of pump house, rock bolts of 32 mm dia and 7.0 m length with spacing of 1.0 m c.c. and perpendicular to crack in six rows from the face is recommended.
8. Controlled blasting should be adopted for rock excavation at the ultimate walls of the project to minimize deterioration of the rock mass and loose rock mass should be removed by mechanical excavator.
9. There is a need to properly scale off the loosened rock fragments all along the walls of the pump house.
10. The shear zones should be treated as specified by NIRM in their earlier geotechnical notes

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ANNEXURE – V

Ref. NIRM/EGD/MGKLIS-II/2014/03 Dated: 26.03.2014

Note on Geotechnical Assessment of the Foundation of Pump House – Pump Units 4 & 5 – MGKLIS-II

Project Title - Construction Stage Engineering Geological Investigations of Surge pool and Pump House (5x30 MW) area of Mahatma Gandhi Kalwakurthi Lift Irrigations Scheme, Stage-II, Mahabubnagar District, Andhra Pradesh (Phase-II)

By
A.K. Naithani and L.G. Singh
National Institute of Rock Mechanics, Kolar Gold Fields, Karnataka

The objective of this study is to advise suitable engineering measures for the treatment of foundation of pump house based on detailed engineering geological investigations. To achieve this objective, large scale engineering geological mapping on 1:200 scale of foundation strata at foundation level of pump house of MGKLIS-II has been carried out. In order to evaluate the foundation design parameters for pump house of MGKLIS-II, engineering geological mapping (on 1:200 scale) was carried out by NIRM Geologists. All the discontinuities with in the zone of influence of the pump house foundation have been identified and mapped. The recommendations made pertain to the foundation of pump house Units-4 and 5.

On the basis of surface geological mapping, the excavated surface is acceptable for foundation because the rock mass is competent. Based on the field observations and evidences, it is found that the entire floor area consists of coarse grained, hard and jointed pink granites. The floor region is fresh to moderately weathered (W-I to W-III) but prominent vertical/inclined joints are present. Total four shear zones are mapped. The width of the shear zones vary from 10 cm to 100 cm. No displacement has been recorded along the shear zones. No evidence of faulting is observed on the surface of the floor area. The structural features observed during the mapping indicated the need for consolidation grouting so that the entire floor area functions as a single rock mass.

Based on the engineering geological mapping carried out at the foundation of pump house Units 4 & 5, and the details collected including lithology and joint patterns measured in the

field, the geological maps were compiled on scale of 1:200, and appended to this note as Drawing Nos. NIRM/MGKLIS-II/EG-13-01/09 & NIRM/MGKLIS-II/EG-13-01/10.

The structural features observed during the mapping indicated that consolidation grouting should be done up to 6.0 m in the foundation of pump house using primary, secondary and tertiary holes so that the entire floor area functions as a single rock mass. The pressure and proportion of grout mixes to be used for injection shall be based on water pressure test and the results of trial grouting operation. Special care should be taken to consolidate the rock mass along the weak zones / shear zones. The grouting should be carried out after laying first stage concrete and surrounding blasting.

(Dr. L.G. Singh) (Dr. A.K. Naithani)

ANNEXURE – VI

Ref. NIRM/EGD/MGKLIS-II/2014/07 Dated: 07.07.2014

Note on Geotechnical Assessment of Foundation of Pump House, Annexure Building and Service Bay Columns – MGKLIS-II

Project Title : Construction Stage Engineering Geological Investigations of Surge pool and Pump House (5x30 MW) area of Mahatma Gandhi Kalwakurthi Lift Irrigations Scheme, Stage-II, Mahabubnagar District, Andhra Pradesh (Phase-II)

By

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This note pertains to the estimation of safe bearing capacity from rock mass rating (RMR) classification for the foundations of RCC columns of Mahatma Gandhi Kalwakurthi Lift Irrigation Scheme-II (MGKLIS-II) has been carried out using the Total Station surveying equipment. These columns will be constructed for the pump house, annexure building and service bay in the pump house. Large scale engineering geological mapping on 1:200 scale of foundation strata at foundation level of pump house, rock ledge and service bay. Grids were prepared for mapping the pump house floor, rock ledge and service bay areas. The size of the grid was 2 m x 2 m, which was decided based on the mapping accuracy and resolution required for such investigations. Detailed examination of rock types in each grid was carried out which includes mineralogical composition, texture, classification and nomenclature and degree/grade of weathering. Fracture filling that have taken place in the study site were examined and recorded. The attitude and structure of the rocks, fractures and joint pattern present in the floor was determined for mapping. ISRM (1978), classifications for weathered rock mass was used to characterize the rock mass into different grades (Table 1). The assessment of RMR (Bieniawski, 1989) for granites rock masses, based on the rock joints and their nature, has been made (Table Nos. 2, 3 and 4).

Based on the field observations and evidences, it is found that the entire floor area consists of coarse grained, hard and jointed greyish pink granites. Pink granites are coarse grained, hard and jointed and show phenocryst of alkali feldspar and quartz. Main mineral composition is alkali feldspars, quartz, mica and amphiboles. Five prominent joints set are developed and along the joint plane clay filling/coating was recorded. Joints are irregular in pattern. Granites are generally fresh to moderately weathered (WI–WIII).

Table 2: Geotechnical parameters of columns at the foundation levels of pump house and service bay - north side

Location North side			Rock type	UCS (MPa)	RQD % Joint volume	Spacing of discontinuity (cm)	Condition of discontinuity	Ground water condition	Orientation of discontinuity	RMR Value/ Class
A	8659.600	952.900	Pinkish grey granite	133-250	49 Jv-20	10-15	High persistence, smooth planar, black coated, unweathered, imperfectly interlocked	Dry	Fair	***52 Class-III Fair***
				12	***8***	***8***	***16***	***15***	***-7***	
B	8659.600	958.800	Pinkish grey granite	133-250	49 Jv-20	10-15	High persistence, smooth planar, black coated, moderately weathered, well interlocked	Dry	Fair	***49 Class-III Fair***
				12	***8***	***8***	***13***	***15***	***-7***	
C	8659.600	963.826	Pinkish grey granite	133-250	65 Jv-15	10-15	High persistence, smooth planar, black coated, unweathered, well interlocked	Dry	Fair	***57 Class-III Fair***
				12	***13***	***8***	***16***	***15***	***-7***	
D	8659.600	973.326	Pinkish grey granite	133-250	65 Jv-15	10-15	High persistence, smooth planar, black coated, unweathered, well interlocked	Dry	Fair	***57 Class-III Fair***
				12	***13***	***8***	***16***	***15***	***-7***	
E	8659.600	979.826	Pinkish grey granite	133-250	65 Jv-15	5-10	High persistence, smooth planar, black coated, unweathered,	Dry	Fair	***57 Class-III Fair***
				12	***13***	***8***	***16***	***15***	***-7***	
F	8659.600	989.326	Pinkish grey granite	133-250	65 Jv-15	5-15	High persistence, smooth planar, black coated, unweathered,	Dry	Fair	***57 Class-III Fair***
				12	***13***	***8***	***16***	***15***	***-7***	
G	8659.600	995.826	Pinkish grey granite	133-250	79 Jv-11	20-30	High persistence, smooth planar, black coated, unweathered,	Dry	Fair	***63 Class-II Good***
				12	***17***	***10***	***16***	***15***	***-7***	
H	8659.600	1005.326	Pinkish grey granite	133-250	85 Jv-9	20-30	High persistence, smooth planar, black coated, unweathered,	Dry	Fair	***63 Class-II Good***
				12	***17***	***10***	***16***	***15***	***-7***	
J	8659.600	1006.151	Pinkish grey granite	133-250	85 Jv-9	20-30	High persistence, smooth planar, black coated, unweathered,	Dry	Fair	***63 Class-II***

Location North side			Rock type	UCS (MPa)	RQD % Joint volume	Spacing of discontinuity (cm)	Condition of discontinuity	Ground water condition	Orientation of discontinuity	RMR Value/ Class
				12	***17***	***10***	***16***	***15***	***-7***	***Good***
K	8659.600	1011.826	Pinkish grey granite	133-250	75 Jv-12	10-15	High persistence, smooth planar, black coated, unweathered,	Dry	Fair	***61 Class-II Good***
				12	***17***	***8***	***16***	***15***	***-7***	
L	8659.600	1021.326	Pinkish grey granite	133-250	82 Jv-10	10-15	High persistence, smooth planar, black coated, unweathered,	Dry	Fair	***61 Class-II Good***
				12	***17***	***8***	***16***	***15***	***-7***	
M	8659.600	1027.826	Pinkish grey granite	133-250	42 Jv-22	5-10	High persistence, smooth planar, black coated, unweathered,	Dry	Fair	***52 Class-III Fair***
				12	***8***	***8***	***16***	***15***	***-7***	
N	8659.600	1037.326	Pinkish grey granite	133-250	65 Jv-15	5-10	High persistence, smooth planar, black coated, unweathered,	Dry	Fair	***57 Class-III Fair***
				12	***13***	***8***	***16***	***15***	***-7***	
P	8659.600	1047.100	Pinkish grey granite	133-250	49 Jv-20	10-15	High persistence, smooth planar, black coated, unweathered,	Dry	Fair	***52 Class-III Fair***
				12	***8***	***8***	***16***	***15***	***-7***	
Q	8659.600	1049.600	Pinkish grey granite	133-250	49 Jv-20	10-15	High persistence, smooth planar, black coated, unweathered,	Dry	Fair	***52 Class-III Fair***
				12	***8***	***8***	***16***	***15***	***-7***	
R	8659.600	1058.100	Pinkish grey granite	133-250	49 Jv-20	5-10	High persistence, smooth planar, black coated, unweathered,	Dry	Fair	***52 Class-III Fair***
				12	***8***	***8***	***16***	***15***	***-7***	
S	8659.600	1067.100	Pinkish grey granite	133-250	75 Jv-12	5-10	High persistence, smooth planar, black coated, unweathered,	Dry	Fair	***61 Class-II Good***
				12	***17***	***8***	***16***	***15***	***-7***	
AC1	8653.200	953.400	Pinkish grey granite	133-250	65 Jv-15	10-15	High persistence, smooth planar, black coated, unweathered, imperfectly interlocked	Dry	Fair	***57 Class-III Fair***
				12	***13***	***8***	***16***	***15***	***-7***	

Location North side			Rock type	UCS (MPa)	RQD % Joint volume	Spacing of discontinuity (cm)	Condition of discontinuity	Ground water condition	Orientation of discontinuity	RMR Value/ Class
AC2	8646.800	953.400	Pinkish grey granite	133-250	75 Jv-12	10-15	High persistence, smooth planar, black coated, unweathered, imperfectly interlocked	Dry	Fair	***61 Class-II Good***
				12	***17***	***8***	***16***	***15***	***-7***	
TC1	8653.200	1066.600	Pinkish grey granite	133-250	65 Jv-15	5-10	High persistence, smooth planar, black coated, unweathered,	Dry	Fair	***57 Class-III Fair***
				12	***13***	***8***	***16***	***15***	***-7***	
TC2	8646.800	1066.600	Pinkish grey granite	133-250	65 Jv-15	5-10	High persistence, smooth planar, black coated, unweathered,	Dry	Fair	***57 Class-III Fair***
				12	***13***	***8***	***16***	***15***	***-7***	

Table 3: Geotechnical parameters of columns at the foundation levels of pump house and service bay - south side

Location South side			Rock type	UCS (MPa)	RQD % Joint volume	Spacing of discontinuity (cm)	Condition of discontinuity	Ground water condition	Orientation of discontinuity	RMR Value/ Class
A1	8640.400	952.900	Pinkish grey granite	133-250	65 Jv-15	10-15	High persistence, smooth planar, black coated, unweathered, imperfectly interlocked	Dry	Fair	***57 Class-III Fair***
				12	***13***	***8***	***16***	***15***	***-7***	
B1	8640.400	958.800	Pinkish grey granite	133-250	65 Jv-15	10-15	High persistence, smooth planar, black coated, unweathered, well interlocked	Dry	Fair	***57 Class-III Fair***
				12	***13***	***8***	***16***	***15***	***-7***	
C1	8640.400	963.826	Pinkish grey granite	133-250	65 Jv-15	10-15	High persistence, smooth planar, black coated, unweathered, well interlocked	Dry	Fair	***57 Class-III Fair***
				12	***13***	***8***	***16***	***15***	***-7***	
D1	8640.400	973.326	Pinkish grey granite	133-250	49 Jv-20	10-15	High persistence, smooth planar, black coated, moderately weathered, well interlocked	Dry	Fair	***49 Class-III Fair***
				12	***8***	***8***	***13***	***15***	***-7***	
E1	8640.400	979.826	Pinkish grey granite	133-250	29 Jv-26	5-10	High persistence, smooth planar, black coated, unweathered,	Dry	Fair	***52 Class-III Fair***
				12	***8***	***8***	***16***	***15***	***-7***	

Location South side			Rock type	UCS (MPa)	RQD % Joint volume	Spacing of discontinuity (cm)	Condition of discontinuity	Ground water condition	Orientation of discontinuity	RMR Value/ Class
F1	8640.400	989.326	Pinkish grey granite	133-250	69 Jv-14	5-15	High persistence, smooth planar, black coated, unweathered,	Dry	Fair	***57 Class-III Fair***
				12	***13***	***8***	***16***	***15***	***-7***	
G1	8640.400	995.826	Pinkish grey granite	133-250	56 Jv-18	10-20	High persistence, smooth planar, black coated, unweathered,	Dry	Fair	***57 Class-III Fair***
				12	***13***	***8***	***16***	***15***	***-7***	
H1	8640.400	1005.326	Pinkish grey granite	133-250	49 Jv-20	10-15	High persistence, smooth planar, black coated, unweathered,	Dry	Fair	***52 Class-III Fair***
				12	***8***	***8***	***16***	***15***	***-7***	
J1	8640.400	1006.151	Pinkish grey granite	133-250	49 Jv-20	10-15	High persistence, smooth planar, black coated, unweathered,	Dry	Fair	***52 Class-III Fair***
				12	***8***	***8***	***16***	***15***	***-7***	
K1	8640.400	1011.826	Pinkish grey granite	133-250	82 Jv-10	10-15	High persistence, smooth planar, black coated, unweathered,	Dry	Fair	***61 Class-II Good***
				12	***17***	***8***	***16***	***15***	***-7***	
L1	8640.400	1021.326	Pinkish grey granite	133-250	65 Jv-15	10-15	High persistence, smooth planar, black coated, unweathered,	Dry	Fair	***57 Class-III Fair***
				12	***13***	***8***	***16***	***15***	***-7***	
M1	8640.400	1027.826	Pinkish grey granite	133-250	65 Jv-15	10-15	High persistence, smooth planar, black coated, unweathered,	Dry	Fair	***57 Class-III Fair***
				12	***13***	***8***	***16***	***15***	***-7***	
N1	8640.400	1037.326	Pinkish grey granite	133-250	75 Jv-12	10-30	High persistence, smooth planar, black coated, unweathered,	Dry	Fair	***61 Class-II Good***
				12	***17***	***8***	***16***	***15***	***-7***	
P1	8640.400	1047.100	Pinkish grey granite	133-250	62 Jv-16	10-30	High persistence, smooth planar, black coated, unweathered,	Dry	Fair	***57 Class-III Fair***
				12	***13***	***8***	***16***	***15***	***-7***	
Q1	8640.400	1049.600	Pinkish grey granite	133-250	62 Jv-16	10-15	High persistence, smooth planar, black coated, unweathered,	Dry	Fair	***57 Class-III***

Location South side			Rock type	UCS (MPa)	RQD % Joint volume	Spacing of discontinuity (cm)	Condition of discontinuity	Ground water condition	Orientation of discontinuity	RMR Value/ Class
				12	***13***	***8***	***16***	***15***	***-7***	***Fair***
R1	8640.400	1058.100	Pinkish grey granite	133-250	49 Jv-20	10-15	High persistence, smooth planar, black coated, unweathered,	Dry	Fair	***52 Class-III***
				12	***8***	***8***	***16***	***15***	***-7***	***Fair***
S1	8640.400	1067.100	Pinkish grey granite	133-250	75 Jv-12	10-20	High persistence, smooth planar, black coated, unweathered,	Dry	Fair	***61 Class-II***
				12	***17***	***8***	***16***	***15***	***-7***	***Good***

Table 4: Geotechnical parameters of columns at the floor of rock ledge

Location North side			Rock type	UCS (MPa)	RQD % Joint volume	Spacing of discontinuity (cm)	Condition of discontinuity	Ground water condition	Orientation of discontinuity	RMR Value/ Class
D2	8631.500	973.326	Pinkish grey granite	133-250	49 Jv-20	10-15	High persistence, smooth planar, black coated, unweathered, imperfectly interlocked	Dry	Fair	***52 Class-III***
				12	***8***	***8***	***16***	***15***	***-7***	***Fair***
E2	8631.500	979.826	Pinkish grey granite	133-250	49 Jv-20	10-15	High persistence, smooth planar, black coated, unweathered, well interlocked	Dry	Fair	***52 Class-III***
				12	***8***	***8***	***16***	***15***	***-7***	***Fair***
F2	8629.500	989.326	Pinkish grey granite	133-250	65 Jv-15	10-15	High persistence, smooth planar, black coated, unweathered, well interlocked	Dry	Fair	***57 Class-III***
				12	***13***	***8***	***16***	***15***	***-7***	***Fair***
G2	8659.600	995.826	Pinkish grey granite	133-250	65 Jv-15	10-15	High persistence, smooth planar, black coated, unweathered, well interlocked	Dry	Fair	***57 Class-III***
				12	***13***	***8***	***16***	***15***	***-7***	***Fair***
H2	8629.500	1005.326	Pinkish grey granite	133-250	49 Jv-20	10-15	High persistence, smooth planar, black coated, unweathered, well interlocked	Dry	Fair	***52 Class-III***
				12	***8***	***8***	***16***	***15***	***-7***	***Fair***
J2	8629.500	1006.151	Pinkish grey granite	133-250	49 Jv-20	10-15	High persistence, smooth planar, black coated, unweathered, well interlocked	Dry	Fair	***52 Class-III***

Location North side			Rock type	UCS (MPa)	RQD % Joint volume	Spacing of discontinuity (cm)	Condition of discontinuity	Ground water condition	Orientation of discontinuity	RMR Value/ Class
				12	***8***	***8***	***16***	***15***	***-7***	***Fair***
K2	8629.500	1011.826	Pinkish grey granite	133-250	49 Jv-20	10-15	High persistence, smooth planar, black coated, unweathered, well interlocked	Dry	Fair	***52 Class-III Fair***
				12	***8***	***8***	***16***	***15***	***-7***	
L2	8629.500	1021.326	Pinkish grey granite	133-250	65 Jv-15	10-15	High persistence, smooth planar, black coated, unweathered, well interlocked	Dry	Fair	***57 Class-III Fair***
				12	***13***	***8***	***16***	***15***	***-7***	
M2	8631.500	1027.826	Pinkish grey granite	133-250	65 Jv-15	10-15	High persistence, smooth planar, black coated, unweathered, well interlocked	Dry	Fair	***57 Class-III Fair***
				12	***13***	***8***	***16***	***15***	***-7***	
N2	8631.500	1037.326	Pinkish grey granite	133-250	75 Jv-12	10-15	High persistence, smooth planar, black coated, unweathered, imperfectly interlocked	Dry	Fair	***61 Class-II Good***
				12	***17***	***8***	***16***	***15***	***-7***	
P2	8631.500	1074.100	Pinkish grey granite	133-250	75 Jv-12	10-15	High persistence, smooth planar, black coated, unweathered, imperfectly interlocked	Dry	Fair	***61 Class-II Good***
				12	***17***	***8***	***16***	***15***	***-7***	
Q2	8631.500	1049.600	Pinkish grey granite	133-250	75 Jv-12	10-15	High persistence, smooth planar, black coated, unweathered, imperfectly interlocked	Dry	Fair	***61 Class-II Good***
				12	***17***	***8***	***16***	***15***	***-7***	
R2	8631.000	1058.100	Pinkish grey granite	133-250	75 Jv-12	10-15	High persistence, smooth planar, black coated, unweathered, imperfectly interlocked	Dry	Fair	***61 Class-II Good***
				12	***17***	***8***	***16***	***15***	***-7***	
S2	8631.000	1067.100	Pinkish grey granite	133-250	75 Jv-12	10-15	High persistence, smooth planar, black coated, unweathered, imperfectly interlocked	Dry	Fair	***61 Class-II Good***

Table 1: Description of weathering grade (ISRM, 1978)

Term	Description	Grade
Fresh	No visible sign of rock material weathering; perhaps slight discolouration on major discontinuity surfaces.	I
Slightly weathered	Discolouration indicates weathering of rock material and discontinuity surfaces. All the rock material may be discoloured by weathering and may be somewhat weaker externally than in its fresh condition.	II
Moderately weathered	Less than half of the rock material is decomposed and / or disintegrated to a soil. Fresh or discoloured rock is present either as a continuous framework or as core stones.	III
Highly weathered	More than half of the rock material is decomposed and / or disintegrated to a soil. Fresh or discoloured rock is present either as a discontinuous framework or as core stones.	IV
Completely weathered	All rock material is decomposed and / or disintegrated to soil. The original mass structure is largely intact.	V
Residual soil	All rock material is converted to soil. The mass structure and material fabric are destroyed. There is a large change in volume, but the soil has not been significantly transported.	VI

Evaluation of Safe Bearing Capacity

Safe Bearing Pressure is an important factor for the design of foundation for large engineering structures. The ultimate bearing capacity (q.ult) is defined as average load per unit area required to produce failure by rupture of a supporting rock mass. The bearing capacity in jointed rock masses can be estimated by Rock Types, Rock Mass Rating (RMR), Uniaxial Compressive Strength (UCS), Point Load Strength, Rock Quality Designations (RQD), Pressure Meter Test and Plate Load Test (IS: 12070–1987, Peck et al., 1974). The method based on the Rock Mass Rating (RMR) is used to evaluate the bearing capacity foundation parameters for the foundation of columns. For this the average Rock Mass Rating (RMR) is taken for the estimation of Safe Bearing Pressure using the procedure given in IS Code : 12070 – 1987 (Table 5).

Table 5 : Estimation of safe bearing capacity of columns

Column Number	Location	Rock Mass Rating			Net Safe Bearing Pressure (t/m^2)
		Average RMR	Classification of Rockmass	Description of Rockmass	
A	North side of pump house	52	III	Fair	225.69
B	North side of pump house	49	III	Fair	205.32
C	North side of pump house	57	III	Fair	259.64
D	North side of pump house	57	III	Fair	259.64
E	North side of pump house	57	III	Fair	259.64
F	North side of pump house	57	III	Fair	259.50
G	North side of pump house	63	II	Good	304.00

Column Number	Location	Rock Mass Rating			Net Safe Bearing Pressure (t/m^2)
		Average RMR	Classification of Rockmass	Description of Rockmass	
H	North side of pump house	63	II	Good	304.00
J	North side of pump house	63	II	Good	304.00
K	North side of pump house	61	II	Good	288.00
L	North side of pump house	61	II	Good	288.00
M	North side of pump house	52	III	Fair	225.69
N	North side of pump house	57	III	Fair	259.64
P	North side of pump house	52	III	Fair	225.69
Q	North side of service bay	52	III	Fair	225.69
R	North side of service bay	52	III	Fair	225.69
S	North side of service bay	61	II	Good	288.00
AC1	Western side of pump house	57	III	Fair	259.64
AC2	Western side of pump house	61	II	Good	288.00
TC1	Eastern side of service bay	57	III	Fair	259.64
TC2	Eastern side of service bay	57	III	Fair	259.64
A1	South side of pump house	57	III	Fair	259.64
B1	South side of pump house	57	III	Fair	259.64
C1	South side of pump house	57	III	Fair	259.64
D1	South side of pump house	49	III	Fair	205.32
E1	South side of pump house	52	III	Fair	225.69
F1	South side of pump house	57	III	Fair	259.64
G1	South side of pump house	57	III	Fair	259.64
H1	South side of pump house	52	III	Fair	225.69
J1	South side of pump house	52	III	Fair	225.69
K1	South side of pump house	61	II	Good	288.00
L1	South side of pump house	57	III	Fair	259.64
M1	South side of pump house	57	III	Fair	259.64
N1	South side of pump house	61	II	Good	288.00
P1	South side of pump house	57	III	Fair	259.64
Q1	South side of service bay	57	III	Fair	259.64
R1	South side of service bay	52	III	Fair	225.69
S1	South side of service bay	61	II	Good	288.00
D2	Rock ledge between SP and PH	52	III	Fair	225.69
E2	Rock ledge between SP and PH	52	III	Fair	225.69
F2	Rock ledge between SP and PH	57	III	Fair	259.64
G2	Rock ledge between SP and PH	57	III	Fair	259.64

Column Number	Location	Rock Mass Rating			Net Safe Bearing Pressure (t/m^2)
		Average RMR	Classification of Rockmass	Description of Rockmass	
H2	Rock ledge between SP and PH	52	III	Fair	225.69
J2	Rock ledge between SP and PH	52	III	Fair	225.69
K2	Rock ledge between SP and PH	52	III	Fair	225.69
L2	Rock ledge between SP and PH	57	III	Fair	259.64
M2	Rock ledge between SP and PH	57	III	Fair	259.64
N2	Rock ledge between SP and PH	57	III	Fair	259.64
P2	Rock ledge between SP and PH	61	II	Good	288.00
Q2	Rock ledge between SP and PH	61	II	Good	288.00
R2	Rock ledge between SP and PH	61	II	Good	288.00
S2	Rock ledge between SP and PH	61	II	Good	288.00

(Dr. Ajay Kumar Naithani)
Project Leader & Coordinator
Head, Engineering Geology Department
National Institute of Rock Mechanics
Ministry of Mines, Govt. of India
P.O. Champion Reefs
Kolar Gold Field – 563 117, Karnataka

Annexure-1 111

Geologist Report

भारत सरकार/Government of India

भारतीय भूवैज्ञानिक सर्वेक्षण/ Geological Survey of India

अभियांत्रिकी भूविज्ञान विभाग / Engineering Geology Division
दक्षिणी क्षेत्र, बंदलागुड़ा/Southern Region, Bandlaguda
हैदराबाद /Hyderabad-500 068.

No. 43 /EGD/GSI/SR/2020 Dated: 04/12/2020

To
The Executive Engineer,
Water resource department,
SRBC Division No. 2,
Panyam, Andhra Pradesh.

Sub: A Inspection note on "Feasibility Stage Geotechnical Investigation of the proposed pump house near Pothulapadu village under Rayalaseema Lift Irrigation Scheme, Kurnool District, Andhra Pradesh" – reg.

Sir,

Please find enclosed herewith a "Feasibility Stage Geotechnical Investigation of the proposed pump house near Pothulapadu village under Rayalaseema Lift Irrigation Scheme, Kurnool District, Andhra Pradesh" for Field Season 2020-21.

This is for your kind necessary action at your end.

Yours faithfully,

04/12/2020

(बी अजय कुमार/B. Ajaya Kumar)
निदेशक /Director

Encl: As above.

Inspection Note on Feasibility Stage Geotechnical Investigation of the proposed pump house near Pothulapadu village under Rayalaseema Lift Irrigation Scheme, Kurnool District, Andhra Pradesh

By

B. Ajaya Kumar,
Director
Engineering Geology Division
Geological Survey of India
Hyderabad

Under Rayalaseema Lift Irrigation Scheme a 250m long, 40 m wide pump house is proposed to lift (60m) 3 TMC water per day from Srisailam Reservoir to SRMC on downstream from Pothireddypadu Head Regulator to stabilize the ayacut of the various projects in Rayalaseema Region and Nellore district including providing drinking water to the drought prone region. The project will facilitate to draw assured /allocated water. The project will allow drawing water even during the lean periods in Krishna River.

The Water shall be drawn thorough an Approach channel. Pump House shall be located beyond FRL line and Water lifted shall be delivered into a Cistern. Water carried through a Link canal, from delivery cistern to SRMC downstream of Pothireddypadu Head Regulator (PRHR)

The Discharge Required in SRMC & capacity of PRHR- and status of SRMC decide WHEN lift has to operate Below 841' level- drawal only by Lift & Between 841' to 874' Drawal will be either by Lift OR Gravity flow depending on required 'discharge' & Srisailam Reservoir level.

The proposed scheme details furnished by project authority are as follows:

1. Approach channel: The approach channel is proposed in the Srisailam fore shore area up to proposed fore bay at left side of existing Pothireddypadu Head Regulator. The approach channel traverses along the valley in Bhavanasi river in Srisailam foreshore area for a required length.
2. Forebay: Forebay of required size is to be constructed from the end of approach channel upto the pump house.
3. Pump house:
    - The pump house is to be constructed to required size to accommodate required 12 no of pumps and motors and operating system.
    - *12 no of volute pumps of 81.*93 cumecs capacity each.

- *Power requirement: 420 MW*
- H.T/L.T Panels, SCADA, HT/LT Cables, HM/EM Components as per approved drawings.
- Water drawing level :+243.85 m/800.0 ft and above
- Delivery level :+269.82 m /885.144 ft

4. Pipe line: The M.S pipe line is proposed from pump house to Delivery Cistern up to the required level. Diameter of Delivery main is 5000mm
5. Construction of One Delivery Cistern of required size.
6. Excavation of Link Canal to connect it from delivery cistern to SRMC down stream of Pothireddypadu Head Regulator.
7. Providing infrastructure
   i. Road to the pump station.
   ii. 400KV Sub-station and electrical power line from the existing HT lines.

At the request of the Executive Engineer, Water resource department, SRBC Division No. 2, Panyam, Andhra Pradesh via letter No. EE/SRBC-DIV.No2/PNM/AW/ATO/511M, dated 17.10.2020 to carryout feasibility stage Geotechnical investigation of the proposed pump house and auxiliary works of Rayalaseema Lift Scheme, the undersigned along with Shri. Bhushan D Kuthe, Senior Geologist visited the site on 30th and 31st October 2020 and carried out core logging of drilled boreholes and geological mapping of the proposed pump house location.

Feasibility Stage Geotechnical Investigation for proposed pump house location:

The proposed pump house is located approximately 100m in north eastern part of Pothireddypadu head regulator.

Regionally, area exposes mainly sediments of Cuddapah Supergroup and Kurnool Group of Meso to Neo-Proterozoic age. A small patch of migmatite and granite gneiss belonging to Peninsular Gneissic Complex (PGC-II) of Archaean to Palaeo-Proterozoic age is exposed in the northwestern part of the area. The Cuddapah Supergroup is divided into Chitravati and Nallamalai Groups and occurs in the northeastern part. The Chitravati Group is represented by the by Pulivendla Formation and Tadipatri Formation. The Pulivendla Formation is essentially an arenaceous unit. It has a thin impersistent basal conglomerate followed by grit and quartzite. The

Tadipatri Formation is constituted by shale, tuff, chert and jasper and lies conformably over Pulivendla Quartzite.

The Nallamalai Group is represented by Cumbum Formation which is exposed in the northeast. It consists of slate, phyllite and shale sequence with intercalations of quartzite.

The Kurnool Group of rocks unconformably overlies the Cuddapah Supergroup. They include Banaganapalle, Narji, Owk, Paniam, Koilkuntla and Nandyal Formations. The oldest unit in this area is Banganapalle Quartzite which is exposed in the northwest. The Narji Limestone, with massive and flaggy members, is exposed in the western margin. The overlying Owk Shale lies directly over Narji Limestone. It occurs as a thin but persistent band preserved due to capping of Paniam Quartzite over it. The shale is predominantly non-calcareous, white, buff or yellow and is often ochrous. Paniam Quartzite occurs capping the Owk Shale, forming plateau. Koilkuntla limestone occurs in the western and northern

The major part of the proposed pump house location is covered with the disposed muck excavated while the construction of Pothireddypadu head regulator. However, the reddish brown, thinly laminated, horizontally bedded shale belonging to Nandyal shale of Kurnool Supergroup is exposed in the cut slopes of adjacent Srisailam Right Main canal.

Sub-surface Exploration:

. The project authority has drilled 04 boreholes up to a depth of 70m in the surrounding area of the proposed pump house location and borehole 5 is in progress. Based on the core logging, it is found that thickness of top layer of dark grey to black clayey soil is varying from 1.5 to 4.5m followed by thinly laminated, reddish brown shale with thin laminations of grey shale up to the bottom of the borehole. The summary of the core logging is given below.

Borehole No.	Location	Drilled Depth	Run	Remark
01	Near PRP inspection path on R/S of PH location	70m	0 to 2m	Black clayey soil
			2 to 4m	Highly weathered, reddish brown shale
			4 to 5.8m	Moderately weathered reddish brown shale with thin lamination of shale
			5.8 to 70m	Slightly weathered to fresh, reddish brown shale with thin laminations of grey shale.
02	PRP pump house & DC	70m	0 to 3m	Black clayey soil
			3 to 4.5m	Highly weathered, reddish brown shale

			4.5 to 6.0m	Moderately weathered reddish brown shale with thin lamination of shale
			6m to 70m	Slightly weathered to fresh, reddish brown shale with thin laminations of grey shale.
03	Approach Channel (Right side)	70m	0 to 4.5m	Black clayey soil
			4.5 to 6m	Highly weathered, reddish brown shale
			6 to 8.5m	Moderately weathered reddish brown shale with thin lamination of shale
			8.5 to 70	Slightly weathered to fresh, reddish brown shale with thin laminations of grey shale. Silicification was recorded between 63-66m depth.
04	Approach Channel (Left side)	70m	0 to 3	Black clayey soil
			3 to 6m	Highly weathered, reddish brown shale
			6 to 8m	Moderately weathered reddish brown shale with thin lamination of shale. Silicification was recorded between 6-8m depth.
			8 to 70m	Slightly weathered to fresh, reddish brown shale with thin laminations of grey shale.

Conclusion & Recommendations:

- Based on the geological set up of the area and borehole core logging, it is opined that the proposed location of the pump house is prima-facie feasible.
- Suggested to remove the disposed muck and to intimate for further geological mapping before start of concrete.
- Based on the core logging, it is expected to encounter a slightly fresh to fresh rock below a depth of about 8 to 10m from the ground level.
- Suggested to drill 3 boreholes along the center line of the proposed pump house location to ascertain the nature of bed rock and also to estimate the stability of the slopes during the construction of the proposed pump house.

04/12/2020

B. Ajaya Kumar
Director

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Ministry of Environment, Forest and Climate Change
Government of India

S.No	Proposal Details	Location	Important Dates	Category	Company/Proponent	Type of project	* Attached Files	View Essential Details Sought by MoEFCC	View TimeLine Details
1	**Proposal No** : IA/AP/RIV/214491/2021 **File No** : J-12011/18/2006-IA.I (R) **Proposal Name** : Rayalaseema Lift Scheme to lift water for 3 schemes which are presently drawing water by gravity from foreshore of Srisailam reservoir viz. 1. Galeru Nagari Sujala Shravanthi (GNSS) Project in District Kurnool, Andhra Pradesh. 2. Srisailam Right Branch Canal, Andhra Pradesh. 3. Telugu Ganga Project, Andhra Pradesh.	**State** : Andhra Pradesh **District** : Kurnool **Tehsil** :	**Date of Submission for EC** : 09 Jun 2021 **Date of previous EC Granted** : 21 Jun 2006	River Valley and Hydroelectric Projects	CHIEF ENGINEER AND DWRO KURNOOL	Amendement	View		

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9/30/2021

ANNEXURE-IV

GOVERNMENT OF ANDHRA PRADESH
WATE RESOURCES DEPARTMENT
***

From
Sri R.Muralinatha Reddy, M.Tech.,
Chief Engineer & DWRO,
Water Resources Department,
Kurnool.

To
The Secretary,
Union Ministry of Environment,
Forest and CC,
Indira Paryavaran Bhavan,
New Delhi-110003.

Lr.No.CE(P)KNL/ICD32-TW/2021/AEE5/RLS ***Date*** **08-06-2021**

Sir,

Sub: WRD- Govt. of A.P - Environment clearance for Rayalaseema Lift Scheme to supplememt 3 TMC per day to SRMC on D/s of Pothiredypadu Head Regulator, which is an integral part of 1. Galeru Nagari Sujala Sravanthi (GNSS0 Project in District Kurnool, Andhra Pradesh. 2. Srsailam Right Branch Canal, Andhra Pradesh 3. Telugu Ganga Project, Andhra Pradesh– Amendment to the Existing Environmental clearances to include Rayalaseema Lift Scheme –Requested - Regarding.

Ref: 1.Hon'ble NGT order in O.A. No.71/2020 dt.29.10.2020

*****

With reference to the above, it is submitted that the Rayalaseema Lift Scheme is envisaged to support the following schemes **whose Environmental Clearances are already obtained, the details are as below**.

I. **Srisailam Right Branch Canal (SRBC):** The scheme was accorded environmental clearance by the Ministry of Environment and Forests vide MOEF, GOI vide MOEF, GOI vide letter No.J.12011/7/95-IA.I dt.07.07.1995.

II. **Telugu Ganga Project (TGP):**The environmental clearance for this project was accorded by the Ministry of Environment and Forests vide MOEF, GOI vide P&F Dept. vide Lr.NO.J-

11016/70/83-IA dt.19.09.1988.

III. **Galeru Nagari Sujala Sravanthi(GNSS):**The environmental clearance for this project was accorded by the Ministry of Environment and Forests vide MOEF, GOI vide letter No.J-12001/18/2006-1/A-1 dt.21.06.2006.

It is further submitted that the above three schemes are presently being fed by an open canal Srisailam Right Main Canal (SRMC) by drawing water from Srisailam Foreshore through Pothireddy Padu Head Regulator (PRPHR) . The SRMC further diverges into three separate canals namely SRBC, TGP and GNSS.

The proposed Rayalaseema Lift Scheme (RLS) is not a new project and does not have an ayacut. It only supplements the existing three schemes mentioned above when the water level in the Srisailam Reservoir is below +854 ft., when the water supply through gravity becomes difficult. The proposed Rayalaseema Lift Scheme will draw water from Srisailam Fore shore and deliver it to SRMC so as to feed the existing three schemes.

The proposed RLS was challenged in the Hon'ble NGT for requirement of Environmental Clearances. The Hon'ble Tribunal in its order dt.20.05.2020 has "appointed a Joint Committee comprising of Expert appraisal committee (River valley projects) of Ministry of Environment Forest and Climate Change (MOEFCC) Central Pollution Control Board (CPCB) Regional Directorate, Bangalore, Indian Institute of Technology, Hyderabad and Krishna River Management Board (KRMB) to examine the scheme and submit a report.

Accordingly MOEFCC convened a meeting online with members of Expert Appraisal Committee (River Valley Project), Central Pollution Control Board, IIT, Hyderabad, KRMB and officials of Water Resources Department, Andhra Pradesh on 29.07.2020. The Expert Appraisal Committee of MOEFCC has opined that

1. *The Expert Appraisal Committee of MOEFCC opined that prima facie requirement of prior environment clearance is not applicable in the case of Rayalaseema Lift Scheme.*
2. *As long as Andhra Pradesh is restricted to drawing its allocated share of water, environmental impacts of the availability of water on other users are not envisaged. Further, state of A.P. in order to ensure that only allocated water of 3 TMC/day is drawn, shall install pumps of capacity capable of pumping only 3 TMC of water (excluding the safety margins).*

The Hon'ble National Green Tribunal after considering the report submitted by the appointed committee has disposed the matter in O.A. NO.71/2020 as under.

"Since, the Tribunal has prima facie found that there is a component of irrigation envisaged in the project and which requires prior Environmental Clearance (EC) and without getting prior Environmental (EC), the 4th respondent (Govt. of A.P) is restrained from proceeding of the work without getting Environmental Clearance (EC)."

As per the MINISTRY OF ENVIRONMENT, FOREST AND CLIMATE CHANGE, Notification, dt. 14-08-2018, though the instant project/ activity falls under 1(c)(ii), because of change in irrigation technology having environmental benefits (Eg. From flood irrigation to drift irrigation etc.) by an existing project leading to increase in CCA but without increase in dam height and submergence will not require amendment/ revision of E.C.

The proposed project has been conceived as an integral part of the existing projects and having E.C.s and thus the proposed additions may require E.C./ amendment of E.C

We intended to lift the water below +854 level and the water so lifted will be used for stabilization of existing command area by changing the technology method i.e. Lift/ micro/ sprinkler irrigation. So that the above Para will be applicable to our proposed project thus the NGT order will also be followed without any intention and the present proposal may be considered for amendment to EC under the above notification.

In view of the above, I herewith submit the application for amendment in Environmental Clearance in **form -4** and request to amend the existing Environmental Clearances so as to include Rayalaseema Lift Scheme for taking up the work at the earliest.

Yours faithfully,

Chief Engineer & DWRO,
WRD :: Kurnool.

Annexure III

GOVERNMENT OF ANDHRAPRADESH

WATER RESOURCES DEPARTMENT

DETAILED PROJECT REPORT FOR

Rayalaseema Lift Scheme to supplement 3 TMC per day to SRMC on D/s of Pothireddypadu Head Regulator, Kurnool District, Andhra Pradesh.

OFFICE OF THE
CHIEF ENGINEER (P)
KURNOOL (Dist.,) 518004
Phone / Fax No. 08518-221313
Email : cepkurnool@gmail.com
ANDHRA PRADESH

DETAILED PROJECT REPORT

FOR

Rayalaseema Lift Scheme to supplement 3 TMC per day to SRMC on D/S of Pothireddypadu Head Regulator, Kurnool District, Andhra Pradesh.

VOLUME-I : REPORT

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CHAPTER – 3
SURVEYS AND INVESTIGATIONS

3.1 TOPOGRAPHICAL SURVEYS

The topographical surveys include map study, reconnaissance survey, preliminary survey and detailed survey. Accordingly, the survey works were taken up using DGPS, Auto levels, Total station etc.

The accuracy of the design of any scheme depends on the accuracy of survey data. As such the survey assumes greater importance in this kind of projects. Every effort was made to collect reliable data.

The objective of the proposed topographical surveys is to assess the topography of the project area, type of terrain, ground features etc and to establish reference Bench Marks to enable planning, engineering and construction work. Following are the various activities undertaken.

3.1.1 Map Study

This is the first activity of any survey. Topo sheets of Survey of India, Satellite imageries from Google earth were collected and studied in detail so as to get first hand information on the general topographical features of the project. Detailed study of these maps in respect of part of Srisailam reservoir, alignment of approach channel, pump house, topographical features, possible hindrances, major streams etc was done. After detailed study of maps, various components of the project were visualized.

The project components were marked on topo sheets. Possible alternatives were also explored on the map. The project area is covered in topo sheets D44A5

3.1.2 Reconnaissance Survey

As a part of reconnaissance survey, in the first instance, a walk through survey was conducted at proposed project site to ascertain the terrain conditions and other ground features. General contours of the area and location of GTS/existing benchmarks and other important information was collected during the reconnaissance survey.

3.1.3 Detailed Survey

In the detailed survey, actual field data was collected. This survey involved establishment of bench marks, collection of ground features and the levels. Following are the various activities covered under this survey.

3.1.4 Bench Marks

The basic principle of surveying i.e., "to work from whole to part" a network of permanent primary control points have been established in the project area using DGPS, auto levels and total stations, w.r.t the existing bench marks.

Levelling : Height control has been established with respect to the bench mark carried from GTS bearing value **+278.965** near Pothireddypadu Head Regulator**.** This Bench mark was established by a team comprising of Engineers from Government of AP, Government of Telangana and KRMB.

The height control for the entire topographic survey was established by connecting the benchmarks to the GTS benchmark at Atmakur. **Double tertiary levelling** (DCBM) procedure was adopted to ensure greater accuracy. Field books/sheets entries and calculations are thoroughly checked and cross checked before finalizing the reduced levels.

Traverse: Traverse has been made in the proposed area by using DGPS, Total Station which ensures accuracy for doing topographic survey. By using these control points traverse has been done by establishing the control points (Bench mark Stations) in the entire project area.

3.1.5 Longitudinal section of the Alignment

In order to generate the longitudinal section of the alignment, x, y and z coordinates are picked up using DGPS with reference to the benchmarks at every 25 m interval along the centre line of the alignment.

3.2 Alternative Alignments :

The alternative alignments are already discussed in Chapter 1.

3.3 GEOLOGICAL STUDIES

A pump house is contemplated near the existing Pothireddypadu Head Regulator near Pothireddypadu village, Pamulapadu Mandal in Kurnool district, Andhra Pradesh. It comprises Forebay, Pump House and Delivery Cistern.

As part of scope of DPR, the following geological and geotechnical studies and investigations have been carried out.

1. Study of Satellite Imageries data of the area (LISS-4).
2. Study of published Regional Geological maps and Geological reports by GSI.
3. Detailed geological mapping of the dam site area covering an area of 2.75 sqkm on scale 1:10000.
4. Subsurface explorations near proposed Pump House by drilling bore holes to a depth of about 70m each.
5. Collection of cores samples of foundations.
6. Conducting permeability tests in bed rock.
7. Laboratory tests on core rock samples of foundation media of pump house for determining their geo -mechanical parameters.
8. A Geologist from the GSI has visited the site to assess the nature of foundation of Pump House.

These studies have been carried out in order to:

1. understand geological set up of the project area, 2. delineate subsurface geological profile, 3. establish nature of foundation media and 4. determine rock mechanics properties of foundation media as well as construction material.

3.4 CONCLUSIONS

1. For the proposed scheme, 5 different alignments have been examined and after considering all options, the present alignment has been selected and geological and geotechnical investigations have been carried out.
2. The Pump House is located near the existing Pothireddypadu Head Regulator on firm ground.
3. On the basis of geological studies and subsurface exploratory data it is inferred that shale type rock forms the foundation media for the Pump House.

Some of the Photographs taken while Drilling the Boreholes

	
1.Core Drilling in progress	**2. Core Drilling in progress**
	
3.Core Samples	**4. Core Samples**

GOVERNMENT OF ANDHRA PRADESH
WATE RESOURCES DEPARTMENT
***

From
Sri R.Muralinatha Reddy, M.Tech.,
Chief Engineer & DWRO,
Water Resources Department,
Kurnool.

To
The Secretary,
Union Ministry of Environment, Forest and CC,
Indira Paryavaran Bhavan,
New Delhi-110003.

Lr.No.CE(P)KNL/ICD32-TW/2021/AEE5/RLS Date.30.06.2021.

Sir,

Sub: WRD- Govt. of A.P - Environment clearance for Rayalaseema Lift Scheme to supplement 3 TMC per day to SRMC on D/s of Pothiredypadu Head Regulator, which is an integral part of 1) Galeru Nagari Sujala Sravanthi (GNSS Project in District Kurnool, Andhra Pradesh. 2) Srisailam Right Branch Canal, Andhra Pradesh 3) Telugu Ganga Project, Andhra Pradesh– Amendment to the Existing Environmental clearances to include Rayalaseema Lift Scheme –Additional information submitted-- Regarding.

Ref: 1.CE(P)KNL/ICD32-TW/2021/AEE5/RLS dt.08.06.2021 uploaded along with Form-4 as Annexure-IV on 09.06.2021 on MoEF Portal.
2.Agenda item No.13.2.8 of 13th EAC (River Valley Projects) meeting held on 17.06.2021 from 2.30 PM to 4.00 PM through Video Conference.
3.Minutes of the meeting held on 17.06.2021 communicated on 25.06.2021 through mail.

*****

With reference to the above subject, It is to submit that the Chief Engineer (P), Kurnool, the project proponent for Rayalaseema Lift scheme EC Amendment has uploaded Form-IV on 09.06.2021 along with Annexures I to IV for granting amendment to the already issued Environmental Clearances of TGP, SRBC and GNSS Projects to include Rayalaseema Lift Scheme. The details of the Environmental Clearances for which amendment is sought are stated below.

Sl.No.	Name of the Project	Environmental Clearance
1.	TGP	P&F Dept. vide Lr.NO.J-11016/70/83-IA dt.19.09.1988.
2.	SRBC	MOEF, GOI vide letter No.J.12011/7/95-IA.I dt.07.07.1995.
3.	GNSS	MOEF, GOI vide letter No.J-12001/18/2006-1/A-1 dt.21.06.2006.

In continuation of the references 1st cited, it is to submit that the Chief Engineer (P), Kurnool has presented the proposal for amendment in Environmental Clearance before the 13th EAC (River Valley Projects) Committee meeting held on 17.06.2021.

It is further submitted that the EAC Committee vide the minutes of the meeting dt.25.06.2021has directed to provide following additional information for further assessment.

Observations of the Hon'ble NGT	i. Impacts due to widening of existing Irrigation canals
	ii. Impacts of pumping water from a level lower than 854 ft.
	iii. Impacts of Geological formations
	iv. Impacts on Ecologically Sensitive zones :
Observations of the EAC	Observation 1: Clear drawings of layout showing all components proposed in the current proposal.
	Observation -2 :_Comparative chart & drawings /layouts of proposal vis-a vis the one considered by the Hon'ble NGT
	Observation -3 : PFR/DPR_ with updated details as the DPR available on the PARIVESH is showing different figures as presented before EAC
	Observation -4:_ Change in Land requirement and land use.
	Observation -5:_ Details of Ecologically Sensitive Areas within 10 Kms of the proposed project. Submission:
	Observation -6: Clarification on water withdrawal methods. Will both the mechanism of water drawl continue to operate?

In compliance to the observations made by the EAC Committee, the point wise replies to the observations along with necessary annexures are enclosed in the report.

It is further submitted that necessary modifications are made accordingly and detailed schematic diagrams of the scheme are included in the DPR and is resubmitted for consideration.

In this connection, I here with submit the additional information as requested further assessment and it is requested to consider the additional information submitted to grant necessary amendment to the Environmental Clearances of TGP, SRBC and GNSS

Encl:
Report along with annexures-1 No

Yours faithfully,

(R.Muralinatha Reddy)
Chief Engineer & DWRO,
WRD::Kurnool. 30/8/21

GOVERNMENT OF ANDHRA PRADESH
WATER RESOURCES DEPARTMENT

REPORT ON REPLIES TO THE OBSERVATIONS OF THE EXPERT APPRAISAL COMMITTEE (RIVER VALLEY PROJECTS) ON ENVIRONMENTAL CLEARANCE FOR RAYALASEEMA LIFT SCHEME IN THE 13TH EAC MEETING HELD ON 17.06.2021.

Agenda item 13.6 of the Minutes of the Meeting

CHIEF ENGINEER & DWRO,
WATER RESOURCES DEPARTMENT,
KURNOOL.

INDEX

Agenda item 13.6 of the Minutes of the Meeting

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Annexures

Annexure-I	Schemes drawing water from foreshore of Srisailam
Annexure-I I	Report of Senior Geologist of GSI
Annexure-IIIA	Report of the Conservator of Forest, Tiger reserve Circle, Srisailam
Annexure-IIIB	Map showing tiger reserve zone with respect to proposed RLS
Annexure-IVA	Comparative drawing of the Layout of present proposal Vis-Vis the initial proposal considered by Hon'ble NGT
Annexure-IVB	Drawing of proposed RLS to the Scale
Annexure-V	Detailed Project Report
Annexure-VIA	Map showing Government land for RLS
Annexure-VIB	Map showing change of land use
Annexure-VII	Undertaking

Replies to the Observations made on Agenda item 13.6 of the 13th EAC (River Valley Projects) held on 17-06-2021

The Government of A.P is glad that the proposal has been considered for appraisal by the EAC (RVP) during the 13th meeting held on 17-06-2021.
The minutes of the meeting are communicated by mail on 25.06.2021.
The minutes of the meeting mentioned certain observations in the proposal which are required to be answered for the furtherance of the proposal.

I) In this connection the concerns raised by the NGT are mentioned in page No. 19 of 24 in the Minutes for which the replies are furnished below:

i. Impacts due to widening of existing Irrigation canals :

It is reiterated that there is no widening of canals.
There is no enhancement of the existing canals either by providing additional canals or diversion canals or by widening or enhancing the dimensions what so ever.
It is proposed to improve the stability of existing canals by lining the canal which will considerably reduce transmission, seepage losses etc. and increase the efficiency of the system.

ii. Impacts of pumping water from a level lower than 854 ft.

There is one power house each in the state of A.P. & Telangana territory and one lift scheme each of A.P. & Telangana territory which are already drawing water below 800 ft level.

The lowest levels recorded in the past 16 years shows that the reservoir has been depleted almost to 800 ft or below every year.

Table-I:Statement showing the lowest reservoir levels from 2004-05 to 2019-20

Sl. No	Year	Lowest Reservoir Level during the year ft
1	2004-05	760
2	2005-06	807
3	2006-07	806
4	2007-08	807
5	2008-09	800
6	2009-10	799.9
7	2010-11	802
8	2011-12	800.2

9	2012-13	805.7
10	2013-14	805
11	2014-15	800
12	**2015-16**	**775**
13	2016-17	775
14	2017- 18	799.7
15	2018-19	804
16	2019-20	810.9

The drawing levels of various existing /proposed schemes from Srisailam foreshore are worth mentioning for perusal of the committee.

Table-II: Statement showing the lowest water drawl levels of various Schemes drawing/proposed to draw water from Srisailam foreshore.

Project	Minimum Water Level-Design in Meters	Lowest Water		Pumping Capacity	
		Meters	feet	Cusecs	Cumecs
TELANGANA					
Power House (Left)	218.99	218.99	**718.50**	44497	1260.0
Palamuru Rangareddy LIS Dindi LIS	243.850	243.85	**800**	24014	680
Kalwakurthy LIS	244.400	244.4	**802**	4000	113
ANDHRA PRADESH					
Power House.(Right)	218.99	218.99	**718.50**	35032	991.99
HNSS Mutchumarri pump house	243.300	243.3	**798**	3850	109
HNSS Malyala pump house	254.200	254.2	**834**		
Rayalaseema Pumping System (Proposed)	243.850	243.850	**800**	34722	983.21

Hence it can be observed that water from the foreshore of Srisailam Reservoir is being drawn at around 800 ft level since many years and there is no adverse impact observed due to such water drawl till date.

The Details of the schemes drawing water from the foreshore of the Srisailam reservoir is enclosed as **ANNEXURE-I**

iii. Impacts of Geological formations :

Location of lift scheme is verified for Geological formation by Senior Geologist of GSI and cleared for stability and will also be inspected regularly during execution of the work to suggest any activity required for the stability of the scheme keeping the geological formation in view.

The canals and Reservoirs are in operation in the region since a long period and subsidence / failure is not noticed till date.

The report of the Senior Geologist of GSI is enclosed as **ANNEXURE-II**

iv. Impacts on Ecologically Sensitive zones :

Neither the pumping station nor any component of the Rayalaseema Lift Scheme is in the eco-sensitive zone or near or within the boundary of any of the protected wild life sanctuary.

Existing projects (TGP, SRBC & GNSS) have already obtained required clearances and constructed in compliance to the same.

The nearest wild life protected area is Nagarjuna Sagar-Srisaisalm Tiger Reserve, which is more than 10 Km away from the RLS. The proposed scheme components are well outside the proposed ESZ draft notification of MoEF dt.11.02.2020.

All components of Rayalaseema lift scheme ie., Approach channel , location of the Pump House and connection from Pump House to Srisailam Right Main Canal (SRMC) , do not fall under Wild Life Sanctuary. Hence there is no impact on Wildlife.

The Scheme envisages neither any enhancement of ayacut nor increase in the canal dimensions nor increase in the utilizations nor increase in existing storage in the reservoirs. Therefore, the Rayalaseema Lift Scheme does not impact any wild life sanctuaries and ecologically sensitive areas.

It is to submit for kind consideration of the committee that a report along with a map earmarking the Tiger reserve Zone, depicting the distances of the proposed Rayalaseema lift Scheme as per draft Notification No. 565 dt. 11 th February 2020 is obtained from the Conservator of Forests, Tiger Reserve Circle, Srisailam, and enclosed as **ANNEXURE-IIIA and IIIB.**