BEFORE THE NATIONAL GREEN TRIBUNAL

SOUTHERN ZONE, CHENNAI

ORIGINAL APPLICATION No. 120 of 2024

IN THE MATTER OF:

Suo Motu based on the news item
appearing in 'Deccan Chronicle' dated
07.01.2024 titled, "CAG reveals damage to
KLIS in 2019 itself". ...Applicant(s)

-Vs-

Irrigation & Command Area Development (CAD)
Through its Engineer in Chief,
Siddipet District, Telangana and Ors. ...Respondent(s)

REPORT FILED BY THE IRRIGATION DEPARTNMENT

1st RESPONDENT

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Place: Chennai

Date: 10.09.2024

Mrs. H. Yasmeen Ali,
Counsel for the 1st Respondent.

BEFORE THE NATIONAL GREEN TRIBUNAL,
SOUTHERN ZONE, CHENNAI

Original Application No.120 of 2024
[Earlier O.A. No.151 of 2024 (PB)]

Suo Motu

.... Applicant

-Vs-

Irrigation & Command Area Development (CAD)
Through its Engineer in Chief, Siddipet District, Telangana

.... Respondents

Report filed by the Irrigation & Command Area Development (CAD) Department R-1

It is to submit that the Hon'ble National Green Tribunal, Chennai in its order dated:07.08.2024 directed to file the report before the Hon'ble Tribunal and in this regard, the following is submitted:-

The Sri Komaravelli Mallannasagar Reservoir is part of Kaleshwaram Project under Link-IV. The Government of India, Ministry of Environment, Forest & Climate Change (I.A.I-Division) has accorded the Environmental clearance vide letter no.J-12011/1/2017-IA-I(R) dated:22.12.2017 (Copy Enclosed).

Sri Komaravelli Mallannasagar Reservoir is a huge reservoir with 50 Thousand Million Cubic feet (TMC) capacity proposed with Full Reservoir Level of +557.000 m in order to provide sufficient water storage system in Kaleshwaram Project to meet operational flexibilities as per suggestions of Central Water Commission and to cater irrigation requirements of Khariff season for the base period of 120 days and to meet other contemplated demands of the project like 30 Thousand Million Cubic feet (TMC) drinking water to Hyderabad and Secunderabad city and 16 Thousand Million Cubic feet (TMC) of water for industrial use etc., throughout the year.

The Government vide G.O.Rt.No.185, Irrigation & CAD (Proj-IV) Dept., dt:08.03.2017 has accorded administrative approval for the work of formation of "Sri Komaravelli Mallanna Sagar Reservoir from Km.0.00 to Km.22.60 with a capacity of 50 Thousand Million Cubic feet (TMC) along with its structures". As huge quantum of work is involved in formation of Sri Komaravelli Mallannasagar reservoir reservoir the work was divided into four reaches for construction convenience so as to complete the work within stipulated time period.

The work of formation of Sri Komaravelli Mallannasagar reservoir has started in May-2018 and completed in August-2021. The water is being impounded from August-2021. The Drawings of Earth bund and its associated structures were approved by Chief Engineer, Central Designs Organization, Hyderabad based on the site surveys and geotechnical investigations.

I. **In the National Green Tribunal hearing Dated:20.02.2024, It is mentioned that that drawings were approved and reservoir was constructed in undue haste without conducting necessary investigations and studies. In this regard, the following replies are submitted:**

1. As per the suggestion of Chief Engineer, Central Designs Organization, Hyderabad, the Executive Engineer, Irrigation Division No.6, Gajwel has addressed the Director, Council

of Scientific and Industrial Research (CSIR)- National Geophysical Research Institute (NGRI), Hyderabad for conducting the site-specific seismic studies pertaining to Sri Komaravelli Mallanna Sagar Reservoir. Subsequently, the Chief Scientist, National Geophysical Research Institute, Hyderabad along with his team visited the site and conducted Ground Penetration Radar studies. As per the results, the Chief Scientist, National Geophysical Research Institute has submitted a Preliminary Seismo-tectonic and Ground Penetration Radar studies Appraisal (Overview) around Mallanna Sagar dated:23.08.2018.

2. Further, the National Geophysical Research Institute has reported that it has carried out Ground Penetration Radar survey at site and as per the latitude and longitude of the location (aa' @ N-17^{0}57.451', E-78^{0}47.915'; 65m length and bb' @ N 17^{0}57.469', E-78^0 47.942'; 68 m length) it falls nearby Full Reservoir Level at (+)557.000m and away from the bund alignment of the Sri Komaravelli Mallannasagar reservoir, where the ground level is almost +557.000m. The water column at the location where Ground Penetration Radar survey conducted by National Geophysical Research Institute is zero for the reservoir full capacity of 50 Thousand Million Cubic feet (TMC) at +557.000m (Marked topo sheet enclosed).

3. As per I.S.Code 1893-Part-1 Sri Komaravelli Mallannasagar Reservoir falls under Seismic Zone-II (lowest seismicity level) category. However, during the design of earth bund, basic horizontal seismic coefficients (α_o=0.02 as per Table-2 of I.S:1893-1984) is considered and designed accordingly by Chief Engineer, Central Designs Organization, Hyderabad. Factor of safety obtained for steady seepage (1.11) and sudden draw down (1.0) conditions are more than required value of 1.0.

4. During execution Cut-off Trench of Sri Komaravelli Mallanna Sagar Reservoir the Director, Geological Survey of India (GSI), Hyderabad has inspected the site regularly. The Director, Geological Survey of India, Hyderabad inspected all along the bund about 22.600 Kms and Saddle bund about 0.620 Km. The observations and suggestions of the Director, Geological Survey of India, Hyderabad are as follows:

    a. Based on the detailed geological inputs from geological mapping along the dam alignment in association with the geotechnical assessment of excavated cut off trench it was opined that the proposed dam alignment is feasible and the excavations of Cut-off trench are found suitable for the formation of the earth dam.
    b. The project authorities have conducted pre-permeability tests at various locations and to assess the permeable characteristics of the foundations.
    c. The strata require grouting to arrest the seepage, if any, from upstream to downstream to become water tightness of the reservoir.
    d. Backfilling shall be done with suitable impervious soils as per the design specifications.
    e. Drilling two rows of grout holes at 6m interval shall be done with suggested depth of grouting and grouting pattern based on the permeability data furnished by the project authorities and nature of strata.
    f. Carry out the grouting operation in 3m depth section after filling and compaction of suitable impervious soil up to a minimum 2m to 3m height from the cut off bed level.
    g. Conduct post grouting permeability tests at random locations to assess the efficacy of grouting for further evaluation.

As per the above observations and suggestions of Director, Geological Survey of India, Hyderabad time to time all the measures were taken and Cut-off trench was filled with impervious soils during execution of the Earth bund.

5. Further, Government constituted a technical committee vide G.O.Rt.No.49 I&CAD (Proj-IV) Dept Dated:28.01.2021 to resolve technical issues related to Designs, Stability analysis, Vetting of Designs pertaining to Sri Komaravelli Mallanna Sagar Reservoir.

    a. The Scientist (Geo-Technical Expert) from Central Water and Power Research Station, Pune, member of the committee has inspected the Sri Komaravelli Mallannasagar Reservoir site. Three cross sections of the dam were analyzed viz. Section-1 of Height 59.60 m at Km.15.600 (maximum height section), Section-II of Height 51.00 m from Km.18.625 to Km.19.925 and Section-III of Height 49.00 m from Km.16.300 to Km.16.700.

    b. After detailed analysis, a detailed report on "Geotechnical studies for seepage and stability analysis of zoned earth dam of Mallanna Sagar reservoir" have been furnished. In the report, the Section.10.0 Conclusions and Recommendation point 'c' states that "*Results of stability analysis indicate that all three cross-sections are safe from slope stability point of view*" and point 'd' states that "*Pseudo-static earthquake analysis indicates that all three sections are safe for steady seepage and reservoir full conditions*".

6. Before the inspection of the Technical Committee in October-2021, the reservoir was filled up to 10.50 Thousand Million Cubic feet (TMC). The committee has inspected the Sri Komaravelli Mallannasagar and conducted Seepage analysis, Stability analysis and Pseudo-static earthquake analysis. After the detailed study, they concluded that the results are within permissible limits. Further, the reservoir filled up to 16.18 Thousand Million Cubic feet (TMC) during March-2022 and subsequently around 5 Thousand Million Cubic feet (TMC) of water is drawn from the reservoir and again refilled up to 15.32 Thousand Million Cubic feet (TMC) in August-2023 and it is observed that the seepage is within the allowable limits as per guidelines of the dam. Hence, the project is in healthy condition.

II. Comptroller and Auditor General of India (CAG) has expressed serious concern over the lapse by stating that a project was built without conducting seismic study. The following replies are herewith submitted:

1. During the performance audit of Kaleshwaram Project, the Comptroller and Auditor General of India (CAG) has pointed out the aspect of seismic studies and as per their report for the year 2024 has recommended to conduct detailed seismic studies for Sri Komaravelli Mallanna Sagar.

2. As per Dam Safety Act- Decemeber-2021 Part-II- Section-I-Chapter-VII Clause no.34(I), every specified dam having a height of thirty meters and above or falling under such seismic zone, as may be specified by the regulations, the owner of the specified dam shall establish a seismological station in the vicinity of each such dam for recording micro and strong motion earthquakes and such other data as may be specified by the regulations.

3. Keeping in view the guidelines of the Dam Safety Act-2021 and the recommendations of Comptroller and Auditor General of India (CAG), The Engineer-in-Chief (I), Gajwel vide

Lr.No.ENC/GJL/DCE/DEE-4/AEE-1/SKMS/2023-24/369 Dt:21.02.2024 have requested the National Geophysical Research Institute, Hyderabad to furnish the expert opinion on conducting further detailed seismic studies for Sri Komaravelli Mallanna Sagar. In response, National Geophysical Research Institute, Hyderabad vide their letter dated:29.04.2024 have opined and recommended to carry out the continuous seismic monitoring of the reservoir as per Central Water Commission guidelines.

4. National Geophysical Research Institute, Hyderabad has submitted a detailed proposal for Supplying and Installation of recommended seismic instruments for monitoring the seismic activity of Sri Komaravelli Mallanna Sagar Reservoir and requested for payment for Rs.534.325 Lakhs. The same proposal has been submitted to Government for according approval. After the approval from the Government, the Seismic monitoring, Delineation of seismically active faults/ lineaments and Determination of Peak Ground Acceleration (PGA) levels of the dam structure during the occurrence of near field earthquakes will be carried out by National Geophysical Research Institute, Hyderabad.

III. As per National Green Tribunal hearing dated:20.02.2024 states that the absence of any emergency action plan, the government has left the reservoir as well as lives of the people nearby at increased risk.

1. The Dam Break Analysis along with the Guidelines for Preparation of Emergency Action Plan have been furnished by the Central Water and Power Research Station, Pune in October-2017. Further, preparation of the Emergency Action Plan for Sri Komaravelli Mallannasagar have been entrusted to Central Water and Power Research Station, Pune.

The news item titled "CAG reveals damage to KLIS In 2019 Itself" appeared in the 'Deccan Chronicle' dated 07.01.2024 stating that construction of Sri Komaravelli Mallannasagar reservoir done without detailed seismic studies. But as per the report of the Chief Scientist, National Geophysical Research Institute, Hyderabad dated:23.08.2018, the water column at the location where Preliminary Seismic Studies conducted is zero for the reservoir full capacity of 50 Thousand Million Cubic feet (TMC) at +557.000m which will not have any effect to the functioning and performance of the reservoir. However, all precautions have been taken care during investigation, Designs and construction of Earth bund and its associated structures.

The reservoir is being monitored day-to-day basis based on the dam safety guidelines and asper the instructions of National Dam Safety Authority, New Delhi & State Dam Safety Organization, Hyderabad and so far, the health of the reservoir is in good condition.

Executive Engineer, I & CADD.,
Irrigation Division No. 6,
Gajwel, Dist: Siddipet.

ANNEXURES

SRI KOMARAVELLI MALLANNASAGAR RESERVOIR

ORIGINAL APPLICATION No.120 (SZ) 2024

NGT-CHENNAI

FROM PAGE NO-1 TO 176

Preliminary Seismo-tectonic and GPR studies Appraisal around Mallanna Sagar Project, Telangana State

Telangana state in southern peninsular shield falls in Seismic Zone II with a few regions of north eastern districts fall in seismic zone III as per Bureau of Indian Standards Seismic zoning map, 2002 (Fig 1). India is divided in to four seismic zones namely zone II to V. Zone II represents lowest seismicity level and hence, lower ground motion accelerations whilst, seismic zone V has the highest level of seismicity and ground motion accelerations. Historically southern Peninsular shield was believed to be stable and free from major earthquakes however, the occurrence of Koyna earthquake M 6.3, in 1967 and the Latur earthquake of M6.3, in 1993 has led to the realisation that the southern Peninsular shield is conspicuous with stable continental region earthquakes. This led to the design and installation of seismological instruments in this region and CSIR-NGRI has installed and operating 16 seismological stations in the states of Telangana and Andhra.

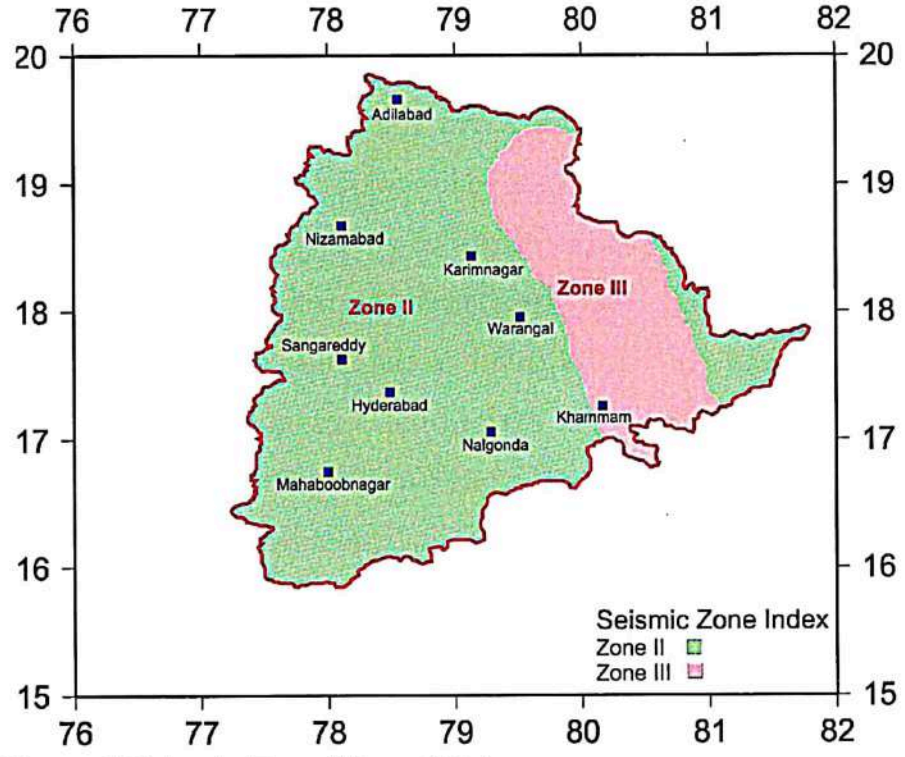

Figure 1 Seismic Zone Map of Telangana

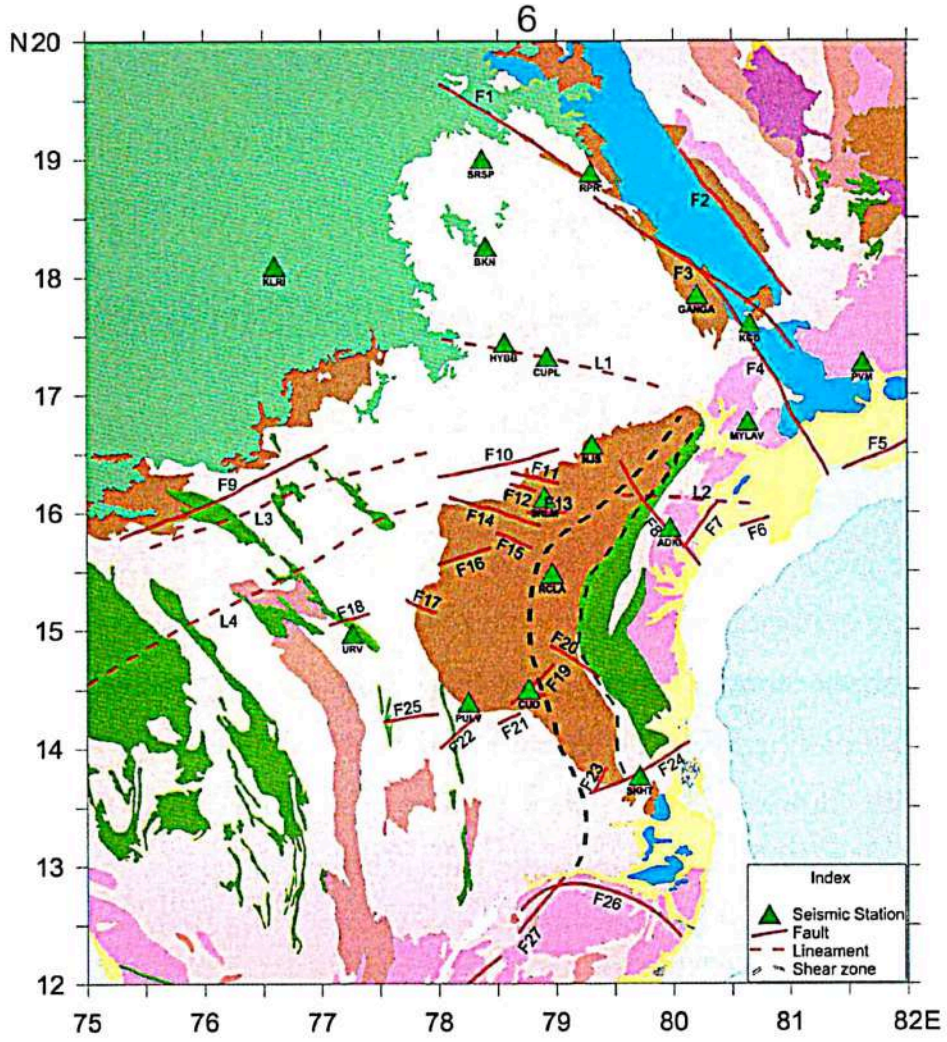

Figure 2 Major faults/Lineaments in Telangana and Andhra Pradesh as per the SEISAT 2000 and locations of seismological stations

Major tectonic features in and around the state:

The major tectonic feature in Telangana is the Godavari graben as shown in Figure 2. The graben forms the north eastern boundary and is linearly trending in the NW–SE direction about 350 km in length and 40 km width. Majority of the lineaments are of Archean age that can be basically characterized into two distinct sets: (1) NW–SE trend, predominantly found in the main basin, and (2) NE–SW trend, in the South eastern part of the valley. The major faults adjoining the rift are the Kadam fault (KF), Kinnerasani–Godavari fault (KGF), Kolleru-lake fault and the Godavari valley fault (GVF) (Figure 2). The green triangles are the seismological stations operating and about 7 of them are operating in Telangana.

Seismicity in the state

Recent seismicity in Telangana state along with the moderate sized earthquakes occurring in Ongole region of Andhra Pradesh and Latur region of Maharashtra. Though Ongole and Latur earthquakes occurred in neighbouring states these caused considerable ground shaking and minor damage to structures in Telangana region. As seen in Figure 3 the seismicity is mainly confined to Godavari Graben and I the neighbourhood of Hyderabad and diffused seismicity near Sriram Sagar Project.

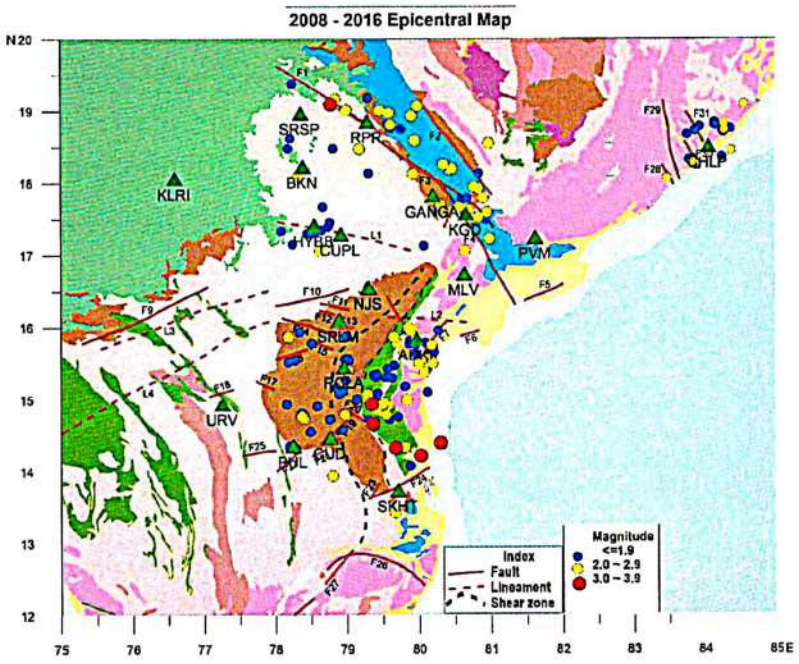

Figure 3 Seismicity map of Telangana and Andhra Pradesh

In the year 1969, moderate earthquake with magnitude 5.7 struck **Bhadrachalam** region in Khammam district as shown in Figure 4. This earthquake was felt in the entire south India Peninsular shield and there were reports of damage to structures in the epicentral region. The iso-seismal map is presented in Figure 5 clearly shows that the Mallanna Sagar Project is located along the Intensity VI contour. The Bhadrachalam earthquake occurred at a distance of about 200 km from Mallanna Sagar Project site.

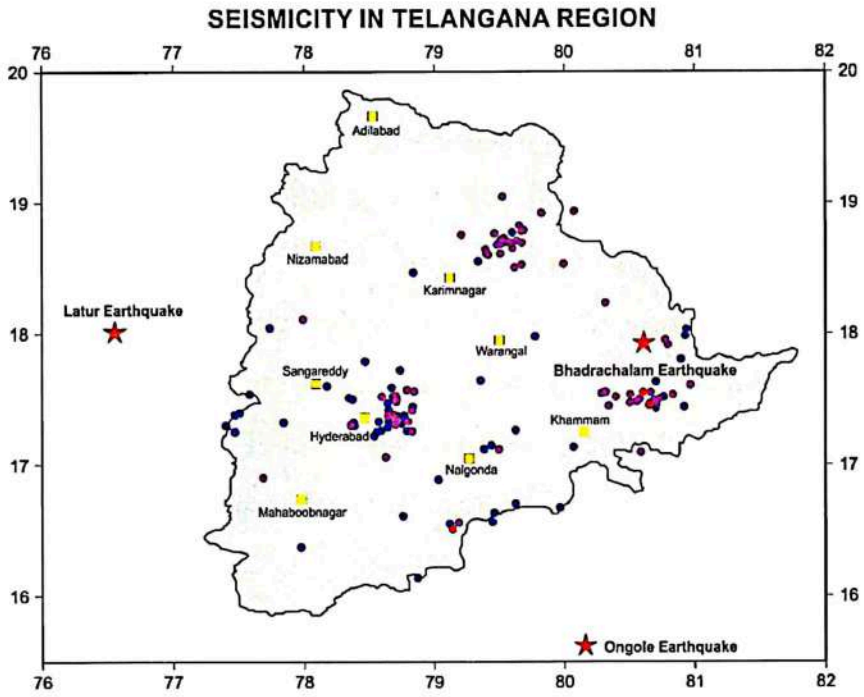

Figure 4 Major earthquake locations around the Mallanna Sagar Project

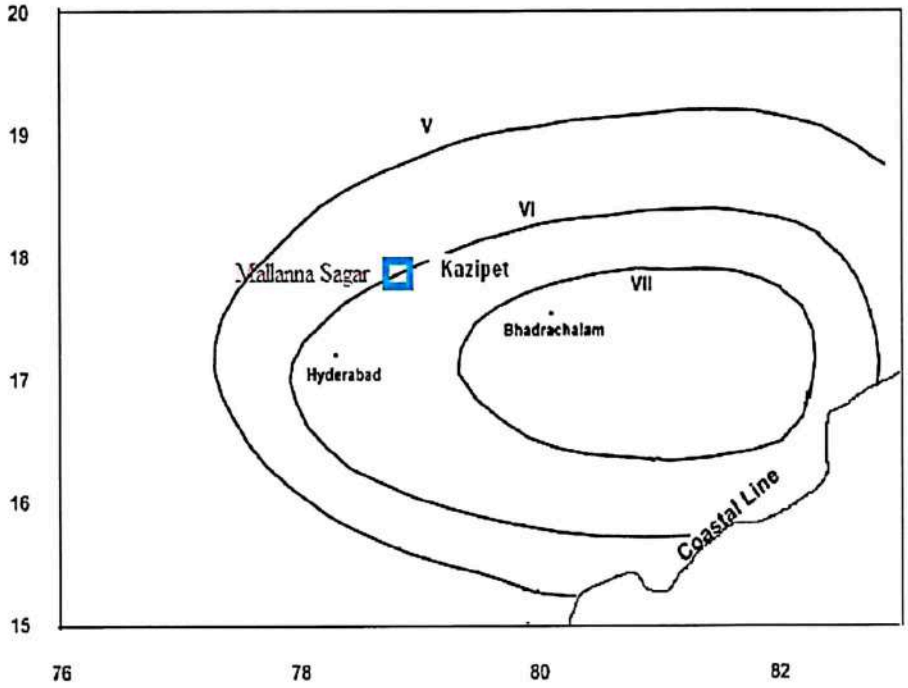

Figure 5 Isoseismal Map of 1969 Badhrachalam earthquake

There other source region is Hyderabad which has reported episodes of swarm activity during the years 1982, 1994, 1995, 1998, 2000 and 2010. Largest swarm activity was in the vicinity of Gandipet reservoir area during 1982 with M 3.5 being the maximum magnitude earthquake. Swarm activities have also been reported from Jubilee hills and Vanasthalipuram of

Hyderabad. Largest magnitude tremor among this swarm sequences is 2.6 which occurred in Jubilee Hills during 2000.

Medchal Earthquake of June 30, 1983

Medchal area in suburbs of Hyderabad experienced earthquake of magnitude 4.9 (Figure 6). This earthquake had a depth of more than 15 km and was felt significantly in Hyderabad and minor cracks in the buildings have been reported. Upto distance of 200 km this earthquake was felt significantly because of its deep seated origin. Using three stations data from Hyderabad, Srisailam and Nagarjuna Sagar operated by CSIR-NGRI, the epicentre is located to the NE of the International Seismological centre epicentre. This epicentre distance of this earthquake is about 20 km from the Mallanna Sagar Project site and could be located on either of the two lineaments/faults which are east-west and north west-south east trending.

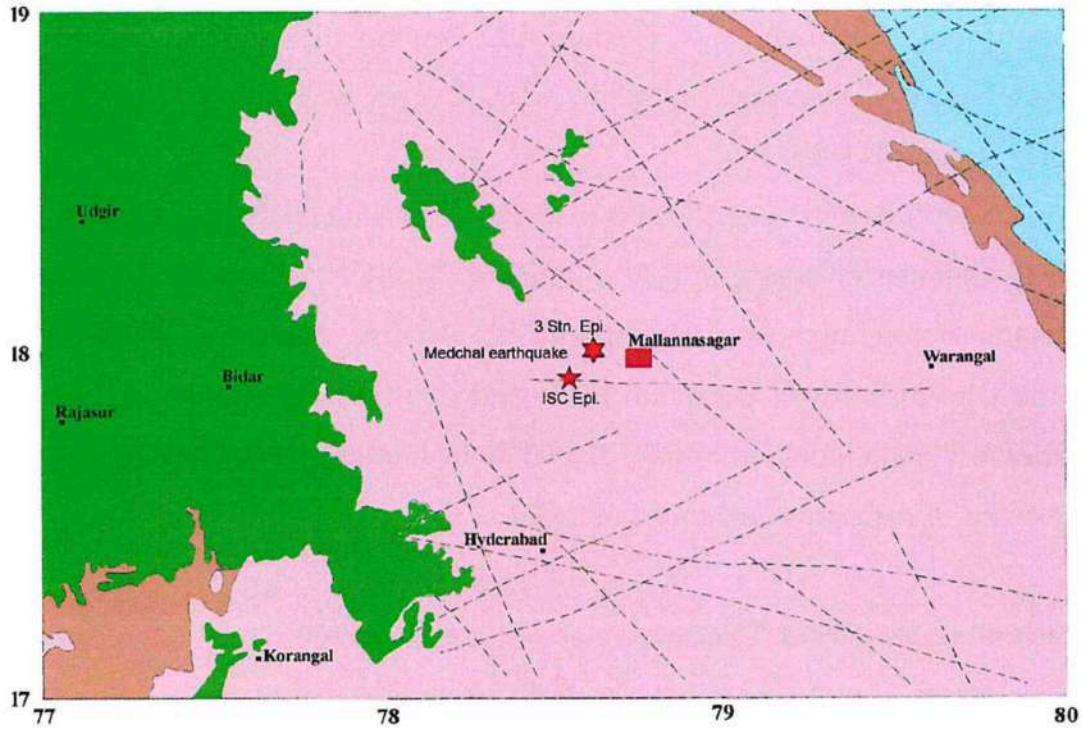

Figure 6 Epicentre location of the 1983 earthquake close to Mallanna Sagar Project

Prominent source regions:

In the year 1967, moderate earthquake with magnitude 5.4 struck Ongole region in Andhra Pradesh. The epicentral region of this earthquake is Located at ~ 300 km from the Mallanna Sagar project site

On September 29, 1993 a major earthquake of Magnitude 6.3 occurred in Latur, Maharastra state. Even though this earthquake occurred in neighbouring state the actual distance of the source region of this is in close distance to Zahirabad surrounding villages (~100 km). The Latur earthquake occurred at a distance of about 240 km to Mallanna Sagar Project site. This earthquake caused lots of damage to structures in epicentral region and also felt strongly in bordering districts Telangana. The seismic activity in this region continued for few years.

Apart from this natural earthquake activity along the Godavari Graben in coal mines most of the reported activity is artificial mine blast activity. Over all there are about 9 seismic stations installed in Telangana region to monitor the seismic activity in continuous mode. They are situated at Rampur, Kothagudem, Gangavaram, Sriram Sagar, Nagarjuna Sagar, Choutuppal, Bikanoor and Hyderabad. Among the above, Hyderabad seismological observatory is the permanent observatory, being operated in world standards since 1967.

Keeping in view of the above historical seismicity status of the region, An earthquake of magnitude 5 or more on Richter scale is likely to cause damage to non engineered structures and property. A level of loss of life or damage to property depends on place and depth of earthquake occurrence. Hence any installations planned should be in standards least to withstand to the levels of respective ground shaking.

Preliminary results of GPR survey across the fault zone

A field survey, to identify the shallow subsurface fault features, was carried out by NGRI team near project site (Figure 7). The area and location for the study were finalized after consulting the site engineer. The Ground

Penetration Radar (GPR) survey at the site was conducted on 17th of January, 2018 with the site engineer. The field pattern and outcrop suggest the area constitute of granite with 3 different phases of dyke emplacement. At the studied section, a ENE-WSW trending fault has displaced the NNW-SSE trending dyke by ~240 m with dextral strike slip disposition on the surface. The fault suggests strike-slip deformation possibly during ENE-WSW trending dyke emplacement during (?) early to mid-Proterozoic period. The GPR survey was conducted to map the shallow subsurface signature of the fault and the profiles are planned along the geomorphic expression of the fault (Figure 7 A).

In order to map the fault features, GPR profiles needed to be placed orthogonally to the fault, which was not possible due to poor accessibility of the rugged uneven terrain. A total 7 GPR 2D profiles with lengths ranging from 25m to 80m, were acquired following the possible accessible route. For this survey, the 200 MHz GPR antenna, having capability of mapping high resolution shallow subsurface, up to a depth of 5m, is deployed. The GPR data is acquired in 'distance mode' with the distance calibrated wheel perimeter. The signal gain was kept in auto mode and the frequency range was set by assigning a low pass and a high pass filter to get the desired signals. The dielectric value of the upper layer was assigned and the total depth of penetration was set to 5m. The acquired raw data was processed using the specialized software at CSIR-NGRI. The processing steps constitute the Auto Peak-Time shift, Background removal (to remove all the horizontal coherent noises using Full pass background removal), FIR (to increase the signal-noise ratio, low pass (=400) and high pass (=35) filters have been applied), Gain (max is 76 is applied in order to reduce the fluctuation of amplitude of traces) to obtain the preliminary results (Figure 7 B, C).

The preliminary results from two profiles at oblique angles (almost orthogonal) with the fault, marked as **aa'** (N17^{0}57.451', E078^{0}47.915': 65m length) and **bb'** (N17^{0}57.469', E078^{0}47.942': 68m length) are presented (Fig B, C). The preliminary shallow subsurface (~5 m) imaging by GPR suggests the

top soil / regolith in the area largely constitute of granite boulders and its weathering product extends for 50-60cm and at places has voids in surveyed sections (Fig. B, C). The top 3 m constitute of weathered granite and largely remain undisturbed except in 2-3 m wide fault zone, where the topsoil and rocks (weathered and fresh at depth) are disturbed by shearing. Since the host rock is massive granite, which does not have lithological layering, no lateral contrast is observed nor any dominant vertical component of deformation along the fault could be deciphered. Though, the top soil and weathered zone show downward perturbation along the fault zone. The preliminary data clearly suggests; it is a deep seated vertical fault with significant strike slip motion. The rocks in the fault zone are highly sheared and fractured. Further, there is at least three sets of dominant lineaments with distinct geomorphic signatures are observed in the region. To characterize their effect on shallow subsurface and understand their mutual relationship, it will be appropriate to conduct detailed survey with planned profile orientations. The same is proposed for future work for the region.

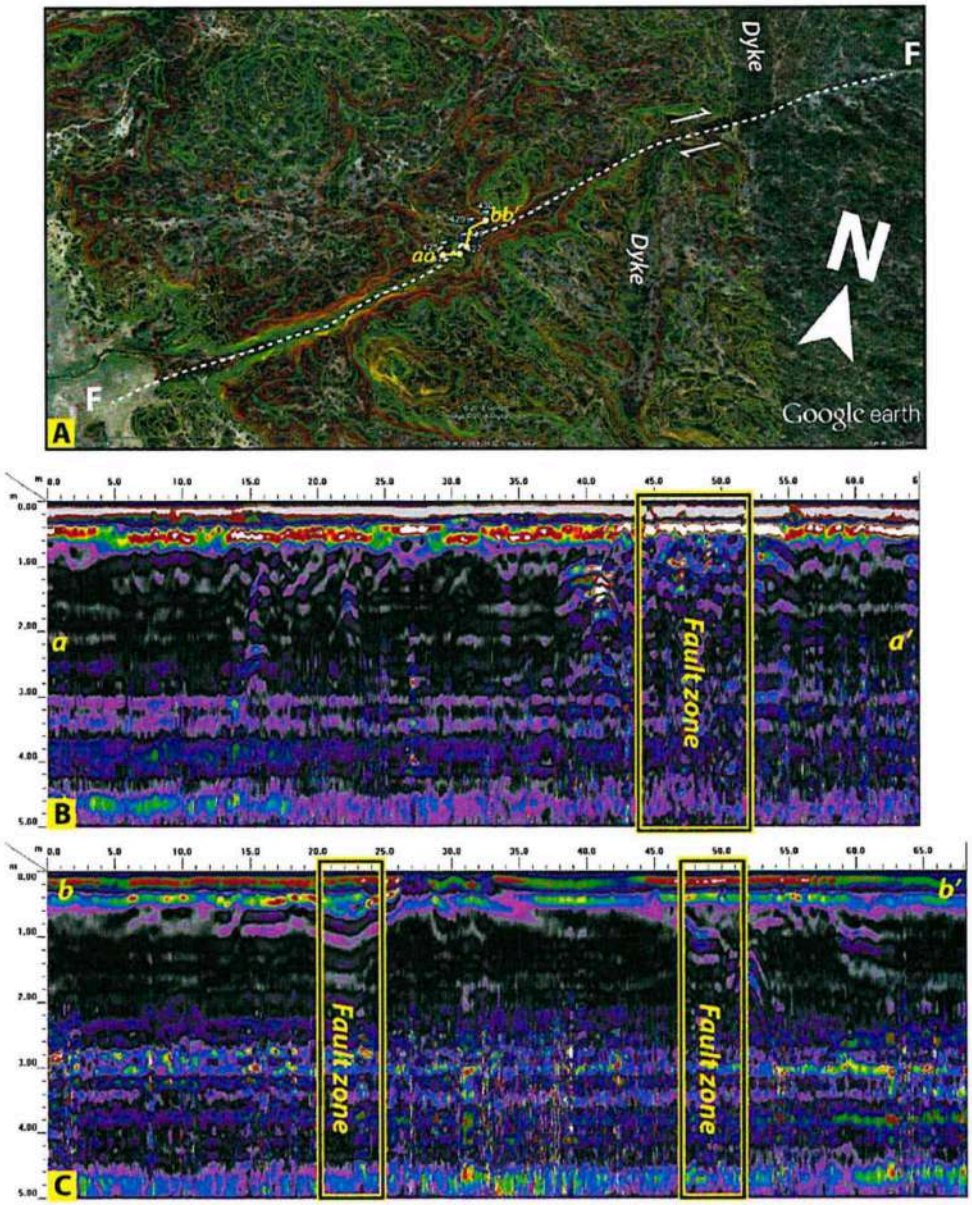

Figure 7. (A) Google image of study site overlaid with the 1 m contour interval marking the location of ENE-WSW trending fault that displace the NNW-SSE trending dyke by ~240 m. Multiple 2D GPR line survey was carried out as per the suggestions of site engineers. Note the location of 2-D profiles aa′ & bb′. (B, C) The preliminary results of two lines **aa′** and **bb′** clearly show ~2-4 m thick disturbed zone along the fault in respective profiles.

Symposium on Earthquake Effects on Plant and Equipment: Dec. 1984

Medchal, Andhra Pradesh Earthquake of June 30, 1983

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ABSTRACT

The paper describes the seismic effects of Medchal, Andhra Pradesh earthquake of June 30 1983. This earthquake is of scientific and general interest as it occurred in the middle of peninsular shield and caused cracks in some buildings in Hyderabad.

The magnitude of the earthquake is estimated to be 4.5 from the recorded duration at Hyderabad seismograph station of NGRI. The maximum intensity is assigned to be V. The area with this intensity is 30 km x 20 km, elongated in N-S direction and stretching about 20 to 50 km north of Hyderabad. The computer located epicentre with near stations data lies within this area at a distance of 30 km from Hyderabad and depth is computed to be 40 km. The earthquake was felt for about 20 sec in the meizoseismal area and 10 sec in Hyderabad. Within the meizoseismal area, intensity was higher in the northern and southern ends. There was less damage in the central part. In higher intensity area, tiles fell down in many houses, many houses developed cracks, one mud wall collapsed and at four places favourably placed rocks were displaced. These effects are described in detail. We also describe the isoseismals and known local geology. The cause of the earthquake is also visualized.

INTRODUCTION

The Medchal earthquake of June 30, 1983 caused general alarm in the twin cities of Hyderabad and Secunderabad as this earthquake is the first earthquake occurring in this area in the living memory. List of historical earthquakes in this area is given in Table I. The 1983 earthquake is of lesser intensity than the one in 1876. The intensity assigned for the 1983 earthquake is V in M.M.Scale. Though the earthquake is of moderate intensity it has aroused interest of scientific community as it occurred in the centre of the Peninsular Shield of India. In this paper we describe the effects of earthquake and mention about the source parameters, local geology and cause of the earthquake. Technical aspects of these investigations are described elsewhere (Rastogi and Chadha, 1984).

INTENSITY SURVEY

Initially, the purpose of the field study was to delineate the meizoseismal area. Analysis of Hyderabad seismograms indicated the epicentre to be about 30 km WNW of the seismic station and reports came in for more damage in the area 20 to 50 km north of Hyderabad (seismic station is in the eastern end of the city). Hence, survey for meizoseismal area was made in this area. The mode of survey was to interrogate as many number of persons possible in a particular area about their feelings and evidences regarding the temporary and permanent effects on objects/buildings. The strategy adopted was to estimate the intensity at a particular place and to approach the area with highest intensity. Once the meizoseismal area was delineated, the boundaries of intensities V/IV, IV/III and III/II (M.M.Scale) were estimated along certain ronds leading out of the meizoseismal area (Figure 1 and 2). During the surveys the following points were observed.

1. The earthquake was felt in twin cities of Hyderabad and the area in the north with intensity IV and more.
2. There was no serious damage to any structure/building anywhere.
3. Damage was more in the area 20 to 50 km north of Hyderabad. This area lies east of N.H. 7 between Medchal and Shamirpet in the south to Tupran in the north. This area was assigned an intensity V.
4. Though intensity V is observed in a large area as shown in Figure 1, there was no clear-cut eye or an area of higher intensity. This suggests some depth of the focus. The depth calculated from isoseismals is 31-34 km. In fact, damage was rather more in the northern and southern parts of the meizoseismal area and lesser in the central part. This is due to the vertical approach of seismic waves immediately above the focus. This is corroborated by the felt report in the central area. The centre of the meizoseismal area is near Kakunda village (Figure 1). Here, a jolt or 'thud' from below was felt, and there were only minor cracks developed in some walls.

5. It was possible to draw isoseismal V clearly and others roughly. Isoseismals IV and III were drawn on very few observations and isoseismal II based on newspaper reports as well as personal communications.

6. There was clear indication of the isoseismal lines V and IV having an elliptical shape with major axis along N-S direction.

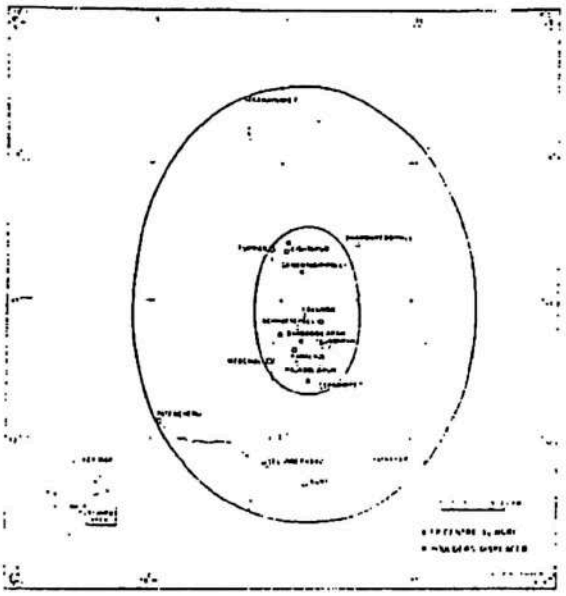


Fig.1 Isoseismal V and IV.

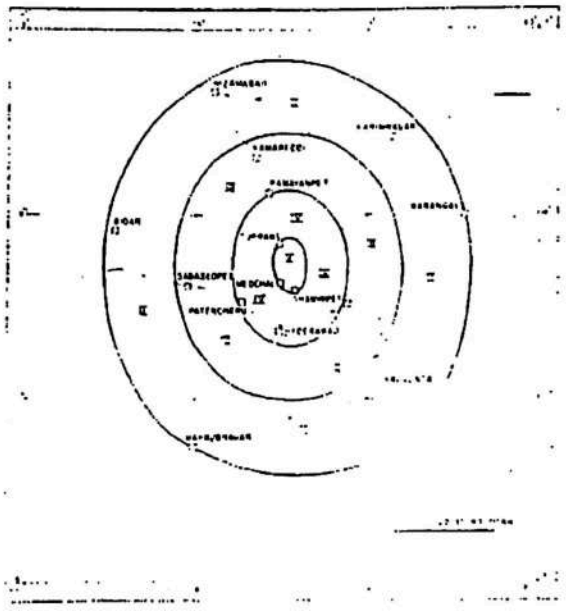


Fig.2 Isoseismal ... for Medchal Earthquake

MACROSEISMIC EFFECTS

The earthquake of 30th June, 1983 was felt for about 20 seconds in the meizoseismal area and about 10 seconds in twin cities of Hyderabad and Secunderabad.

The earthquake was accompanied by loud sound variously described as thunder, passing of an aeroplane, moving of heavy trucks, rumbling and underground explosion. In the meizoseismal area, the most prominent sound was described as a thunder in the peripheral area and as explosion in the centre. In the intensity IV area the sound was mostly described as that of passing of heavy trucks or booming of an aeroplane. The sound was not much as compared to that in the meizoseismal area.

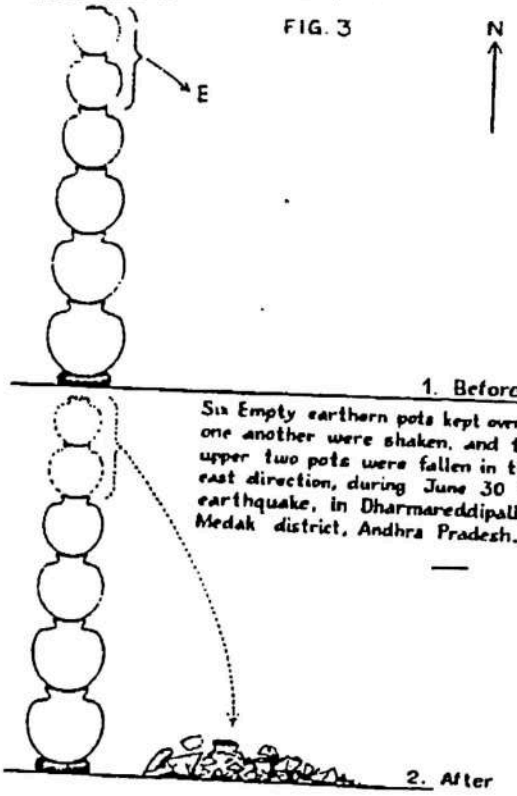
At a place around Kakunda near the centre of intensity V area people felt a jolt from below and were slightly pushed up. In the extreme south of meizoseismal area also near Rajo Bolaram Tanda, people felt a jolt from below and a person felt that his lunch plate was thrown upwards.

Utensils kept in the racks and tiles were thrown down at many places in the V intensity area. A corner of tiled roof collapsed near Kishtapur in the north and a portion of tiled roof along with the mud wall near Bandamallaram in the south . At Dharmareddipalli, two out of 6 stacked earthen pots fell down and broke to pieces (Figure 3). In the southern portion of the meizoseismal area at Shamirpet and Yadawaram and in the north at Ananthagiripalli and Kishtapur, huge boulders, placed favourably were rolled down due to this earthquake (Figures 4 and 5).

Observations at the individual places in the meizoseismal area are as follows. In the northern part of meizoseismal area near Kishtapur, huge chuncks of rocks, favourably placed were displaced. Large sound of explosion type was heard in the area. Cracks were developed in the walls and in a house a corner of the tiled roof was collapsed. Just south of Nacharam, near Ananthagiripalli, some boulders were displaced and also explosion like sound was heard. Cracks in the walls and roofs are very frequent in this area. Just outside the meizoseismal area near Dharamareddipalli and Gajwel in the east, the sound was of a passing heavy vehicle. In the centre of the meizoseismal area near Kakunda, a thud from below was felt, and there were only minor cracks developed in some walls. Near Bandamallaram, just south of Kakunda, a corner of tiled roof and portion of the mud wall of a house was collapsed. Utensils were thrown out from the racks. Near Vehhavyapalli, (in the centre of Meizoseismal area) thunder sound was heard from west. Tiles were fallen and utensils were thrown out of the racks. In Dasaripalli also in the centre of meizoseismal area) large thunder sound was heard. Towards south of the meizoseismal area, in Yadavaram boulders were rolled down. Large sound as of a passing aeroplane was felt and a jolt from below was felt by some people. Roofs of many houses were cracked. In Biwalkol, in the south, sound from west was heard. In the extreme south of meizoseismal area, near Raju Bolaram

landa, people felt a jolt from below and plates were thrown upwards. In the south west of meizoseismal area, i.e., near Medchal, rumbling sound was heard with rattling of utensils. Minor cracks were developed.

FIG. 3



Six Empty earthern pots kept over one another were shaken, and the upper two pots were fallen in the east direction, during June 30 1983, earthquake, in Dharmareddipalli village, Medak district, Andhra Pradesh.

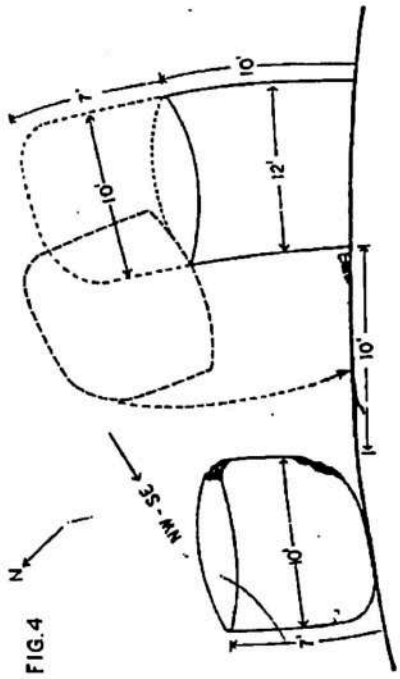
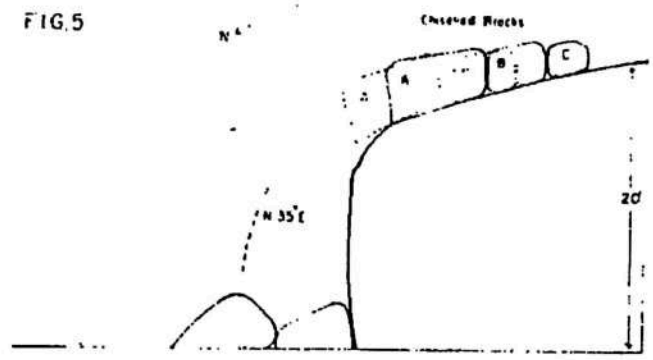


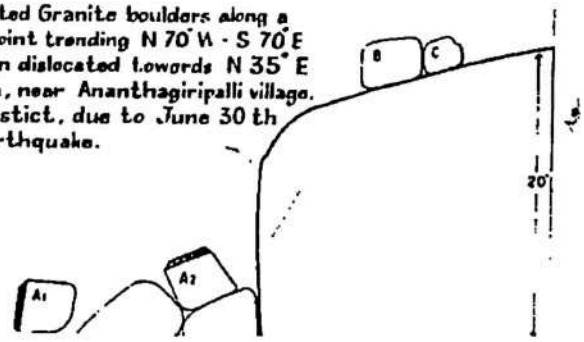
FIG.4

A Granite boulder resting on another boulder along a pre-existing joint, fallen upside down, near kishtapur village, Medak district, due to June 30, 1983 earthquake

FIG.5



Pre-jointed Granite boulders along a vertical joint trending N 70° W - S 70° E have been dislocated towards N 35° E direction, near Ananthagiripalli village, Medak distict, due to June 30 th 1983 earthquake.



In many areas of intensity IV, like Ramavanpet, Secunderabad and Hyderabad shaking was felt prominently. Few buildings developed hair-line cracks in Hyderabad including those of the NGRI (Figures 6 to 8) and Board of Intermediate Education at Nampalli. In these two buildings cracks are between pillars and walls, beams and walls and sometimes at the junction of two walls. A wall of one house under construction in Lalapet developed crack in the middle.

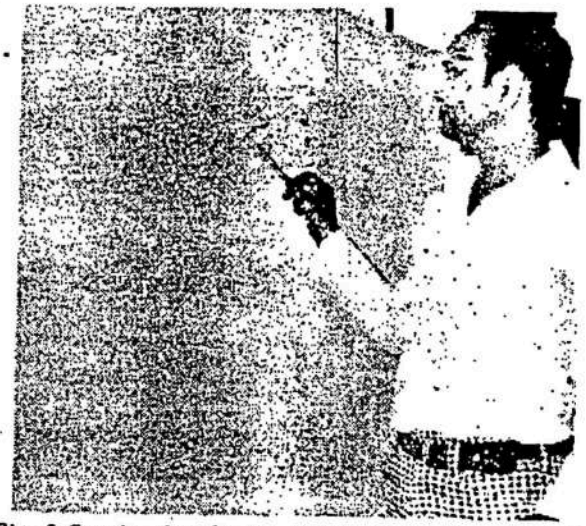


Fig.6 Cracks developed in the wall of ground floor canteen of NGRI, due to June 30 earthquake.

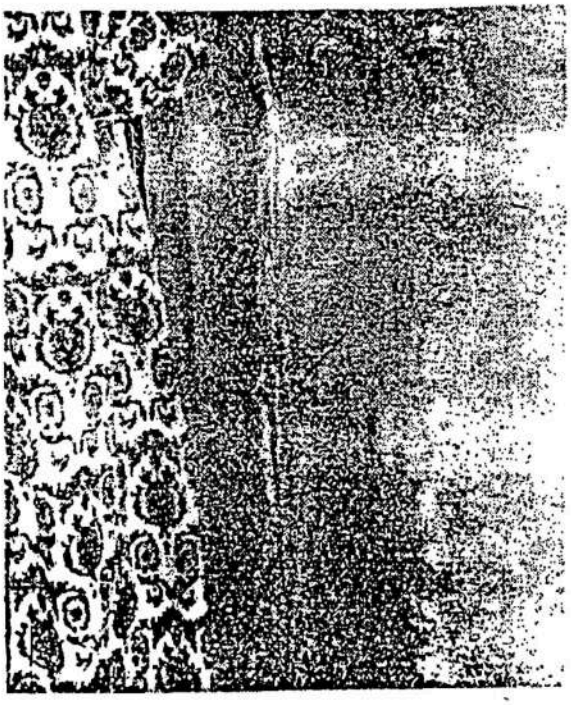


Fig.7 Crack developed at the contact of two adjacent walls in the second floor dining hall of NGRI, due to June 30, earthquake.

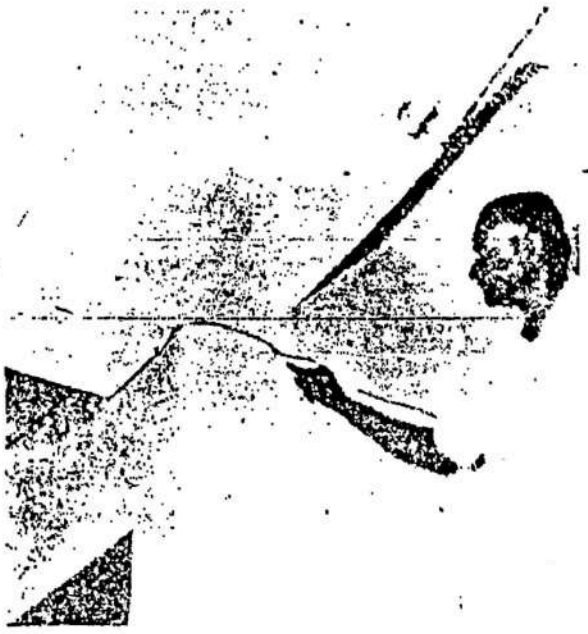


Fig.8 Cracks developed along the contact of beam and wall in NGRI library due to June 30, 1983 earthquake.

Direction of approach of earthquake waves or sound as noticed by persons at different places is shown in Figure 9. South of Tupran majority of the people reported west to east direction, while north of Tupran the reported direction was usually southwest to northeast.

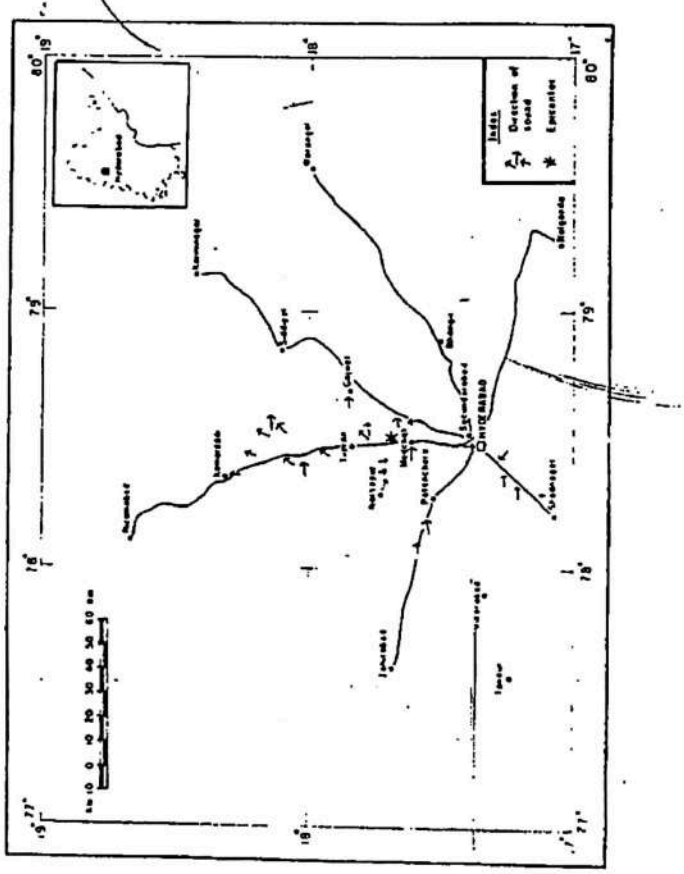


Fig.9 Direction of approach of sound or earthquake waves.

SOURCE PARAMETERS

The epicenter of the Medchal earthquake of June 30, 1983 determined by using the near seismic stations data is 17° 41'N, 78° 30'E. This epicentre is near the centre of the meizoseismal area. Depth is of the order of 30 km. Seismogram portions showing this earthquake at different near stations are shown in Figures 10 to 13. As described earlier intensity is V on M.S.K.Scale. Magnitude of the earthquake is estimated to be 4.5. The epicentres determined by IMD and [illegible] using distant stations are far off from the meizoseismal area. The magnitude determined by IMD at New Delhi station is an over estimate.

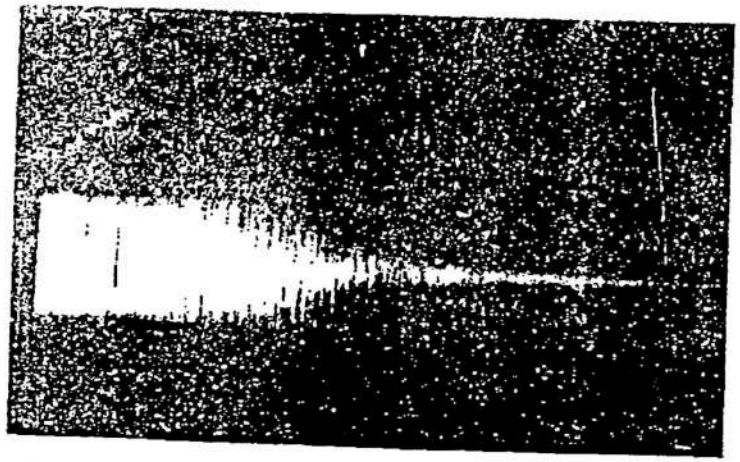


Fig.11 June 30, 1983 earthquake as recorded at Nagarjunasagar. Seismograph deployed is portacorder, and S 500 Seismometer

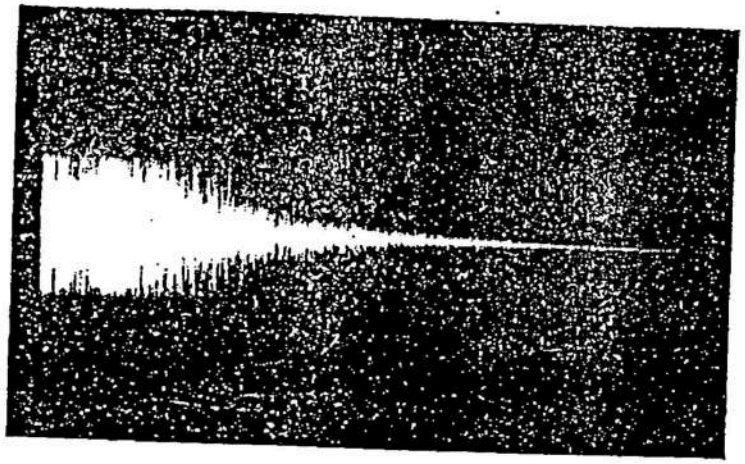


Fig.10 June 30, 1983 earthquake as recorded at Srisailam Seismograph deployed is portacorder, and S 500 Seismometer.

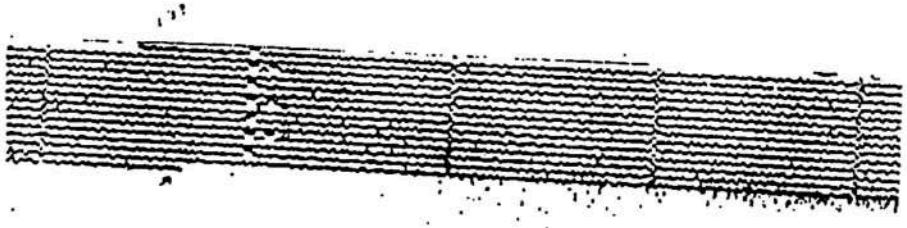


Fig.12 June 30, 1983 earthquake as recorded at Hyderabad short period Benioff seismograph, vertical component.

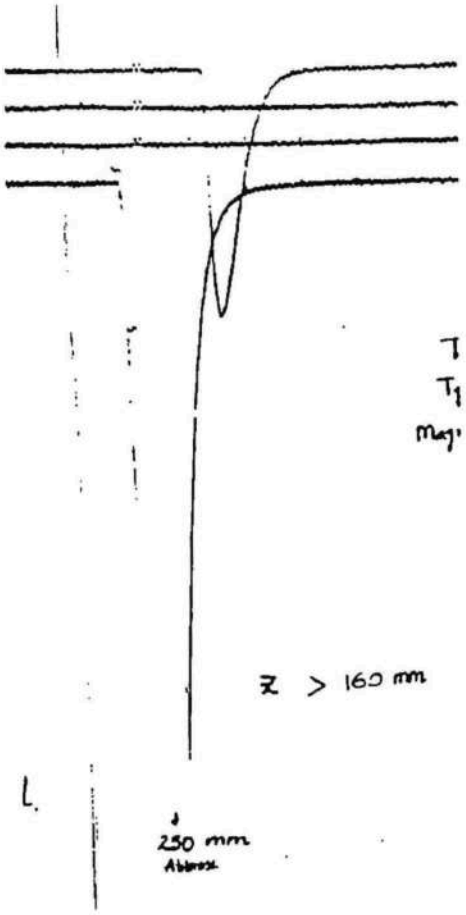


Fig.13 June 30, 1983 earthquake as recorded at Hyderabad vertical component long-period Press-Ewing seismograph.

LOCAL GEOLOGY AND CAUSE OF THE EARTHQUAKE

The country rocks in the area are Archean granites and gneisses. These rocks are intruded by dolerite dykes, pegmatite, aplite and quartz veins. The most predominant directions of the dykes are NE-SW and N-S. From the lineament map prepared by GSI, the lineaments passing through the meizoseismal area are as follows. One NE-SW trending megalineament passes through Medchal. One small lineament parallel to it passes through the centre of the meizoseismal area where it meets a small E-W trending lineament. The ground check of these lineaments has not been done. Any of these lineaments could be the zone of weakness along which the present earthquake has occurred The present earthquake is a part of regional seismicity and is of tectonic origin. The small stresses, due to northward movement of the Indian continent, slowly accumulate. When these stresses exceed elastic limit, the earth blocks adjust themselves to equilibrium along zones of weakness (Chandra, 1977).

CONCLUSION

The Medchal earthquake of 30th June 1983 was of intensity V on M.M.Scale and Ms magnitude 4.5. Intensity V area is 530 sq.km. The earthquake was felt in an area of 450,00 sq.km. Felt duration in meizoseismal area was about 20 sec and in twin cities of Hyderabad and Secunderabad about 10 sec. There was no serious damage anywhere. In view of this earthquake and intensity VI earthquake in 1876, seismic coefficient in this area may have to be revised.

ACKNOWLEDGEMENTS

The authors are thankful to India Meteorological Department and Bhabha Atomic Research Centre for providing their data. M/s. Indra Mohan, C.V.R. Rao and Md. Khamruddin helped in intensity survey. Mr.S.C.Bhatia obtained the computer location. The authors are grateful to Prof. V.K.Gaur, Director, NGRI for his keen interest and guidance in this study. Mr.K.Ramana Rao assisted in typing this manuscript.

REFERENCES

1. Chandra,U. (1977) "Earthquakes of Peninsular India - A seismotectonic study", Bull.Seism.Soc.Am. 67, 1387-1413.

2. Rastogi, B.K. and Chadha, R.K. (1984), "Source Parameters of the Medchal, Andhra Pradesh Earthquake of June 30, 1983", Communicated to Mausam.

TABLE I

HISTORICAL EARTHQUAKES NEAR HYDERABAD

Date	Place	Description of Earthquake	Magnitude/ intensity	Source
1843 Mar 12	Hyderabad	Shock felt around Hyderabad	IV	Oldham, 1883
1876 Oct/Nov.	Secunderabad	Felt throughout the city caused general alarm, glass panes broken in some of the houses, a number of sparrows found dead after the earthquake; Barracks in cantonment area were more or less in an oscillating condition during a period of 55-60 secs. Effects in different areas ranged from being thrown out of bed to as if being rocked in a cradle. Punkah wires jingled, doors and windows shook, parrots screamed, dogs barked and men woke up by the rolling and loud noise accompanying the earthquake ; some private bunglows in and out of cantonment were damaged, but no large scale destruction or loss of life.	VI	TOI 7.11.76

[TOI : Times of India]

Annexure -I

Tel: 020–24103444, 24103387
Fax: 020-24381004

e-mail: rsrgp@rediffmail.com
Website: www.cwprs.gov.in

Government of India
Ministry of Jal Shakti
Department of Water Resources, River Development & Ganga Rejuvenation
Central Water & Power Research Station
Khadakwasla, Pune 411024

No. CWPRS/F&S/GE-II(Soil)/1-Mallanasagar/2022/ 71

Date : 01/04/2022

Shri B. Hari Ram,
Engineer-in-Chief (Irrigation)
Irrigation and CAD Department (I & CAD)
Gajwel,
Siddipet - 502278

Sub : Technical Report on "Geotechnical studies for seepage and stability analysis of zoned earth dam of Mallannasagar reservoir, Telangana"

Ref : 1) CWPRS cost estimate submitted vide No. TC/2021/344 dated 22/06/2021
2) Your letter No. EE/Irrg/D6/Gajwel/DB/2020-21/395 dated 12/08/2021

Sir,

With reference to above, Technical Report No. 6008 dated March, 2022 on "Geotechnical studies for seepage and stability analysis of zoned earth dam of Mallannasagar reservoir, Telangana" is enclosed herewith in duplicate. Kindly acknowledge receipt of the same.

As a part of CWPRS commitment to continuous improvement, we would appreciate your assessment on how we have performed in conducting the studies. It is requested to kindly fill and submit the attached **Feedback Form**.

Thanking you,

Yours sincerely,

Encl : As above

(Dr. R. G. Patil)
Scientist 'E'

Annexure -II

Government of India
Ministry of Jal Shakti
Department of Water Resources,
River Development and
Ganga Rejuvenation

सत्यमेव जयते

भारत सरकार
जल शक्ति मंत्रालय
जल संसाधन, नदी विकास
और गंगा संरक्षण विभाग

TECHNICAL REPORT NO. 6008

GEOTECHNICAL SEEPAGE AND STABILITY STUDIES FOR ZONED EARTH DAM OF MALLANNASAGAR RESERVOIR, TELANGANA

March, 2022

केन्द्रीय जल और विद्युत अनुसंधान शाला, पुणे
CENTRAL WATER AND POWER RESEARCH STATION, PUNE

Dr. R. S. Kankara
Director

GOVERNMENT OF INDIA
MINISTRY OF JAL SHAKTI
DEPARTMENT OF WATER RESOURCES, RIVER DEVELOPMENT AND GANGA REJUVENATION

CENTRAL WATER AND POWER RESEARCH STATION
KHADAKWASLA, PUNE 411024

GEOTECHNICAL ENGINEERING – II (SOIL)

TECHNICAL REPORT NO. : 6008
March 2022

GEOTECHNICAL SEEPAGE AND STABILITY STUDIES FOR ZONED EARTH DAM OF MALLANNASAGAR RESERVOIR, TELANGANA

Dr. R. S. Kankara
DIRECTOR

REPORT DOCUMENTATION SHEET

Technical Report No. 6008 **Month : March, 2022**

Title: GEOTECHNICAL SEEPAGE AND STABILITY STUDIES FOR ZONED EARTH DAM OF MALLANNASAGAR RESERVOIR, TELANGANA

Officers responsible for conducting the studies

Smt. J. S. Edlabadkar, Scientist 'C', Dr. (Smt.) Tanusree Samanta, Scientist 'B', Shri A. D. Khot and Smt. S. S. Waghmare, Research Assistants

Dr. R. G. Patil, Scientist 'E' was in-charge of Geotechnical Engineering-II (Soil) division during conducting the studies and preparation of report.

Name and address of organization conducting the studies

Foundations and Structures Laboratory
Central Water and Power Research Station, Pune – 411024, India

Name and address of authority sponsoring the studies

Shri B. Hari Ram, Engineer-in-chief (Irrigation)
Irrigation and CAD Department (I & CAD)
Gajwel, Siddipet District

Synopsis

The Irrigation & CAD department, Government of Telangana has taken up execution of Kaleshwaram lift irrigation project to cater to irrigation and drinking water needs of drought prone areas in Telangana. The Kaleshwaram project envisages construction of various barrages, storage reservoirs, pump houses and canal network system. Sri Komuravelli Mallannasagar is one of the storage reservoirs with 50 TMC feet capacity. The reservoir is being created by constructing a multi-zoned earth dam of length 22.6 km and maximum height of about 60 m. To expedite the construction of reservoir, total length of the earth bund is divided into four reaches. Considering size and importance of the reservoir, the Engineer-in-Chief, Irrigation & CAD Department, Gajwel, Siddipet requested CWPRS to conduct geotechnical seepage and stability studies for the earth dam.

Three cross-sections of the dam were analyzed viz. **Section I** in Reach III of Ht. 59.6 m (at Ch. 15.6 km, maximum height section), **Section II** in Reach IV of Ht. 51.0 m (Ch.18.625 km to Ch.19.925 km, tank bed portion) and **Revised section III** in Reach III of Ht. 49.0 m (Ch. 16.3 km to 16.7 km, hillock portion). Seepage analysis using software PLAXIS 2D for steady state condition was conducted to establish phreatic line, seepage discharge, pore pressures and hydraulic heads in various zones of the dam. Transient state seepage analysis was conducted to establish phreatic line for drawdown condition simulating drawdown rate of 0.5 m/day.

Results indicated that total seepage discharge (dam body + foundation) works out to be 0.6667 m^3/day/m, 0.1497 m^3/day/m and 0.6269 m^3/day/m for cross-sections 'I', 'II' and 'III' respectively. It was observed that seepage quantity through foundation was 67.6% to 82.4% of total discharge. For cross-section 'I' and 'III', discharge values were more than the specified lower permissible limit of 0.4 m^3/day/m but less than the specified higher limit of 0.8 m^3/day/m . For cross-section 'II' the discharge was less than lower permissible limit of 0.4 m^3/day/m. It was recommended to undertake appropriate remedial measures for foundation seepage if still lower permissible values are decided upon by project authorities.

Results of slope stability analysis indicated that all three dam cross-sections were safe with Factor of Safety (FS) values more than required values of 1.5 for steady seepage and 1.3 for sudden drawdown conditions as per IS 7894:1975. Pseudo-static analysis for earthquake condition indicated that the dam is safe with FS more than required value of 1.0 for conditions of steady seepage and full reservoir. It was recommended to design zone-I on upstream and downstream sides as transition zone. It was also suggested to install adequate monitoring devices viz. piezometers, 'V' notch weirs, etc on the dam sections along with appropriate drainage arrangements as per relevant IS codes. Regular dam monitoring and maintenance as per CWC guidelines was suggested.

Key words: Earth dam, Multi zoned, Seepage, Slope stability, Pseudo-static

CONTENTS

GEOTECHNICAL SEEPAGE AND STABILITY STUDIES FOR ZONED EARTH DAM OF MALLANNASAGAR RESERVOIR, TELANGANA

1.0 INTRODUCTION

The Irrigation & CAD department, Government of Telangana has taken up execution of Kaleshwaram lift irrigation project to cater to irrigation and drinking water needs of drought prone areas in Telangana. The Kaleshwaram project envisages construction of various barrages, storage reservoirs, pump houses and canal network system. Sri Komuravelli Mallannasagar is one of the storage reservoirs with 50 TMC feet capacity. The reservoir is being created by constructing a multi-zoned earth dam of length 22.6 km and maximum height of about 60 m. To expedite the construction of reservoir, total length of the earth bund is divided into four reaches (Fig. 1) as given in Table 1. Section of maximum height (59.6 m) is located at chainage 15.6 km i.e. in Reach 'III'.

Table 1: Details of earth dam of Mallannasagar reservoir

Reach	Chainage	Length of bund
I	0.0 km to 8.5 km	8.5 km
II	8.5 km to 12.5 km	4.0 km
III	12.5 km to 16.7 km	4.2 km
IV	16.7 km to 22.6 km	5.9 km

Considering size and importance of the reservoir, the Engineer-in-chief, Irrigation & CAD department, Gajwel, Siddipet vide No. ENC(I)/Gajwel/DCE/DEE-4/AEE-7/SKMS/2021/ 825 dated 29/05/2021 requested CWPRS to conduct geotechnical seepage and stability studies for the earth dam. The scope of studies includes:

i) Conducting seepage studies for three dam cross-sections using 2D numerical modeling for computation of phreatic line, discharge quantity, pore pressure, hydraulic head, etc. in different zones of dam.

ii) Conducting static slope stability analysis (slip circle method) for determination of factor of safety of upstream and downstream slopes for sudden drawdown and steady seepage conditions respectively. Pseudo-static slope stability analysis of upstream and downstream slopes to assess earthquake stability.

iii) Recommendations for modification in the dam sections, required if any, from seepage and stability point of view.

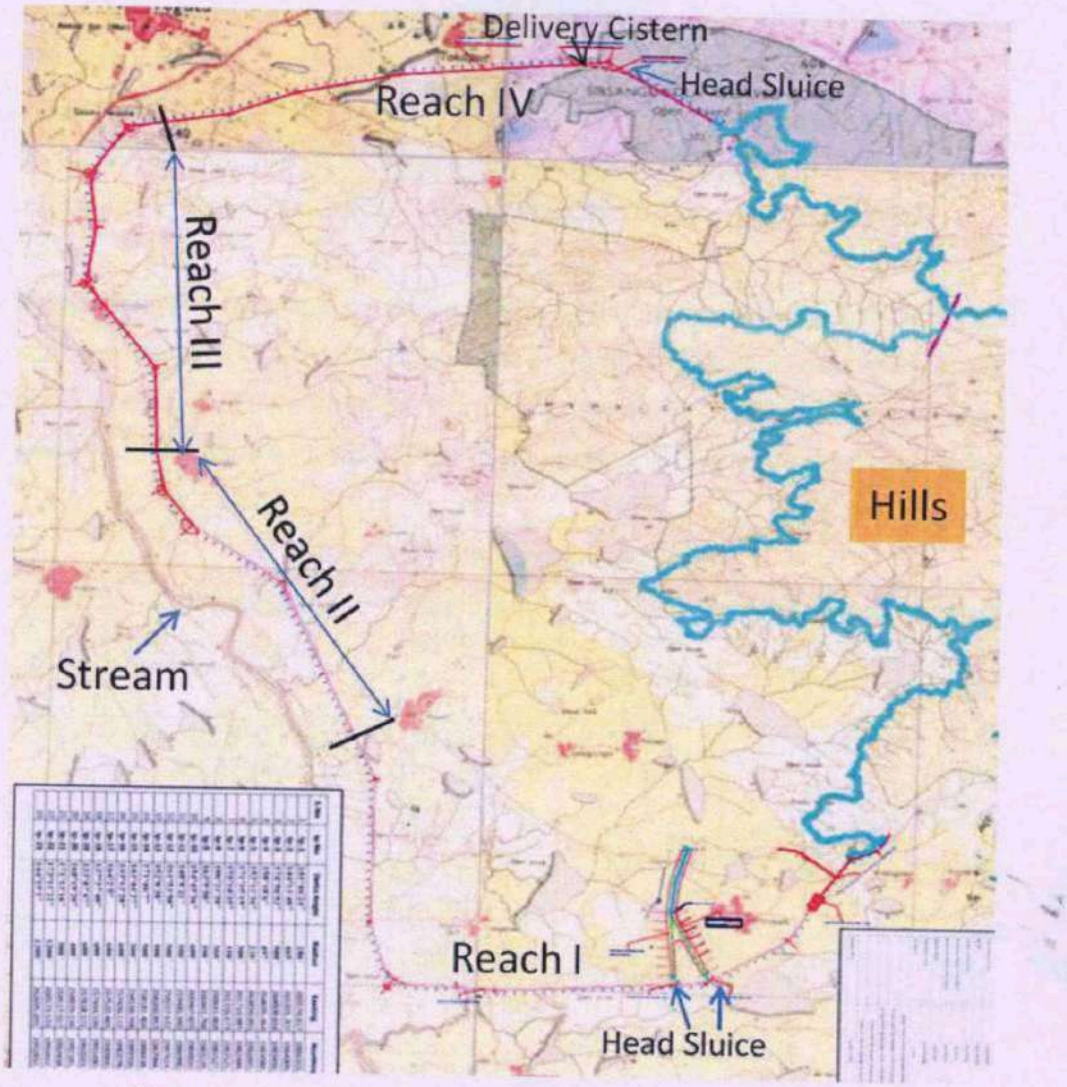


Figure 1: Alignment of earth dam of Mallannasagar reservoir

2.0 SITE VISIT

To have comprehensive understanding of site conditions, a visit was conducted by CWPRS officers on 13/10/2021 to the dam site. Various aspects of earth dam construction were witnessed during the visit and discussions with project authorities were conducted to finalize data/ inputs for present study. Detailed visit report submitted to project authority vide email dated 8/12/2021 is enclosed as ANNEXURE for ready reference.

3.0 OVERVIEW OF STUDIES

Geotechnical analysis of an earth dam comprises of seepage and slope stability studies for various cross-sections (*referred to as 'sections'*) of the dam along its alignment. Accordingly,

as suggested by project authorities, following three sections are analyzed from seepage and slope stability point of view

(i) **Section I** - in Reach III at Ch. 15.6 km (cross-section of maximum height, 59.6 m)

(ii) **Section II** - in Reach IV (from Ch. 18.625 km to Ch. 19.925 km, tank bed portion) and

(iii) **Section III** - in Reach III (from Ch 16.3 km to Ch. 16.7 km, hillock portion).

Steady state and transient seepage studies are conducted using two-dimensional finite element software PLAXIS 2D. Slope stability of the sections is assessed using Bishop's limit equilibrium method of slip circle analysis. Phreatic line obtained from steady state and transient state analyses for drawdown with rate of 0.5 m/day is adopted in limit equilibrium slope stability analysis.

Table 2: Details of dam sections

Section	Reach	Applicable for	Maximum height (m)	Dam Base Level RL (m)	Hydraulic head at FRL$ (m)	CoT details	
						Depth# (m)	Width (m)
I	III	Ch. 15.380 km to 15.875 km (Max. height section)	59.6 m at Ch. 15.6 km	502.6	54.4	17.43	13.3
II	IV	Ch. 18.625 km to Ch. 19.925 km (Tank bed portion)	51 m at Ch. 19.0 km	511.2	45.8	7.81	10.0
III	III	Ch 16.3 km to Ch. 16.7 km (Hillock portion)	49 m at Ch. 16.3 km	510.7 *	46.3	9.13	11.5

Top berm level (TBL) = 562.2 m

* *Dam base level at upstream toe (for section 'III' the dam base is inclined with upstream toe level at lower elevation than downstream toe). GL level at dam centre is taken as RL 513.2 m and height of the dam is calculated with respect to level at centre.*

$ *Full Reservoir Level (FRL) = 557 m*

\# *From Stripped Ground Level (SGL) for section 'I', from excavated level for section 'II' and from level of dam centre line for section 'III'*

In view of urgency expressed by project authorities for submission of study report, an interim report comprising of results of section 'I' was submitted to project authorities vide email dated 8/12/2021. The present report consists of results of all three sections along with discussions and recommendations. Data adopted for studies and slope stability/ seepage analyses conducted for each section are described in detail in paras 4.0 to 8.0. The results are summarized in para 9.0 while conclusions and recommendations are given in para 10.0.

4.0 DATA FOR STUDIES

For conducting geotechnical analyses; geometry of dam sections along with stratification of foundation layers is required to create geotechnical model in software. All three dam sections are multi-zoned, comprising of: (i) impervious hearting & CoT zone (zone 2, CI type soil), (ii) transition zone (zone 1, SC type soil) and (iii) casing zone (zone 3, SM type soil). Material properties of soil and rock layers in dam body and foundation viz. density (saturated and bulk), cohesion, angle of internal friction, Young's modulus, Poisson's ratio and permeability are given as input to the model. Following data was provided by project authorities for conducting the studies:

(i) Dam sections of height 59.6 m (section of maximum height), 51.0 m (section for tank bed portion), and 49.0 m (section for hillock portion).
(ii) 'L' section of earth dam in all four reaches
(iii) Contour plan of reservoir area
(vi) Borehole logs for Reach 'III' and Reach 'IV'
(iv) Soil test reports for Reach 'III' and Reach 'IV'
(v) L-section drawing along with foundation stratification, CoT level, depth of grout holes and pre/ post grouting permeability values for Reach 'III' and Reach 'IV'
(vi) L-section drawing with upstream, downstream toe level and level of centre line for Reach 'III' and Reach 'IV'.
(vii) Construction stage geotechnical investigation reports from GSI
(viii) Permeability test results for Reach 'IV'
(ix) Additional data as requested by CWPRS (received on 22/09/2021 and 6/01/2022)

Based on the above data, geometry of sections and soil parameters to be adopted for analyses are finalized. Most of the soil properties in dam body and foundation are adopted from design section drawings. Those which were not available in design drawings are obtained from other data sources. Some parameters viz. Young's modulus and Poisson's ratio are adopted from literature. The sources of data from which various parameters are adopted are listed below. Design input parameters adopted for analyses corresponding to each dam section are listed in paras 6.0, 7.0 and 8.0 for section 'I', 'II' and 'III' respectively.

(i) <u>Data adopted from design drawings:</u>

(a) Density, cohesion and friction angle (*MDD/SMC*) of zone 1, 2 and 3 of all three sections
(b) Density of overburden layer in foundation for dam section 'I'

(c) Permeability of zone 1, zone 2 and zone 3 for dam section 'III'
(d) Permeability of zone 1 and zone 2 for dam section 'I'
(e) Permeability of zone 2 for dam section 'II'
(f) Permeability of overburden layer in foundation for dam section 'I'

(ii) Data adopted from L-section with foundation stratification:

(a) Permeability of HR layer and grout influenced zone in foundation for section 'III'
(b) Permeability of grout influenced zone in foundation for section 'II'
(c) Foundation stratification for all three sections
(d) Depth of grout hole for all three sections

(iii) Data adopted from Permeability test results:

(a) Permeability of zone 1 and zone 3 for dam section 'II'
(b) Permeability of HDR, SDR, F&F rock and HR layer in the foundation for dam section 'II'

(iv) Data adopted from soil test report:

(a) Permeability of zone 3 soil for section 'I' was adopted from soil test report of Rajadhani Labs, Hyderabad for zone 3 soil sample collected at Ch. 15.6 km

(v) Data adopted from additional data sheet received from project authority:

(a) Width of CoT for all three sections
(b) Cohesion and angle of friction for overburden soil for section 'I'
(c) Permeability of HDR, HR and grout influenced zone for section 'I'

(vi) Assumed data:

(a) Permeability of filter and rock toe
(b) Young's modulus and Poisson's ratio of all zones in dam body and foundation
(c) Density, cohesion and angle of friction of SDR, HDR, F&F rock and hard rock layer in foundation
(d) Density, cohesion and angle of friction for overburden soil (gravelly soil) in the foundation of section 'II'

5.0 SEEPAGE AND SLOPE STABILITY ANALYSES

Seepage analyses of sections 'I', 'II' and 'III' of earth dam of Mallanasagar reservoir are conducted using software PLAXIS 2D for steady state condition to establish phreatic line, seepage discharge, pore pressure and hydraulic head in various zones of the dam. In addition

to steady state analysis; transient state seepage analysis is also conducted to simulate drawdown condition. PLAXIS 2D is a finite element programme used for two dimensional analysis of seepage, deformation and stability in geotechnical engineering. A 2D model of dam section along with soil/ rock layers in foundation is modeled in the software. Properties of various soil layers (finalized as explained in para 4.0) with appropriate boundary conditions are assigned to the model. Upstream water level corresponding to FRL (RL 557.0 m) is considered in analysis.

Static slope stability analysis of downstream and upstream slopes is conducted by limit equilibrium method for conditions of steady seepage and drawdown as per IS 7894-1975 [Ref. (i)]. Bishop's method of slip circle analysis is used. In this method, a potential circular failure surface passing through the slope is considered. Number of vertical slices are drawn through the circle. At equilibrium condition, resisting and driving moments are determined for each slice. The summation of all resisting and driving moments is computed. The ratio of resisting moment to driving moment is defined as the Factor of Safety (FS) for that slip circle. Many possible potential slip circles are drawn and factor of safety is evaluated for each circle. The critical slip circle is one which has minimum factor of safety. A software with facility of automatic search of factor of safety by taking trials for various slip circles, is used. The slope is considered to be safe if factor of safety is greater than 1.5 for steady seepage and 1.3 for sudden drawdown condition. Phreatic line obtained from steady state seepage analysis is adopted for slope stability studies of downstream slope to incorporate effect of pore pressure.

Factor of safety of upstream slope during drawdown from Full Reservoir Level (FRL) to Minimum Draw Down Level (MDDL) depends on two factors viz. (i) permeability of soil and (ii) rate of drawdown. Lower factor of safety values are obtained if the rate of drawdown is such that sufficient time is not available for dissipation of pore water pressure developed in soil mass during steady state condition. Hence, faster rate of drawdown for slopes with low permeability soil may lead to lower values of factor of safety. To incorporate the effect of soil permeability and rate of drawdown; transient drawdown analysis is conducted in PLAXIS 2D simulating drawdown from FRL (RL 557.0 m) to MDDL (RL 532.165 m). Drawdown rate of 0.5 m/day is adopted, as this is the expected rate at which water will be released from the balancing Mallannasagar reservoir to lower reservoirs (*Ref: email from project authorities dated 04/02/2022*). The phreatic line obtained from transient seepage analysis is used in limit equilibrium method to determine factor of safety for drawdown condition.

Seismic stability of the dam is analyzed by pseudo-static seismic coefficient method. In this method, a static horizontal inertia force (F_h) representing the effect of earthquake, is applied to the potential circular sliding surface in limit equilibrium slope stability analysis. The force (F_h) is expressed as product of horizontal seismic coefficient (α_h) and weight of the potential sliding mass. Coefficient of horizontal seismic acceleration (α_h) is calculated as per IS1893-1984 [Ref. (ii)]:

$$\alpha_h = \beta * I * \alpha_0 \quad \text{.....(1)}$$

Where, α_h : Design horizontal seismic coefficient

β : Coefficient depending upon soil foundation system (for dams, β=1)

I : Importance factor

α_0 : Basic horizontal seismic coefficient depending on location of site in seismic map of India

Mallannasagar reservoir lies in seismic zone II, as per seismicity map of India [Ref. (ii)]. The basic horizontal seismic coefficient (α_0) of zone II is 0.02. Value of 'β' is taken as 1.0 and importance factor 'I' as 3.0. The seismic coefficient (α_h) computed using above equation works out to be 0.06. As such, a horizontal acceleration equal to 0.06g is considered in the analysis. Dynamic slope stability of dam section is determined using pseudo-static approach for two conditions as per IS 7894-1975 [Ref. (i)] viz. (i) steady seepage (downstream slope) and (ii) reservoir full (upstream slope).

Details of seepage and slope stability (static and dynamic) analyses conducted for three dam sections viz. (i) maximum height section (section 'I'), (ii) section in tank bed portion (section 'II'), and (iii) section in hillock portion (section 'III') are discussed in paras 6.0, 7.0 and 8.0 respectively.

6.0 STUDY OF MAXIMUM HEIGHT SECTION

Maximum height section (section 'I') of height 59.6 m at chainage 15.6 km of Mallannasagar earth dam is analyzed in the present study. Details of the section are described below.

6.1 Section 'I' (Reach 'III', Maximum height 59.6 m)

Section 'I' with maximum height of 59.6 m (Fig.1) is applicable from chainage 15.38 km to 15.875 km of Reach 'III'. Upstream slope of the section is 1(V):3(H) from dam base level (RL 502.61 m) to RL. 522.2 m; 1(V):3.5(H) from RL 522.2 m to RL 552.2 m and 1(V):2.5(H) from RL

552.2 m to top berm level (RL 562.2 m). Upstream slope has total five berms including one berm of width 8 m at RL 512.2 m, three berms of width 12 m at RL 522.2 m, RL 532.2 m, 542.2 m and one berm of width 10 m at RL 552.2 m. Downstream slope is 1(V):2.5(H) from dam base level to RL 512.2 m; 1(V):3(H) from RL 512.2 m to RL 522.2 m and 1(V):2.5(H) from RL 522.2 m to top berm level. Downstream slope has total five berms, four of width 8 m at RL 512.2 m, RL 522.2 m, RL 532.2 m, RL 542.2 m and one berm of width 6 m at RL 552.2 m. The dam cross-section is multi-zoned with central impervious hearting zone (zone 2) and casing zones viz. zone 1 and zone 3. An inclined filter of varying thickness i.e. 1.0 m, 1.2 m, 1.5 m and 1.75 m is provided in between zone 2 and zone 1 on downstream side to permit free drainage of seepage water. Inclined filter is connected to rock toe through 1.7 m thick horizontal filter. A central cut-off-trench (CoT) of base-width 13.3 m below hearting zone is provided to restrict seepage through foundation (Fig. 2).

6.2 Foundation strata and design soil parameters

In numerical model for section 'I', foundation strata below dam base level is adopted from L- section drawing with foundation stratification for Reach 'III' provided by project authority vide email dated 26/10/2021. The foundation strata, as obtained from the given data, consist of 5.573 m of overburden clayey soil, underlain by 11.854 m of soft disintegrated rock (SDR). Hard rock (HR) is considered below the SDR layer. As informed during site visit, top 2 m of overburden soil layer is replaced by zone 3 type of casing soil and same is considered in the model. Foundation strata adopted for section 'I' is given in Table 3.

Table 3: Foundation stratification for section 'I'

Section	Dam base level (RL)	GL in L-section drawing (RL)	Foundation strata	Thickness (m)
I	502.61 m	502.037 m	Overburden soil replaced by zone 3 casing soil	2.0
			Overburden soil	3.573
			Soft Disintegrated Rock (SDR)	11.854
			Hard Rock (HR)	26.0*

** Up to base of model*

Grout curtain is constructed below CoT all along length of the dam to prevent seepage through foundation. Staggered grout holes are drilled in two rows (3 m apart) with 6 m center to center distance by core drilling method up to maximum depth of 21 m below CoT. To measure efficacy of grouting, pre and post grouting permeability tests are conducted in the grout holes at

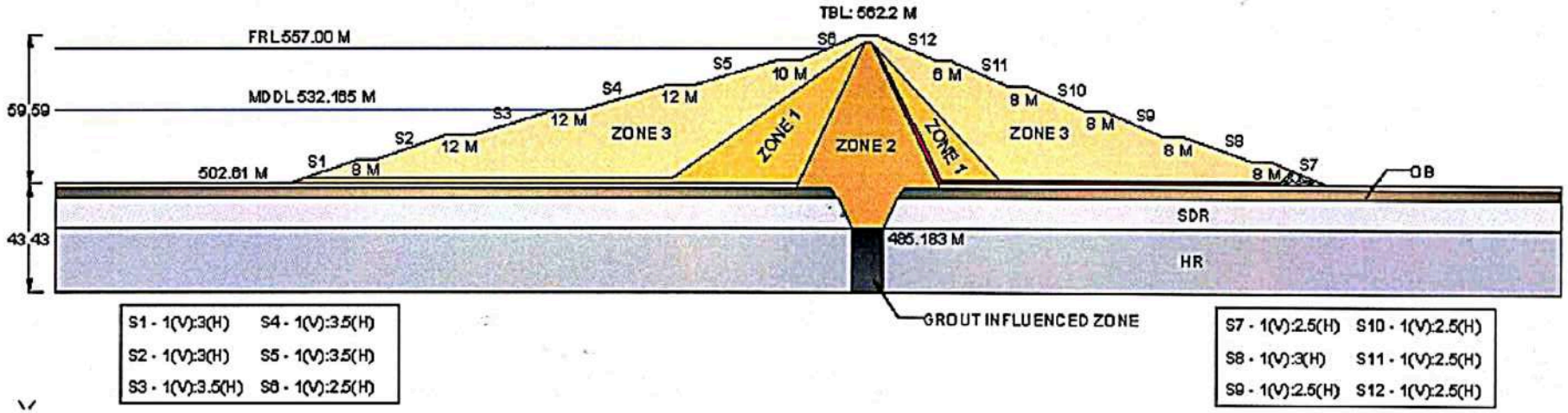


Figure 2: Design dam section 'I' (Maximum height section at Ch. 15.6 km)

different depths. The reduction in permeability of rock strata in foundation due to grouting, will be applicable to a zone (grout influenced zone) in which the grout has penetrated laterally from grout holes (see Fig. 2). However, the exact horizontal distance from grout holes in upstream and downstream direction, up to which the grout has penetrated (width of grout influenced zone); is not known. In geotechnical modeling, post-grouting permeability will be applicable to the grout influenced zone while pre-grouting permeability will be applicable to rest of the rock strata. Due to difference in pre and post grouting permeability, the width of grout influenced zone will particularly govern the quantity of seepage discharge through foundation. However, since exact width of this zone is not known, it is assumed to be equal to base width of CoT. Material properties of soil in various zones of the dam body and foundation are finalized based on the given data. The properties adopted for analysis are listed in Table 4 and 5.

Table 4: Design soil parameters for section 'I'

Sr.No.	Parameter	Zone 1 (SC)	Zone 2 (CI)	Zone 3 (SM)	Filter	Rocktoe
1	Bulk density (kN/m^3)	19.8	19.554	18.603	18	20
2	Saturated density (kN/m^3)	20.78	20.172	20.104	18	20
3	Cohesion (kN/m^2)	14.71	24.52	1.96	0	0
4	Friction Angle (degree)	21	12	28	30	40
5	Young's Modulus of elasticity (MPa)	50	20	50	50	200
6	Poisson's ratio	0.3	0.35	0.3	0.3	0.26
7	Permeability (m/sec)	1.426×10^{-7}	3.906×10^{-8}	1.05×10^{-5}	1×10^{-3}	1×10^{-3}

Table 5: Design parameters of soil / rock in foundation for section 'I'

Sr. No.	Parameter	OB (U/S)	OB (D/S)	SDR	HR	Grout zone
1	Bulk density (kN/m^3)	17.505	17.75	19.62	20.60	20.60
2	Saturated density (kN/m^3)	20.77	20.75	20.59	21.57	21.57
3	Cohesion (kN/m^2)	24.52	17.65	0	0	0
4	Friction Angle (deg.)	18	17	35	35	35
5	Young's Modulus of elasticity (MPa)	20	20	250	250	250
6	Poisson's ratio	0.35	0.35	0.25	0.25	0.25
7	Permeability (m/sec)	10.48×10^{-8}	2.3×10^{-8}	6.64×10^{-7}	6.64×10^{-7}	2.35×10^{-7}

6.3 Results of seepage analysis

Seepage analysis of section 'I' is conducted using software PLAXIS 2D for steady state and drawdown conditions with drawdown rate of 0.5 m/day to establish phreatic line, seepage discharge, pore pressure and hydraulic head in various zones of the dam. A 2D model of dam

cross-section along with soil/ rock layers in foundation is modeled in the software. Properties of various soil layers as per Tables 4 and 5 along with appropriate boundary conditions are assigned. Upstream water level corresponding to FRL of the dam (RL 557.0 m) is considered. As mentioned earlier, the width of grout influenced zone is adopted equal to base width of CoT. Results of seepage analysis viz. phreatic line, pore pressures, hydraulic heads and quantity of seepage discharge in various zones of the dam body and foundation obtained from seepage analysis for steady state condition are described below.

(i) **Phreatic line:** For a safe dam section, it is desired that the phreatic line should drop up to dam base level in hearting zone and emerge out on downstream side through horizontal filter; indicating that the downstream side is not in saturated condition. Contrary to this situation, an elevated phreatic line (one which does not drop up to dam base level in hearting zone) indicates that soil in downstream casing zone is in saturated condition inducing pore pressures in that region. Increased pore pressure reduces effective shear strength of soil thereby affecting stability of downstream slope. Results of seepage analysis indicate that for section 'I' of Mallannasagar dam the phreatic line drops up to dam base level in hearting zone 2 and emerges out through horizontal filter. This indicates that favourable condition exists for section 'I', as downstream transition and casing zones (zone 1 and 3 respectively) are not in saturated condition (Fig. 3).

(ii) **Pore pressure:** Steady state pore pressure values on upstream side increase gradually downwards with 0 kPa at phreatic surface to -550.089 kPa at dam base level near upstream toe (*as per convention of software PLAXIS 2D, negative values of pore pressure indicate compressive pressure on soil mass while positive values indicate suction*). Instrumentation plays a vital role in earth dam safety assessment, as any change in dam section behaviour can be monitored well in time based on measured data and remedial measures can be taken up. Installation of piezometers to monitor pore pressure in the dam body and foundation as per recommendation of IS 7356 (Part 2)-2003 [Ref. (iii)] is recommended. Contour plots (Fig. 3) indicate steady state pore pressures developed in the dam body for conditions adopted in seepage analysis. Pore pressure readings from piezometers may be monitored periodically and compared with design values at respective locations. Any change in values be noted, cause of the same be found out and acted upon as per requirement. Also change in pore pressure with respect to change in reservoir water level may also be monitored.

(iii) **Hydraulic head:** It is seen that hydraulic head dissipates in hearting zone 2 from maximum value of 54.4 m to 1.235 m near horizontal filter on downstream side (Fig. 4)

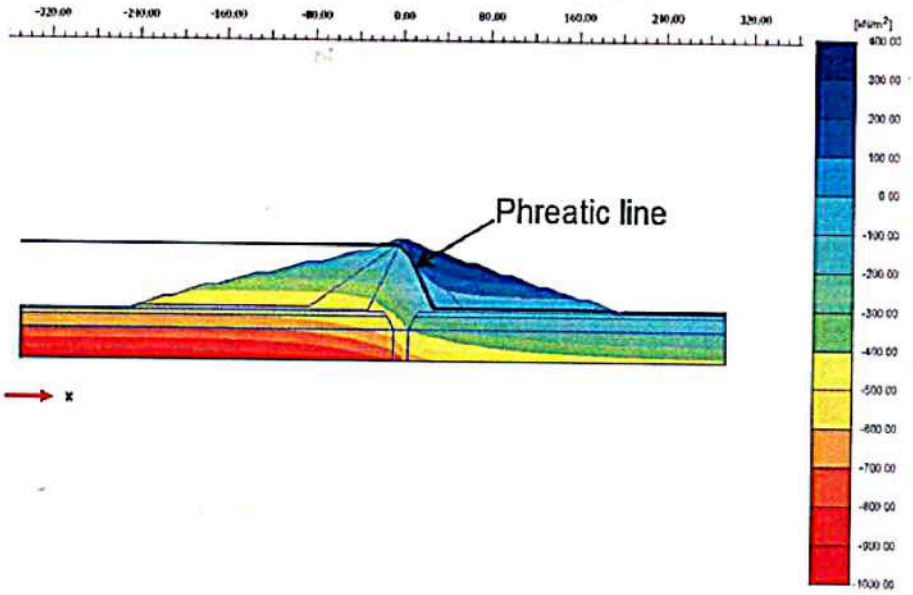


Figure 3: Steady state pore pressure contours with phreatic line for section 'I'

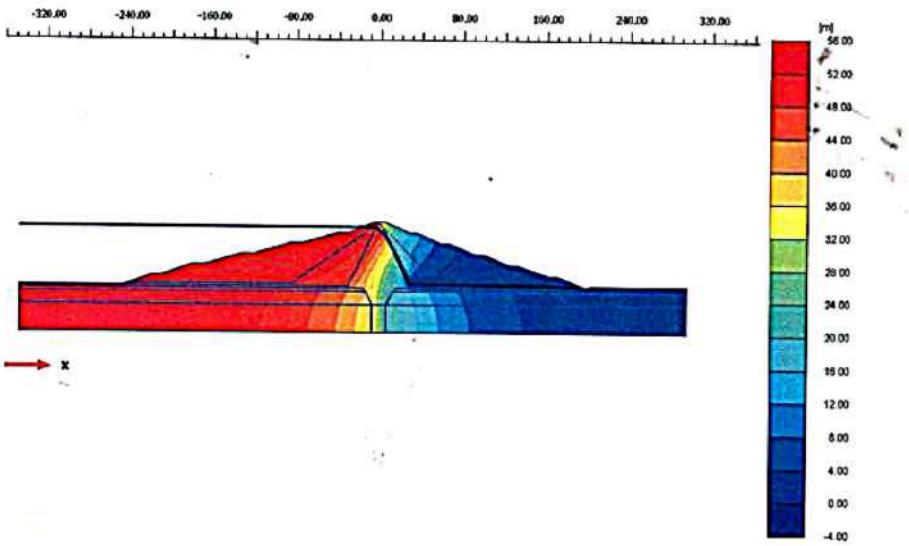


Figure 4: Hydraulic head contours (steady seepage condition) for section 'I'

(iv) Quantity of seepage discharge – Groundwater flow vectors on vertical section at the center of dam cross-section (Fig. 5) indicate total seepage discharge value of 0.6667 m^3/day/m. Quantity of seepage through dam body and foundation is 0.1172 and 0.5495 m^3/day/m respectively. These values indicate that major seepage discharge (82.42%) is occurring through foundation and 17.58% through dam body.

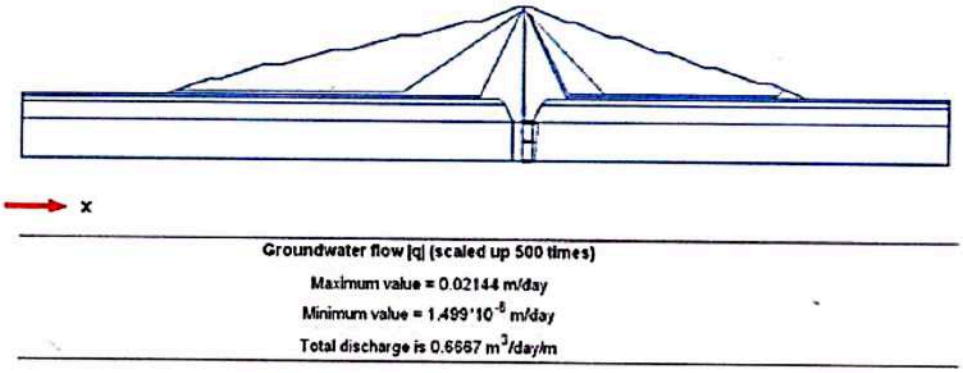


Figure 5: Quantity of seepage discharge (steady seepage condition) for section 'I'

6.4 Results of static slope stability analysis

In slope stability analysis, factor of safety of downstream slope is determined for steady state seepage condition while that of upstream slope is determined for sudden drawdown condition. Phreatic line for steady state and drawdown condition with rate 0.5 m/day is used in limit equilibrium method to evaluate factor safety of downstream and upstream slope respectively. The value of FS for both steady seepage and sudden drawdown conditions is found to be 1.55. Critical slip circles are shown in Figs. 6 and 7. It is seen from analysis that the dam slopes are stable for static loads with FS more than the required values of 1.5 for steady seepage and 1.3 for sudden drawdown condition as per IS 7894:1975.

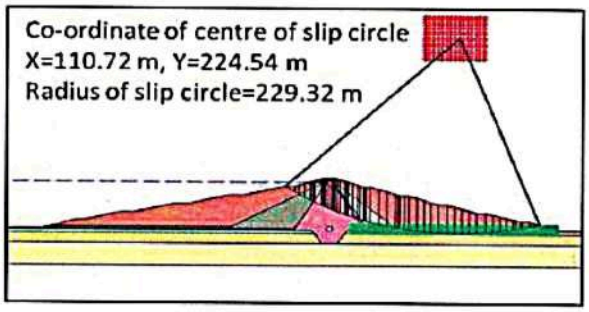


Figure 6: Critical slip circle for steady seepage condition (FS = 1.55)

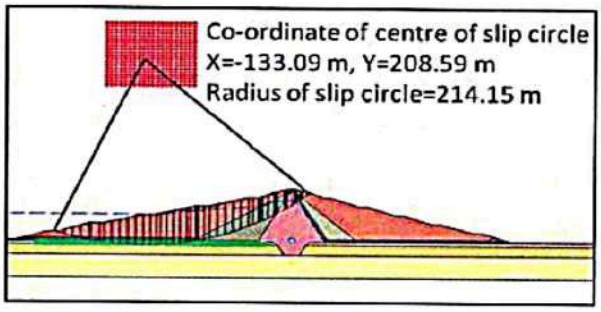


Figure 7: Critical slip circle for drawdown condition with rate 0.5 m/day (FS = 1.55)

6.5 Results of pseudo-static slope stability analysis

As described in para 5.0; dynamic stability of dam sections is determined using pseudo-static approach. Critical factor of safety values for downstream (steady seepage condition) and upstream slope (reservoir full condition) are found to be 1.21 and 1.43 for section 'I'. These values are more than the minimum required value of 1.0, thus it is inferred that downstream and upstream slopes of dam section 'I' are safe for earthquake loading conditions.

7.0 STUDY OF SECTION IN TANK BED PORTION

Portion of the dam from Ch. 18.625 km to Ch.19.925 km (1.3 km) in Reach 'IV' is known as the tank bed portion. Prior to construction of the dam in this region, slushy soil mixed with lime was encountered in the foundation [Ref. Site visit report (Annex. I)]. This foundation soil was removed up to certain depth and dam construction was started from the excavated level. Depth of refilled soil adopted in geotechnical model is 7.7 m below the natural/ stripped ground level. Detailed analysis of dam section 'II' (height 51.0 m) at chainage 19.0 km of Mallannasagar dam is described below.

7.1 Section 'II' (Tank bed portion, Height 51.0 m)

Section 'II' with maximum height of 51.0 m is applicable from Ch. 18.625 km to Ch.19.925 km of Reach 'IV'. Upstream slope of the section is 1(V):2.5(H) from dam base level (RL 511.2 m) to RL 522.2 m; 1(V):3(H) from RL 522.2 m to RL 532.2 m; 1(V):3.5(H) from RL 522.2 m to RL 532.2 m and 1(V):2.5(H) from RL 552.2 m to top berm level (562.2 m). Upstream slope has total four berms including one berm of width 6 m at RL 522.2 m and three berms of width 12 m at RL 532.2 m, RL 542.2 m, 552.2 m. Downstream slope is 1(V):2.5(H) from dam base level to RL 522.2 m; 1(V):3(H) from RL 522.2 m to RL 532.2 m and 1(V):2.5(H) from RL 532.2 m to top berm level. Downstream slope has three berms of width 8 m at RL 522.2 m, RL 532.2 m RL 542.2 m and one berm of width 6 m at RL 552.2 m. The dam cross-section is multi-zoned with central impervious hearting zone (zone 2) and casing zones viz. zone 1 and 3. An inclined filter of varying thickness i.e. 1.0 m, 1.2 m, 1.5 m and 1.75 m is provided in between zone 2 and zone 1 on downstream side to permit free drainage of seepage water. Inclined filter is connected to rock toe through 1.7 m thick horizontal filter at ground level (RL 511.2 m). The dam section with three zones as described above is extended below ground level up to RL 503.5 m in place of excavated slushy soil in foundation. A central cut-off-trench (CoT) of base-width 10.0 m below hearting zone is provided to restrict seepage through foundation (Fig. 8)

7.2 Foundation strata and design soil parameters

In geotechnical model of section 'II', foundation strata below ground level is adopted from L-section drawing indicating foundation stratification for Reach 'IV' provided by project authority during site visit on 13/10/2022. As foundation strata below CoT base level (RL 495.69 m) is not indicated in L-section drawing, the same is adopted from borehole log at Ch. 19.05 km. Section 'II' is extended up to RL 503.5 m below ground level i.e. foundation strata below dam base was excavated and refilled with soil material of zone 1, 2 and 3 for replacing the

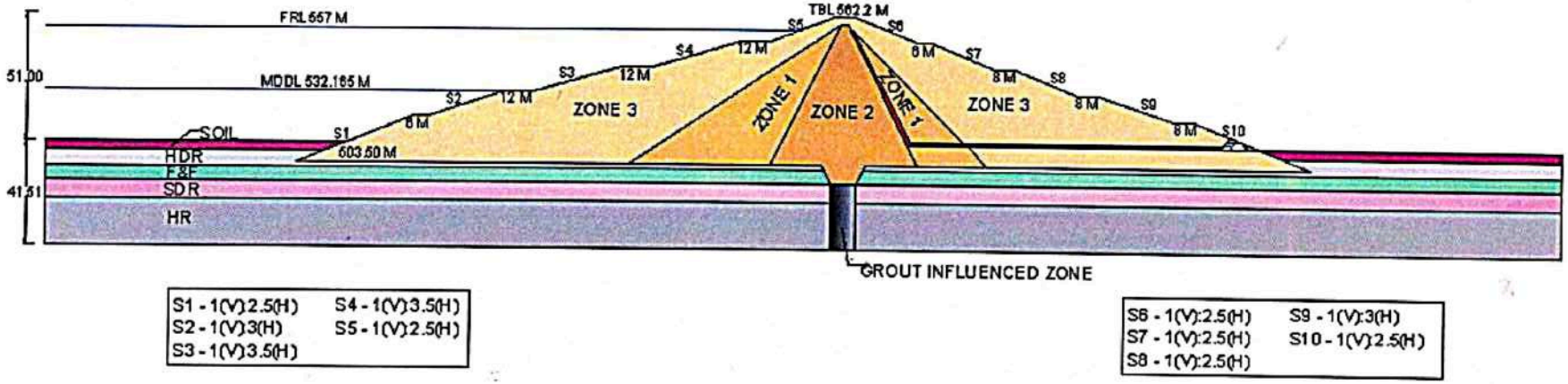


Figure 8: Design dam section 'II' (Tank bed portion at Ch. 19 km)

slushy soil. Foundation strata adopted in studies is given in Table 6 whereas design soil parameters are listed in Tables 7 and 8. As mentioned earlier in para 6.2, effect of grout curtain is considered by grout influenced zone of width equal to base width of CoT i.e. 10 m.

Table 6: Foundation stratification for section 'II'

Section	Dam base level	GL in L-section drawing (RL)	Foundation strata	Thickness (m)
I	511.2 m	511.697 m	Overburden soil	3.53
			Hard Disintegrated Rock (HDR)	6.15
			Fractured & Fissured Rock (F&F)	5.83
			Soft Disintegrated Rock (SDR)	7.04
			Hard Rock (HR)	18.96*

** Up to base of the model*

Table 7: Design soil parameters for section 'II'

Sr. No.	Parameter	Zone 1 (SC)	Zone 2 (Cl)	Zone 3 (SM)	Filter	Rocktoe
1	Bulk density (kN/m^3)	20.18	18.55	21.07	18	20
2	Saturated density (kN/m^3)	20.986	19.51	21.56	18	20
3	Cohesion (kN/m^2)	19.61	19.61	4.9	0	0
4	Friction Angle (degree)	18	9	24	30	40
5	Young's Modulus of elasticity (MPa)	50	20	50	50	200
6	Poisson's ratio	0.3	0.35	0.3	0.3	0.26
7	Permeability (m/sec)	7.1×10^{-8}	1.88×10^{-8}	1.28×10^{-6}	1×10^{-3}	1×10^{-3}

Table 8: Design parameters of soil / rock in foundation section 'II'

Sr. No.	Parameter	OB	HDR	F&F Rock	HDR	HR	Grout zone
1	Bulk density (kN/m^3)	18.5	19.62	19.62	19.62	20.60	20.60
2	Saturated density (kN/m^3)	19	20.59	20.59	20.59	21.57	21.57
3	Cohesion (kN/m^2)	0	0	0	0	0	0
4	Friction Angle (deg.)	35	35	35	35	35	35
5	Young's Modulus of elasticity (MPa)	100	250	250	250	250	250
6	Poisson's ratio	0.28	0.25	0.25	0.25	0.25	0.25
7	Permeability (m/sec)	1×10^{-5}	3.44×10^{-7}	2.98×10^{-7}	2.98×10^{-7}	1.88×10^{-6}	2.4×10^{-8}

7.3 Results of seepage analysis

Various seepage parameters obtained from steady state seepage analysis of section 'II' are described below.

(i) Phreatic line: Steady state seepage analysis of section 'II' indicates that the phreatic line drops up to dam base level in hearting zone 2 and emerges out through filter. This implies favourable condition as downstream transition and casing zones (zone 1 and 3 respectively) are not in saturated condition (Figure 9).

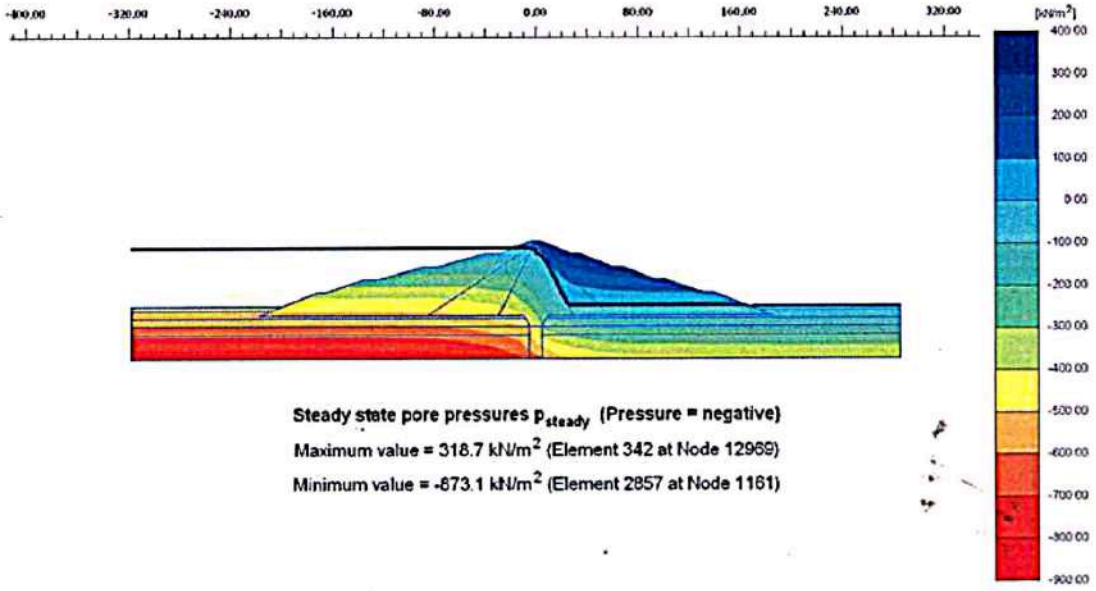


Figure 9: Steady state pore pressure contours with phreatic line for section 'II'

(ii) Pore pressure: It is seen from the results of seepage analysis that steady state pore pressure values on upstream side (Figure 9) increase gradually downwards with 0 kPa at phreatic surface to - 460.226 kPa at dam base level below upstream toe.

(iii) Hydraulic head: It is seen that hydraulic head dissipates in hearting zone 2 from maximum value of 45.8 m to 0.833 m near horizontal filter on downstream side (Figure 10).

(iv) Quantity of seepage discharge – Groundwater flow vectors on vertical section at the centre of dam cross-section (Figure 11) indicate total seepage discharge value of 0.1497 m^3/day/m. Quantity of seepage through dam body and foundation is 0.0485 and 0.1012 m^3/day/m respectively. These values indicate that 67.6% of seepage discharge is occurring through foundation and 32.4% through dam body.

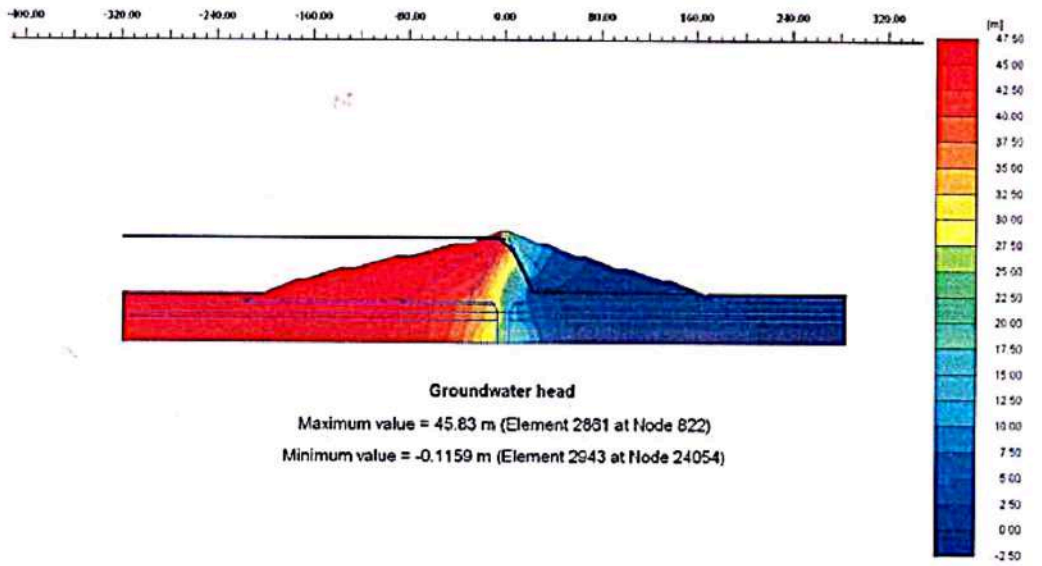


Figure 10: Hydraulic head contours (steady seepage condition) for section 'II'

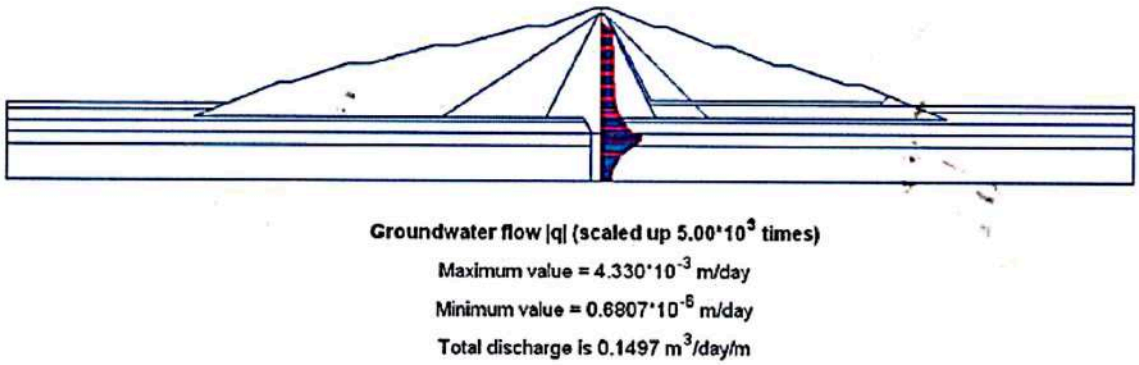


Figure 11: Quantity of seepage discharge (steady seepage condition) for section 'II'

7.4 Results of static slope stability analysis

In slope stability analysis, factor of safety of downstream slope is determined for steady state seepage condition while that of upstream slope is determined for sudden drawdown condition. Phreatic line for steady state condition and drawdown condition with rate 0.5 m/day obtained from PLAXIS 2D is used in limit equilibrium method to evaluate factor of safety of downstream and upstream slope respectively. The values of FS for steady seepage and drawdown conditions with rate 0.5 m/day are found to be 1.56 and 1.41, both of which are greater than the required values as per IS 7894:1975. Therefore, the downstream and upstream slopes of section 'II' are considered to be safe for steady seepage and drawdown conditions. Critical slip circles are shown in Figs. 12 and 13.

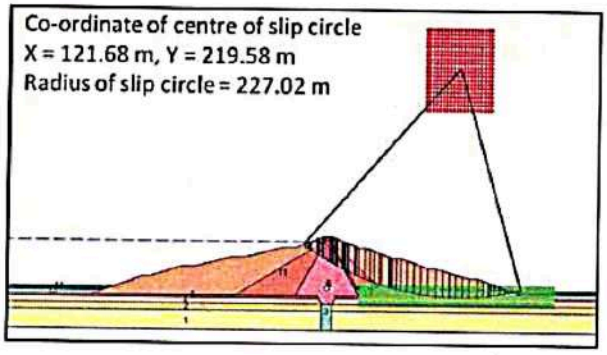


Figure 12: Critical slip circle for steady seepage condition (FS = 1.56)

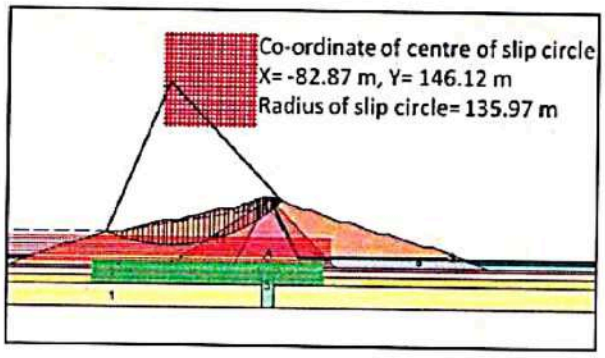


Figure 13: Critical slip circle for drawdown condition with rate 0.5 m/day (FS = 1.41)

7.5 Results of pseudo-static slope stability analysis

As described in para 5.0; dynamic stability of dam section 'II' is determined using pseudo-static approach. Critical factor of safety values for downstream (steady seepage condition) and upstream slope (reservoir full condition) are found to be 1.25 and 1.38 respectively. These values are more than the minimum required value of 1.0, thus it is inferred that downstream and upstream slopes of dam section 'II' are safe for earthquake loading conditions.

8.0 STUDY OF SECTION IN HILLOCK PORTION

Portion of the dam from Ch. 16.3 km to Ch.16.7 km (0.4 km) in Reach 'III' is known as the hillock portion where hard rock is encountered in foundation below dam base level. At this location the natural ground surface is inclined with downstream toe level at higher elevation than upstream toe level. Detailed analysis of dam section in the hillock portion (section 'III') of maximum height 49.0 m at chainage 16.3 km of Mallannasagar earth dam is described below.

8.1 Section 'III' (Hillock, Maximum height 49.0 m)

Section 'III' with maximum height of 49.0 m is applicable from Ch. 16.3 km to Ch.16.7 km of Reach 'III'. The ground level in this portion is lower on upstream side as compared to downstream side (Fig. 14). As such, the stripped ground level indicated with horizontal line in dam cross-section drawing at RL 513.2 m, is adopted as RL at dam centre. Ground levels at upstream and downstream toe are taken at RL 510.705 m and RL 523.9 m respectively based on the L-section drawing. Upstream slope of the section is 1(V):2.5(H) from upstream toe level to top berm level (562.2 m). Upstream slope has total four berms including one berm of width 8 m at RL 522.2 m, one berm of width 12 m at RL 532.2 m and two berms of width 10 m

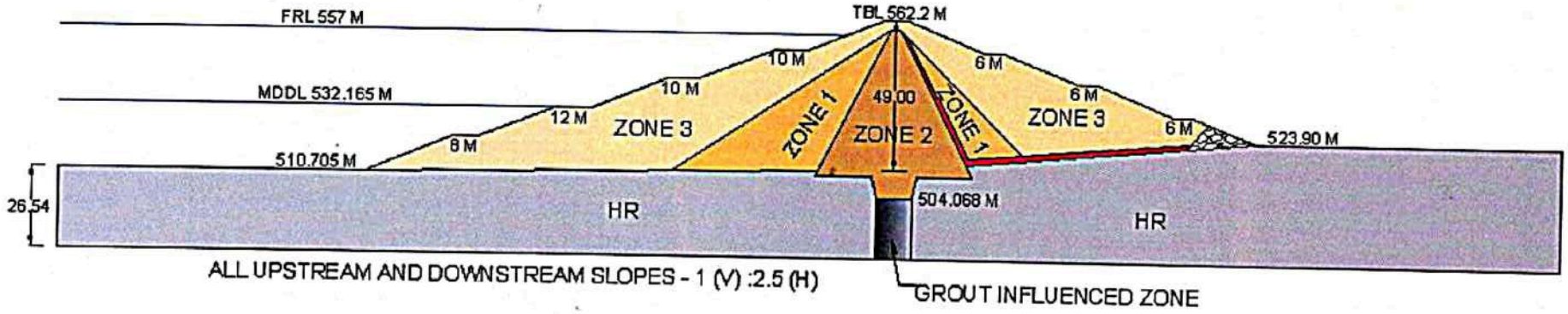


Figure 14: Design dam section 'III' (Hillock portion at Ch. 16.3 km)

at RL 542.2 m and 552.2 m. Downstream slope is 1(V):2.5(H) from downstream toe level to top berm level. Downstream slope has three berms of width 6 m at RL 532.2 m, RL 542.2 m and RL 552.2 m. The dam cross-section is multi-zoned with central impervious hearting zone (zone 2) and casing zones viz. zone 1 and 3. An inclined filter of varying thickness i.e. 1.0 m, 1.25 m, 1.5 m and 1.75 m is provided in between zone 2 and zone 1 on downstream side to permit free drainage of seepage water. Inclined filter is connected to rock toe through 1.7 m thick filter laid parallel to the natural ground level (*as per information received from project authorities vide email dated 04/02/2022*). A central cut-off-trench (CoT) of base-width 11.5 m below hearting zone is provided to restrict seepage through foundation (Fig. 14).

8.2 Foundation strata and design soil parameters

In geotechnical model for section 'III', foundation strata below ground level is adopted from L-section drawing with foundation stratification for Reach 'III' provided by project authority vide email dated 26/10/2021. The foundation strata consist of Hard Rock layer. In geotechnical model, 26.64 m of foundation layer below upstream toe level is considered. Effect of grout curtain is considered by grout influenced zone of width equal to base width of CoT i.e. 11.5 m. Foundation strata used in model is given in Table 9 and design soil parameters adopted for analysis are listed in Tables 10 and 11.

Table 9: Foundation stratification for section 'III'

Section	Upstream toe level (RL)	Downstream toe level (RL)	Foundation strata	Thickness (m)	
				from upstream toe	from downstream toe
III	510.705 m	523.9 m	Hard Rock (HR)	26.5	39.7

Table 10: Design soil parameters for section 'III'

Sr.No.	Parameter	Zone 1 (SC)	Zone 2 (CI)	Zone 3 (SM)	Filter	Rocktoe
1	Bulk density (kN/m^3)	19.81	19.56	18.61	18	20
2	Saturated density (kN/m^3)	20.79	20.18	20.11	18	20
3	Cohesion (kN/m^2)	14.72	24.53	1.96	0	0
4	Friction Angle (degree)	21	12	28	30	40
5	Young's Modulus of elasticity (MPa)	50	20	50	50	200
6	Poisson's ratio	0.3	0.35	0.3	0.3	0.26
7	Permeability (m/sec)	1.43×10^{-7}	3.91×10^{-8}	1.10×10^{-5}	1×10^{-3}	1×10^{-3}

Table 11: Design parameters of rock in foundation for section 'III'

Sr. No.	Parameter	HR	Grout zone
1	Bulk density (kN/m^3)	20.60	20.60
2	Saturated density (kN/m^3)	21.57	21.57
3	Cohesion (kN/m^2)	0	0
4	Friction Angle (deg.)	35	35
5	Young's Modulus of elasticity (MPa)	250	250
6	Poisson's ratio	0.25	0.25
7	Permeability (m/sec)	$3.79x10^{-6}$	$1.36x10^{-7}$

8.3 Results of seepage analysis

Various seepage parameters obtained from steady state seepage analysis of section 'III' are described below.

(i) **Phreatic line:** Steady state seepage analysis of section 'III' indicates that the phreatic line drops in hearting zone 2 up to RL 525.39 m and emerges out almost horizontally at the downstream toe. As the downstream toe is at elevated level than hearting toe, the phreatic line does not lower down up to hearting toe level and up to point 'A' in the filter (Ref. Fig. 16). Hence, instead of emerging into rocktoe through filter, the phreatic line is emerging through casing zones 1 and 3.

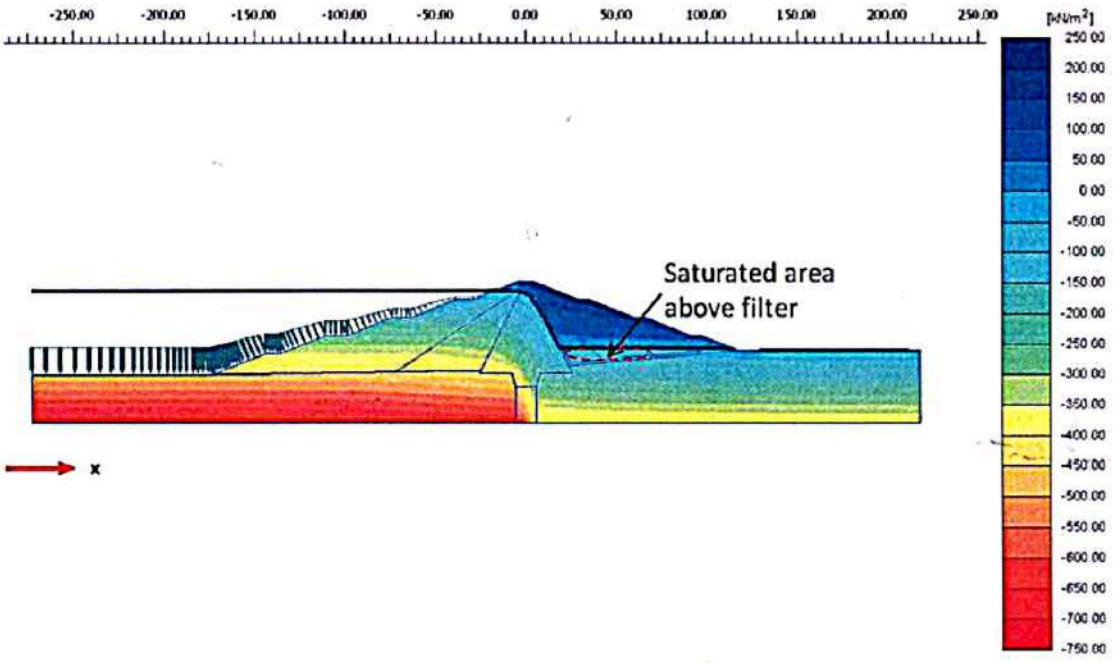


Figure 15: Steady state pore pressure contours with phreatic line for section 'III'

(ii) Pore pressure: It is seen from the results of seepage analysis that steady state pore pressure values on upstream side (Fig. 15) increase gradually downwards with 0 kPa at phreatic surface to -470.350 kPa at upstream toe level. Moreover due to the elevated phreatic line, a critical region of zone 1 and 3 on downstream side (area above filter and below phreatic line), as indicated in Fig. 15, remains in saturated condition where non dissipated pore pressure exists.

(iii) Hydraulic head: It is seen that hydraulic head dissipates in hearting zone 2 from maximum value of 46.3 m to 14.663 m at point 'A' in horizontal filter (Fig. 16). Hydraulic head is defined as the sum of pressure head and elevation head. Elevation of point 'A' is RL 5.261 m. Thus the pressure head at point 'A' is calculated as 9.402 m (14.663 m – 5.261 m).

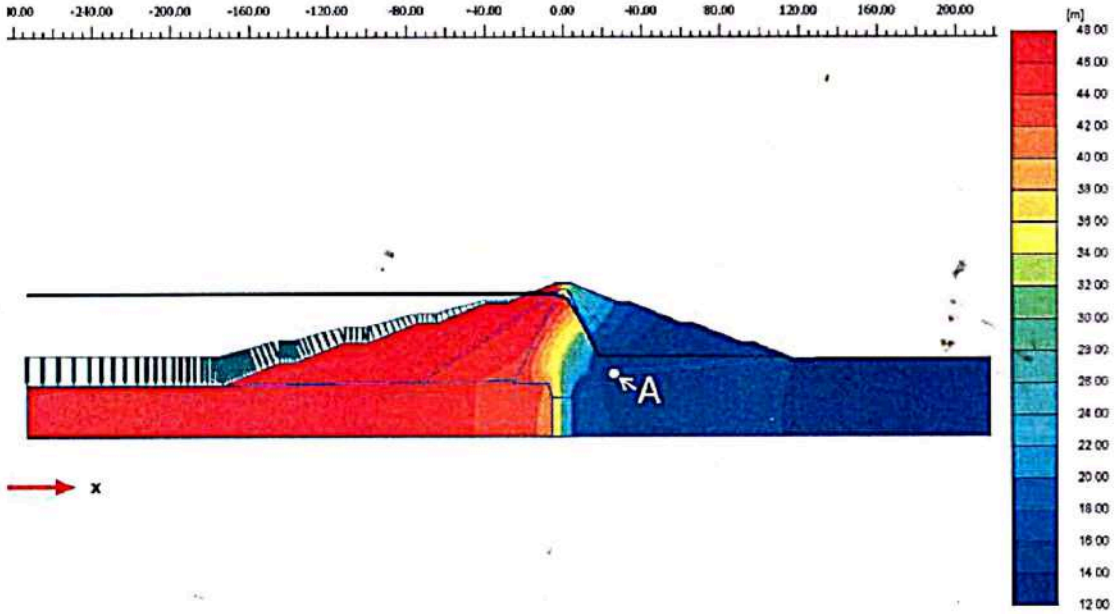


Figure 16: Hydraulic head contours (steady seepage condition) for section 'III'

In case if the dam section in hillock portion is constructed as described in para 8.1, with inclined filter of uniform thickness at the location of high pressure head (point 'A') (as shown in Fig. 16); then the presence of pore water pressure and non-dissipated pressure head in downstream zone 1 and 3 above filter (below phreatic line) may lead to movement of soil particles near point 'A'. With time, the movement of particles can lead to blockage of filter and zones 1 and 3 below phreatic line. In view of the above, it is recommended that the critical area as demarcated in Fig. 15 be monitored meticulously by installing piezometers. Any anomalous pore pressure readings be identified, cause of the same be found out and remedial measures

be taken up. Any signs of muddy water discharge, wetness on downstream slope, deformations, etc. should also be monitored by periodic visual inspections.

(iv) Quantity of seepage discharge: Groundwater flow vectors on vertical section at the center of dam (Fig. 17) indicate total seepage discharge value of 0.6433 m^3/day/m. Quantity of seepage through dam body and foundation is 0.1070 and 0.5363 m^3/day/m respectively. These values indicate that major seepage discharge (83.4%) is occurring through foundation and 16.6% through dam body.

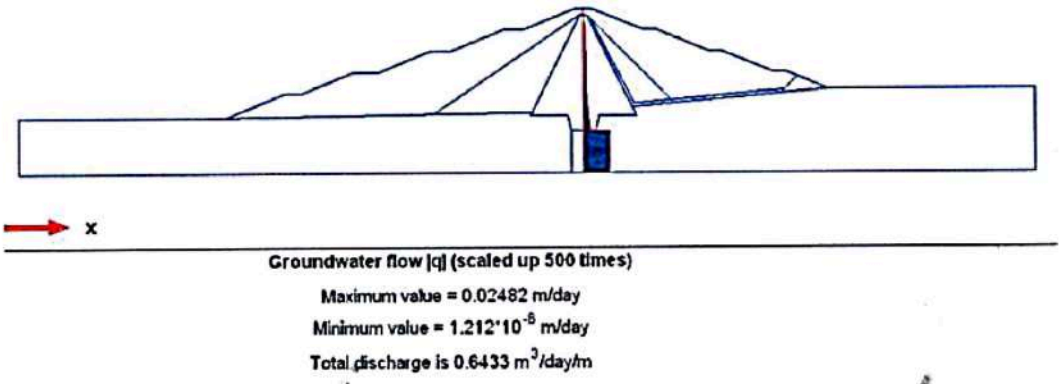


Figure 17: Quantity of seepage discharge (steady seepage condition) for section 'III'

8.4 Results of static slope stability analysis

The values of FS for steady seepage and drawdown conditions with rate 0.5 m/day are found to be 1.74 and 1.40. These values are greater than the required values as per IS 7894:1975. Therefore, both downstream and upstream slope are considered to be safe for steady seepage and drawdown.

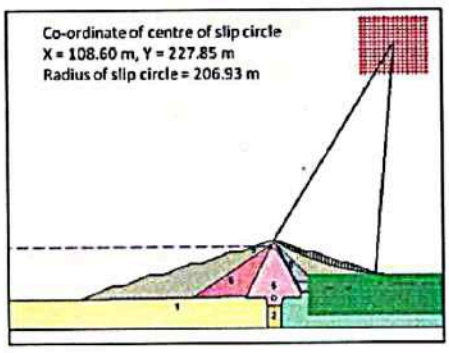


Figure 18: Critical slip circle for steady seepage condition (FS = 1.74)

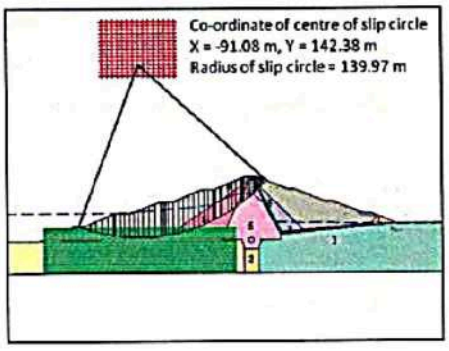


Figure 19: Critical slip circle for drawdown condition with rate 0.5 m/day (FS = 1.40)

8.5 Results of pseudo-static slope stability analysis

As described in para 5.0; dynamic stability of dam sections is determined using pseudo-static approach. Critical factor of safety values for downstream (steady seepage condition) and upstream slope (reservoir full condition) are found to be 1.45 and 1.35 for section 'III'. These values are more than the minimum required value of 1.0, thus it is inferred that downstream and upstream slopes of dam section 'II' are safe for earthquake loading conditions.

8.6 Studies for executed dam cross-section in hillock portion at Ch. 16.3 km

A draft technical report incorporating results of three dam cross-sections viz. section 'I', 'II' and 'III' (Figs. 2, 8 and 14 respectively) was submitted to the I&CAD Department, Telangana vide email dated 28/02/2022. Further to the above, the I&CAD Department vide email dated 9/03/2022; informed that the dam section in hillock portion is not constructed as per Fig. 14 and submitted the actually executed dam cross-section in hillock portion as shown in Fig. 20.

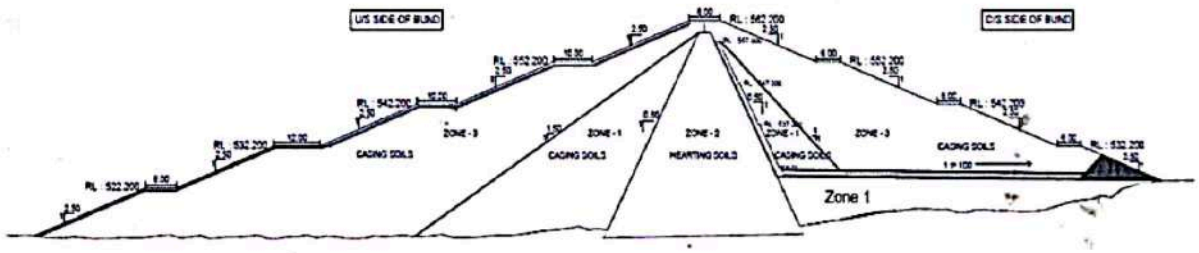


Figure 20: Actually executed dam section in hillock portion (Ch: 16.3 km)

Fig. 20 indicates that during construction of dam in hillock portion, the downstream of hearting was suitably raised by laying zone 1 type of soil in uniform layers for maintaining a slope of 1 in 100 from hearting edge towards the toe drain. The filter laid was also horizontal with gentle slope of 1(V):100(H) for disposal of seepage water into the rock toe. In view of the revised cross-section, stability of dam in hillock portion was re-assessed considering the actually constructed section as indicated in Fig. 20. Results of studies for revised section 'III' are described below:

8.7 Results of seepage analysis

Various seepage parameters obtained from steady state seepage analysis of revised section 'III' are described below.

(i) Phreatic line: Steady state seepage analysis of revised section 'III' indicates that the phreatic line drops up to horizontal filter in hearting zone 2 and emerges out almost horizontally at the downstream toe (Fig. 21). As the downstream toe is at elevated level than hearting toe, the zone 1 type of soil used for raising the existing ground level, remains in saturated condition.

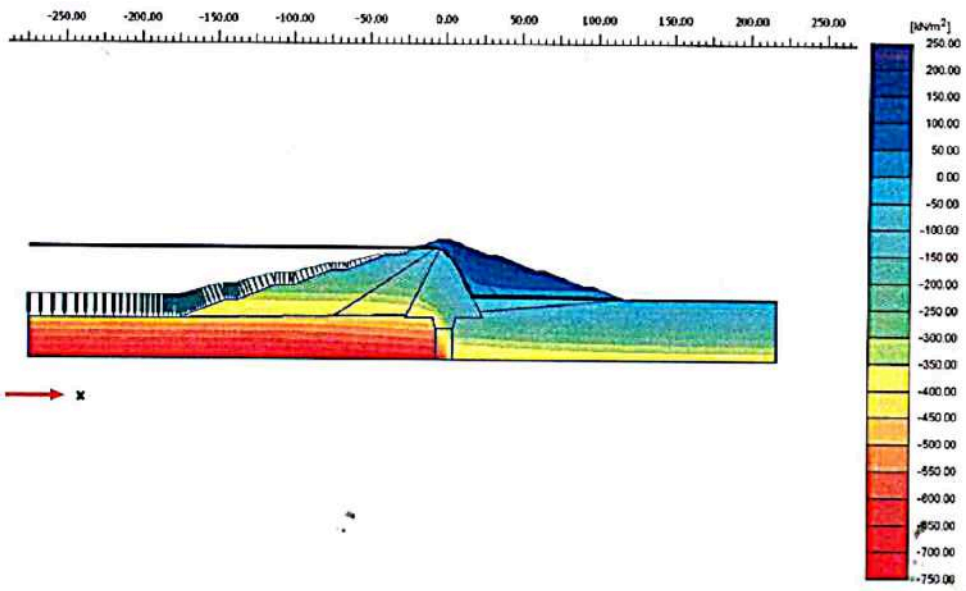


Figure 21: Steady state pore pressure contours with phreatic line for revised section 'III'

(ii) Pore pressure: It is seen from the results of seepage analysis of revised section 'III' that steady state pore pressure values on upstream side (Fig. 21) increase gradually downwards with 0 kPa at phreatic surface to -470.418 kPa at upstream toe level. The zone 1 below phreatic line (below filter) on downstream side remains in saturated condition where non dissipated pore pressure exists.

(iii) Hydraulic head: It is seen from analysis of revised section 'III' that hydraulic head dissipates in hearting zone 2 from maximum value of 46.3 m to 14.374 m near horizontal filter on downstream side (Fig. 22). Hydraulic head is defined as the sum of pressure head and elevation head. Total hydraulic head obtained at point 'A' is 14.374 m. Elevation of point 'A' is at RL 5.26 m. Thus the pressure head at 'A' is 9.114 m (14.374 m – 5.26 m). It is seen that if the filter is located in the area of non dissipated pressure head i.e. near point 'A' (as in the case of original dam section 'III' shown in Fig. 14), possibility of particle movement exists. So ideally the filter should be located in the area of nominal pressure head. In revised section 'III' the filter is raised at the level of downstream toe. Hence pressure head near filter

at point 'B' was determined. The total hydraulic head at point 'B' was found to 14.374 m from analysis. Elevation of point 'B' is at RL 14.34 m. Thus the pressure head at point 'B' is 0.034 m (14.374 m – 14.34 m), which is nominal. Thus, the revised dam cross-section 'III' is found to be favorable as the filter is located in the area of nominal pressure head.

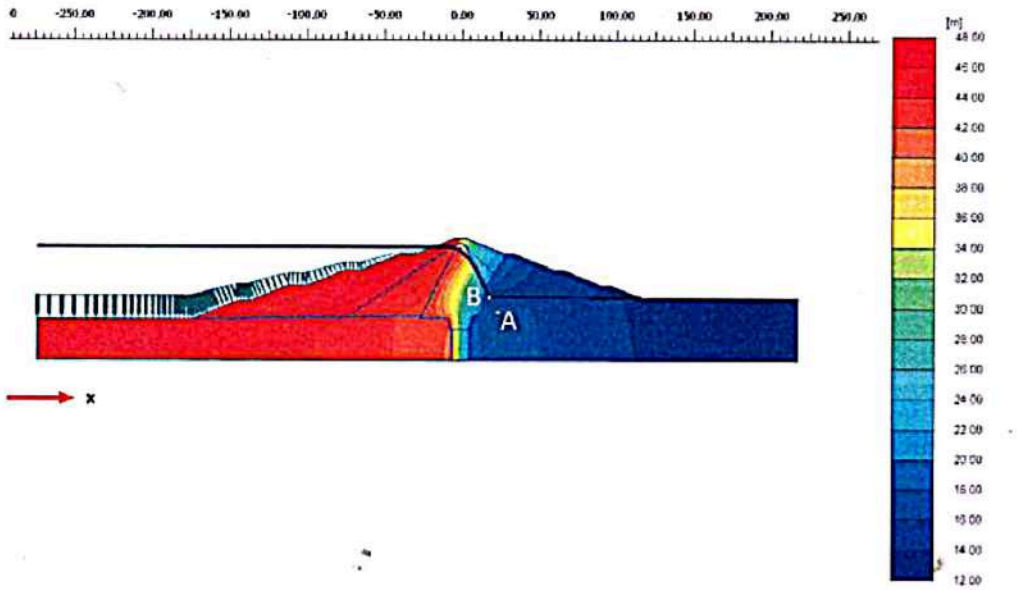


Figure 22: Hydraulic head contours (steady seepage condition) for revised section 'III'

(iv) Quantity of seepage discharge: Groundwater flow vectors on vertical section at the center of dam (Fig. 23) indicate total seepage discharge value of 0.6269 m^3/day/m. Quantity of seepage through dam body and foundation is 0.1167 and 0.5102 m^3/day/m respectively. These values indicate that major seepage discharge (81.4%) is occurring through foundation and 18.6% through dam body.

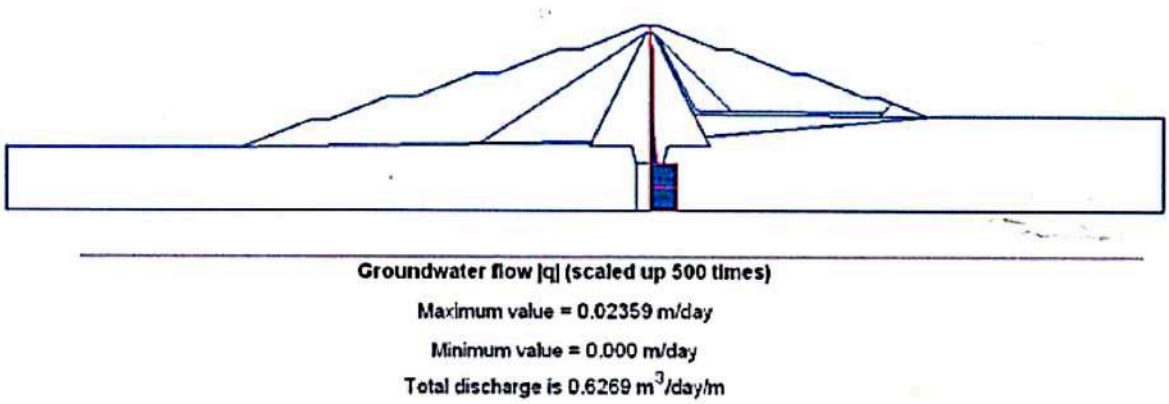


Figure 23: Quantity of seepage discharge (steady seepage) for revised section 'III'

8.8 Results of static slope stability analysis

The values of FS for steady seepage and drawdown conditions with rate 0.5 m/day for revised section 'III' are found to be 1.64 and 1.41. These values are greater than the required values as per IS 7894:1975. Therefore, both downstream and upstream slopes are considered to be safe from slope stability point of view.

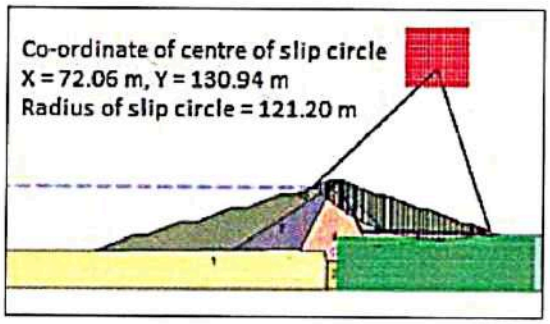


Figure 24: Critical slip circle for steady seepage condition (FS = 1.64)

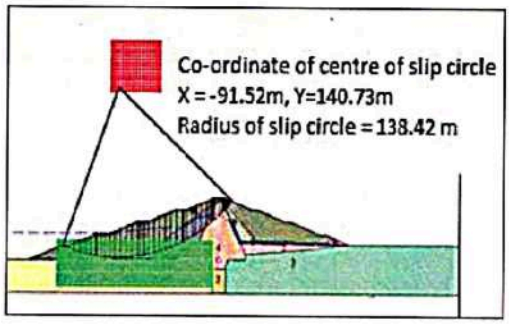


Figure 25: Critical slip circle for drawdown condition with rate 0.5 m/day (FS = 1.41)

8.9 Results of pseudo-static slope stability analysis

Critical factor of safety values for downstream (steady seepage condition) and upstream slope (reservoir full condition) from pseudo-static slope stability analysis for revised section 'III' are found to be 1.33 and 1.36. These values are more than the minimum required value of 1.0, thus it is inferred that downstream and upstream slopes of revised section 'III' are safe for earthquake loading conditions.

As per email dated 9/03/2022 from project authority, it is learnt that the dam section constructed at site in hillock portion is as per revised section 'III' and not as per the original section 'III' as indicated in Fig. 14. As such, results of section 'I', 'II' and revised section 'III' only are summarized below. The conclusions drawn and recommendations made are also based on results of sections 'I', 'II' and revised section 'III'.

9.0 SUMMARY OF RESULTS

Two dimensional seepage analysis using software PLAXIS 2D and slope stability analysis by Bishop's limit equilibrium method of slip circle analysis is conducted for three sections of Mallannasagar earth dam. Aim of the study is to assess seepage and stability aspects of the dam and suggest remedial measures required if any. Results of seepage analysis for sections 'I', 'II' and revised section 'III' are summarized in Table 12. Values of factor

of safety from slope stability analyses are summarized in Table 13. All three sections are found to be safe from slope stability point of view for steady seepage and drawdown conditions for drawdown rate of 0.5 m/day.

Table 12: Results of seepage analysis

Section	Seepage discharge (m^3/day/m)			Pore pressure[$] (kPa)	Hydraulic head (m)	
	Dam body	Foundation	Total		Maximum	Minimum[#]
I	0.1172	0.5495	0.6667	-378.534	54.4	1.235
II	0.0484	0.1012	0.1497	-576.585	45.8	0.833
Revised 'III'	0.1167	0.5102	0.6269	-470.418	46.3	14.374

[$] *In foundation below upstream toe near dam base*
[#] *In horizontal filter near downstream toe of hearting*

Table 13: Factor of safety values

Section	Static		Pseudo-static	
	Steady seepage (downstream)	Sudden drawdown (upstream) with rate 0.5 m/day	Steady seepage (downstream)	Reservoir full (upstream)
I	1.55	1.55	1.21	1.43
II	1.56	1.41	1.25	1.38
Revised 'III'	1.64	1.41	1.33	1.36

10.0 CONCLUSIONS AND RECOMMENDATIONS

Two dimensional seepage analysis using software PLAXIS 2D and limit equilibrium slope stability analysis using Bishop's slip circle method is conducted for multi-zoned earth dam sections viz. section 'I' at Ch. 15.6 km; section 'II' (tank bed portion) and revised section 'III' (hillock portion) of Mallannasagar reservoir. Aim of the study is to determine safety of the dam sections from seepage and stability point of view and recommend suitable remedial measures if required. Conclusions of the studies and recommendations are presented below.

a) Results of seepage analysis indicate that total seepage discharge (dam body + foundation) is 0.6667 m^3/day/m, 0.1497 m^3/day/m and 0.6269 m^3/day/m for dam sections 'I', 'II' and revised section 'III' respectively. Results also indicate that major percentage of seepage discharge is through foundation.

b) The current BIS standards do not indicate any value of permissible seepage through earth dam. However, according to "Handbook of Geotechnical investigations and design tables"

by Burt Look [Ref. (iv)], the permissible seepage through earth dam of height more than 40 m should be ideally less than 0.4 m^3/day/m and in any case not more than 0.8 m^3/day/m. For all the sections of Mallannasagar dam the total discharge values are less than the upper permissible limit of 0.8 m^3/day/m; but for section 'I' and revised section 'III' the discharge value is more than lower permissible value of 0.4 m^3/day/m. As purpose of the project is to store water by lift irrigation, water loss through seepage is undesirable. Project authorities may take a call on permissible seepage discharge values and remedial measures for seepage prevention if required may be taken up depending upon on-site seepage measurement values.

c) Results of stability analysis indicate that all three dam cross-sections are safe from slope stability point of view for static loading, with FS more than required values of 1.5 for steady seepage and 1.3 for sudden drawdown condition as per IS 7894:1975. The rate of drawdown adopted in analysis is 0.5 m/day as provided by project authorities. The factor of safety may decrease further for faster rate of drawdown.

d) Pseudo-static earthquake analysis indicates that all three dam sections are safe for steady seepage and reservoir full conditions with factor of safety more than required value of 1.0.

e) As the dam sections comprise of three zones of different soil types, it is recommended that zone 1 (SC) on upstream side be designed as transition zone for zone 2 (CI) and zone 3 (SM). Gradation of zone 1 should be such that gradual change in size of particles occurs. Similarly, zone 1 on downstream side should be designed as transition zone in between filter media and downstream casing zone 3. This will prevent erosion of soil particles due to seepage flow thus avoiding clogging, creation of voids, piping, etc.

f) It is suggested to install adequate monitoring devices viz. piezometers, 'V' notch weirs, etc. on all the three dam sections along with appropriate drainage arrangements designed as per IS 7356 (Part 2)-2003 [Ref. (iii)] and IS 9429-1999 [Ref. (v)]. Variation in pore pressures and seepage discharge with respect to reservoir water level be monitored periodically and any change in values be noted. The values from instrumentation could be compared with design values as obtained in the present studies. Any discrepancy in the values should be noted, cause of the same be found out and acted upon as per requirement.

g) Regular maintenance of the dam as per CWC guidelines is recommended.

11.0 REFERENCES

(i) IS 7894-1975: *CODE OF PRACTICE FOR STABILITY ANALYSIS OF EARTH DAMS*

(ii) IS 1893 (PART 1)- 2002: *CRITERIA FOR EARTHQUAKE RESISTANT DESIGN OF STRUCTURES*

(iii) IS 7356 (Part2)-2003: *INSTALLATION, OBSERVATION AND MAINTENANCE OF INSTRUMENTS FOR PORE PRESSURE MEASUREMENTS IN EARTH AND ROCKFILL DAMS — CODE OF PRACTICE*

(iv) *HANDBOOK OF GEOTECHNICAL INVESTIGATIONS AND DESIGN TABLES BY BURT LOOK* (TAYLOR & FRANCIS PUBLICATION)

(v) IS 9429-1999:*DRAINAGE SYSTEM FOR EARTH AND ROCKFILLDAMS - CODE OF PRACTICE*

ANNEXURE

Inspection report of tour to "Earth dam of Mallannasagar reservoir of Kaleshwaram lift irrigation project, Telangana"

1.0 Introduction

The Irrigation & CAD (I&CAD) Department, Government of Telangana has taken up execution of Kaleshwaram lift irrigation project to cater to irrigation and drinking water needs of drought prone areas in Telangana. The Kaleshwaram project envisages construction of various barrages, storage reservoirs, pump houses and canal network system. Sri Komuravelli Mallannasagar is one of the storage reservoirs with 50 TMC ft capacity. The reservoir is being created by constructing a multi-zoned earth dam of length 22.6 km and maximum height of about 60 m. To expedite the construction of reservoir, total length of the earth dam is divided into four reaches as given in Table I. Section of maximum height (59.59 m) is located at chainage 15.6 km i.e. in Reach III. Alignment of the dam with different reaches is shown in Fig.1.

Table 1: Details of earth dam of Mallannasagar reservoir

Reach	Chainage	Length of bund
I	0.0 km to 8.5 km	8.5 km
II	8.5 km to 12.5 km	4.0 km
III	12.5 km to 16.7 km	4.2 km
IV	16.7 km to 22.6 km	5.9 km

Considering size and importance of the reservoir, the Engineer-in-chief, I&CAD Department, Gajwel, Siddipet vide letter no. ENC(I)/Gajwel/DCE/DEE-4/AEE-7/SKMS/2021/ 825 dated 29/05/2021 requested CWPRS to conduct geotechnical seepage and stability studies for the earth dam. Along with studies for cross-section of maximum height i.e. **Section 1** at Ch. 15.6 km; seepage and stability studies for two more critical cross-sections viz. **Section 2** in Reach IV (from 18.625 km to 19.925 km, tank bed portion) and **Section 3** in Reach III (from Ch 16.3 to 16.7 km, hillock portion) are proposed to be assessed. For conducting the studies estimate amounting to Rs. 15,16,060/- was sanctioned by project authorities in August, 2021. The scope of studies includes:

i) Conducting seepage studies for above mentioned cross-sections using 2D numerical modeling for computation of phreatic line, discharge quantity, pore pressure, hydraulic head, etc. in different zones of dam.

ii) Conducting static slope stability analysis (slip circle method) for determination of factor of safety of upstream and downstream slopes for sudden drawdown and steady seepage

conditions respectively. Pseudo-static slope stability analysis of upstream and downstream slopes to assess earthquake stability.

iii) Recommendations for modification in the dam sections, required if any, from seepage and stability point of view.

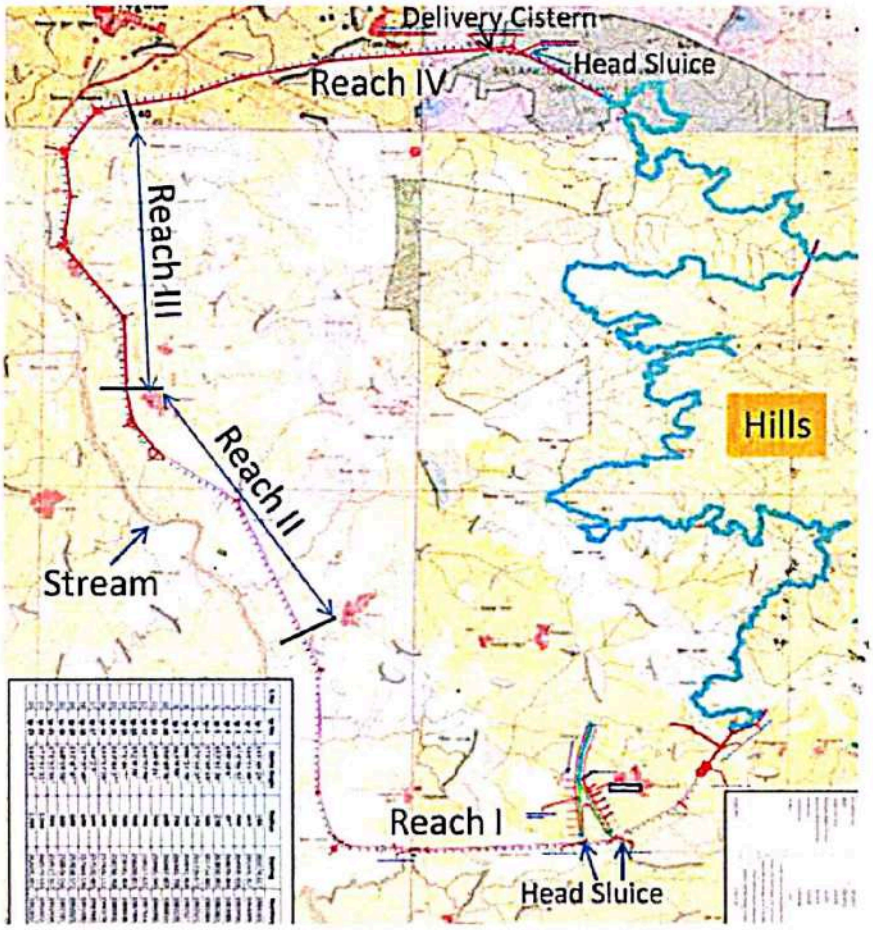


Figure 1: Alignment of earth dam of Mallannasagar reservoir

2.0 Site visit

To have comprehensive understanding of site conditions and to finalize data/ inputs required for studies from discussions with project authorities; a site visit was conducted by Smt. J. S. Edlabadkar, Scientist 'C' and Dr. (Smt) Tanusree Samanta, Scientist 'B' on 13/10/2021. Shri K.S.S. Chandrasekhar, Chief Engineer; Shri T. Venu, Superintending Engineer; Shri Ram Srinivas, Superintending Engineer; Shri Venketeshwar Rao, Executive Engineer, Shri Pochamallu, Executive Engineer from Irrigation and CAD department, Govt. of Telangana accompanied CWPRS officers during visit. At the outset, a discussion was held during which the current status of construction activity was briefed by project authorities. It was informed that construction of the dam up to top berm level was almost complete. Pitching on upstream slope was also completed from dam base

level to berm level at 542.2 m; while pitching work above 542.2 m was ongoing. Turfing work on downstream slope was also in full swing. Project authorities expressed concern regarding any effect on stability of the dam due to proximity of a stream flowing parallel to downstream toe of the dam at some locations, mainly in Reach II (Fig. 1). Reservoir filling started in August, 2021 and 10.5 TMC ft water was filled in the reservoir in two stages. On the day of visit water level in the reservoir was at RL 533.0 m.

3.0 Observations at different locations of the dam

During visit some important locations on top berm and at downstream toe of the dam in Reach I, II, III and IV were inspected. Detailed observations at different locations are described below.

i) **Location 1- Reach I:** Site visit was started from dam top at Ch 7.6 km which is located in Reach I. Height of the dam at this chainage is 42.5 m and water head at existing water level was 13.3 m. It was informed that foundation strata at this chainage comprises of 1 m thick soil layer followed by 13.62 m of Hard Disintegrated Rock (HDR). Depth of COT varies from 12 m to 16 m. Throughout the length of dam grout curtain was constructed below COT by drilling grout holes at 6 m center to center distance in two rows 3 m apart (staggered pattern). Depth of grout holes at this location was 21 m below COT.

ii) **Location 2- Reach II:** This location was at top berm level at Ch. 2.2 km in Reach II. Height of the dam at this chainage is 52.4 m and water head was 23.2 m. For this section depth of COT is 12.5 m and below COT grouting was done up to depth of 18 m. The location was suspected to be critical from stability point of view due to proximity to the stream flowing almost parallel to downstream toe for complete length of Reach II and some portions of Reach I and III [Fig. 1].

iii) **Location 3- Reach II:** Downstream toe at Ch 13.0 km was inspected [Fig. 2]. Dam height at this chainage is 53.1 m and water head was 23.9 m. It was observed that water was flowing through toe drain along with wet patches in rocktoe. Toe drain was equipped with V-notch weir to measure discharge quantity [Fig. 3]. Since the reservoir filling had started only from August 2021, it is very unlikely that steady seepage condition has reached. Also, it was informed by project authorities that flowing water in toe drain was seen even before filling of reservoir. As such it is supposed that the water in toe drain is not due to seepage from dam body but due to passage of rain water entering the downstream slope of dam through turfing and draining out from rocktoe. To confirm the source of water in toe drain, it was suggested to monitor the rate of flow with reservoir water level, time and seasonal variations. If the source is due to dam body

seepage, the discharge quantity should increase with reservoir water level. Also, as the level of toe drain is lower than the present water level of stream located in near proximity on downstream side; it is also suspected that water in toe drain may be due seepage of water from stream. It was also recommended to monitor the discharge in toe drain with respect to water level in the stream.

Figure 2: Downstream toe of dam at Ch 13.0 km

Turfing on downstream slope was completed at this location. It was observed that the growth of turfing grass at this location was dense and green [Fig. 4] as compared to other locations. The uneven growth of turfing may be an indication of wetness in some patches of downstream slope. However, it was informed that different types of grass were used which may be the reason for uneven turfing growth. However, it was recommended to critically monitor this location for seepage through dam body if any.

iv) **Location 4 - Reach II:** Clear flowing water was seen through toe drain at chainage 13.6 km. Dam height at this location is 52.9 m and water head was 23.7 m. Discharge quantity measured in toe drain was 4.7 liter/sec. Wetness and growth of algae were seen on both sides of the toe drain [Fig. 5] indicating sustained accumulation of water. Cross drains on the downstream slope at this location are shown in Fig. 6. It is recommended to critically monitor this location as well for seepage through dam body if any.

Figure 3: V-notch weir in toe drain

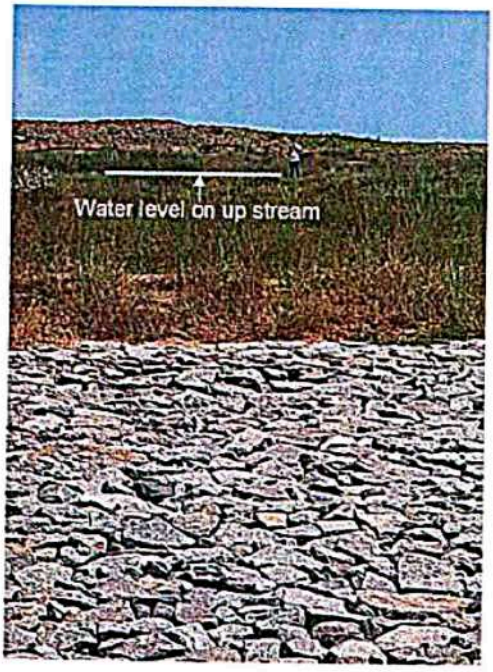


Figure 4: Heavy growth of turfing on downstream slope at Ch 13.0 km below existing water level

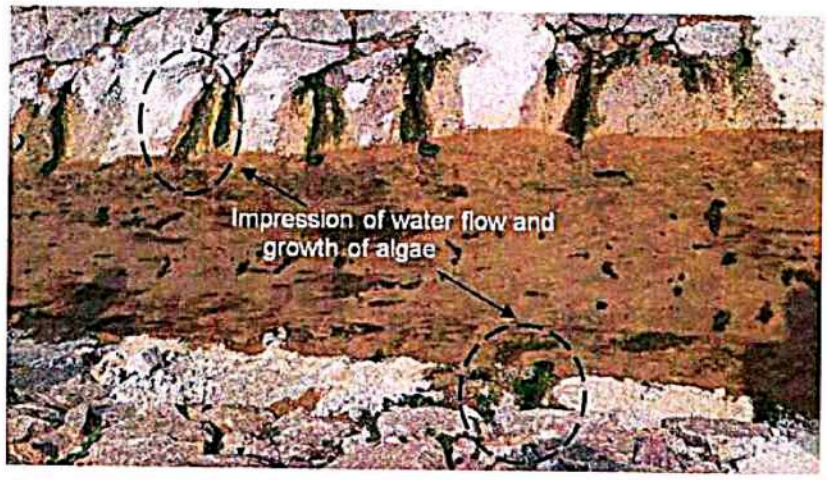


Figure 5: Wetness and algae growth in toe drain at Ch. 13.6 km

Figure 6: Cross drains on downstream slope at Ch. 13.6 km

v) **Location 5 - Reach III:** Location 5 was at the downstream toe of chainage 15.6 km at which the dam height is maximum (59.59 m). Existing water head at this location was 29 m which is more than half the total head applicable for this section (54.39 m) after complete filling of reservoir up to FRL (557 m). Flow of water through toe drain was observed at this location also, with measured discharge quantity of 1.9 litre/sec. Installation of turfing was ongoing at this location. Before placement of turfing, a layer of black cotton soil was dumped on the downstream slope over which grass was laid [Fig. 7]. It was informed by the project authorities that at this location during excavation of COT, slushy clay layer was encountered in the foundation. To increase stability of the dam, clay layer was excavated up to 2 m depth on both upstream and downstream side and was replaced by casing soil material (Zone 3). Sand drains of 4 m depth were also provided below dam base on downstream side to expedite consolidation and strength gain of the clay layer.

Figure 7: Installation of turfing on downstream slope at Ch 15.6 km

vi) **Location 6 - Reach III:** The maximum height cross-section at Ch. 15.6 km was inspected from dam top. On the upstream slope, pitching work above RL 542.2 m was ongoing. PCC profile walls at 30 m c/c distance were constructed initially; the space between which was later being filled with stones (Fig. 8).

Figure 8: Upstream slope of earth dam at Ch. 15.6 km

Figure 9: Downstream slope of earth dam at Ch. 15.6 km

vii) Location 7- Reach III (Hillock portion): Ch. 16.3 to Ch. 16.7 km in Reach III is the hill rock portion where hard rock below dam base level was encountered in foundation. Rocky morphology on the downstream side at this chainage is shown in Fig. 10. At this location, the natural ground surface is inclined, with upstream toe level at lower elevation than downstream toe level. The dam height at this location is 40.1 m and existing water head was 10.9 m. It was informed that before construction of the dam, foundation rock was treated to enhance bonding between HDR and soil for dam construction. Also in this portion, additional foundation grouting apart from grouting below CoT, was implemented in two rows of grout curtains up to 15 m depth from dam base level on upstream and downstream side. Support wall to provide additional shearing support to the rocktoe was constructed at downstream toe (Fig. 11).

Figure 10: Rocky morphology on downstream side of hill rock portion

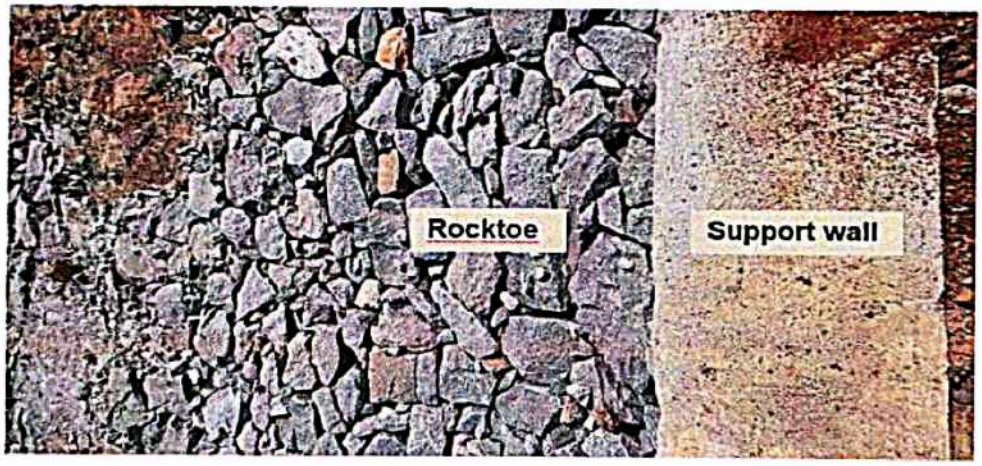


Figure 11: Support wall at downstream toe in hillrock region

viii) **Location 8 - Reach IV:** Length of the dam from Ch. 18.625 km to Ch.19.925 km (1.3 km) in Reach IV is known as the tank bed portion. Inspection of this portion was conducted at Ch.18.85 km. Dam height at this location is 49.4 m and existing water head was 20.2 m. It was informed that in the tank bed portion, slushy soil mixed with lime was encountered in the foundation. During construction of the dam, this foundation soil up to 6 m depth was removed and the dam base was laid at the excavated level i.e. 6 m below the natural/ stripped ground level. Clean water was seen to be flowing in toe drain at this location. As the turfing work was not complete, soil from downstream slope was seen to be washed away due to rain and deposited in rocktoe [Fig. 12]. It was suggested to clear the deposited soil to enable free draining of seepage water through rocktoe. Stone pitching is considered to be better for downstream slope protection in comparison to turfing. Inadequately maintained turfing may lead to soil erosion from slope surface during rainfall. To avoid recurring effort and expenditure towards maintenance of turfing, it was suggested to use stone pitching, at least at critical dam locations.

Figure 12: Deposition of soil in rocktoe at Ch 18.85 km (tank bed portion)

4.0 Meeting at site office and data collection

After the site visit, discussion was held with project authorities at site office for clarifications regarding data to be adopted in analysis. Some additional data was also collected. During meeting, it was informed that instruments to measure pore pressure, settlement, earth pressure, etc. were installed in the dam body at five cross-sections; two in Reach I and one each in Reach II, III and IV. Project authorities were requested to provide the recorded instrumentation data to CWPRS to compare the measured values with those obtained from analysis. Following data were collected during the meeting:

i) L-section of Reach IV indicating ground level at upstream toe, downstream toe and dam center line

ii) L-section of Reach IV with foundation strata, COT details, grouting details, values of pre and post grouting permeability of foundation

iii) Instrumentation drawing for cross-section of height 50 m.

5.0 Meeting at the office of Irrigation and CAD, Hyderabad

A meeting was held with Shi B. Hariram, Engineer-in-Chief at the office of I&CAD Department, Hyderabad to discuss overall observations and suggestions related to the inspection of earth dam of Mallannasagar reservoir. Following recommendations are made with respect to stability of the dam:

i) CWPRS will conduct following studies for three dam cross-sections viz. maximum height cross-section at Ch. 15.6 km, tank bed portion and hillock portion.

   a) Limit equilibrium slope stability studies (static and pseudo-static) for upstream and downstream slopes

   b) Seepage studies using 2D numerical modeling to assess seepage characteristics

   Based on the results of studies, modifications in the cross-sections/ remedial measures from seepage and stability point of view will be recommended if required. The analysis for section 'I' i.e. maximum height cross-section at Ch. 15.6 km will be conducted on priority basis and interim results of the same will be submitted at the earliest.

ii) The locations on downstream side where flowing water is observed in toe drain should be critically inspected. The discharge in toe drain should be monitored periodically with respect to (a) reservoir water level, (b) stream water level and (c) seasonal variations to enable determine the source of water. The downstream slope should be monitored for wet patches, uneven / dense vegetation growth, which may be indication of seepage.

iii) The turfing on downstream slope should be maintained adequately so as to prevent drying of grass. The turfing if not maintained adequately may lead to soil erosion causing instability in the downstream slope and blocking of rocktoe. The rocktoe if blocked may prevent free drainage of seepage water through filter, building undue pore pressures in downstream zone of the dam. In view of importance of the structure and also to avoid recurring efforts and expenditure towards maintenance of turfing, it is suggested to use stone pitching instead of turfing; at least at critical locations. The already blocked rocktoe at some locations where turfing has not been installed should be cleared of soil deposits.

Overall the site visit was informative as various aspects of earth dam construction could be witnessed. Discussions with project authorities were helpful in finalizing inputs for proposed studies. CWPRS officers are thankful to Shri B. Hariram, Engineer –in –Chief; Shri K.S.S. Chandrasekhar, Chief Engineer; Smt. Anita, AEE and other officers and staff of I&CAD Department, Gajwel and Hyderabad for their co-operation and arrangements during the tour and site visit.

FEEDBACK FORM ON COMPLETION OF STUDIES
(DESK / MATHEMATICAL MODEL / PHYSICAL MODEL STUDIES)

1 **Name and designation of Issuing Officer** : Engineer-in-chief (Irrigation), Irrigation and CAD Department (I & CAD) Gajwel, Siddipet District

2 **Address** : Irrigation and CAD Department (I & CAD) Gajwel, Siddipet District- 502278

3 **Details of work awarded**

i) Name of the Work : Geotechnical studies for seepage and stability analysis of zoned earth dam of Mallannasagar reservoir, Telangana

ii) Work order/ Estimate No. & Year/Month/Date : D-7847/GE-II/D of August 2021

iii) Date of Commencement of Work : August, 2021

iv) Stipulated date of completion : January, 2022

v) Actual date of completion : March, 2022

vi) Estimated amount of work order : Rs. 15,16,060/-

CUSTOMER SATISFACTION SURVEY

Name & designation of officer (project)	
Signature	
Name of the Organization	

As part of CWPRS commitment to continuous improvement, we would appreciate your assessment on how we have performed in conducting studies. Please circle the appropriate number below using the following scales and fax / send (email) this form back to the address of Director, CWPRS, Khadakwasla, Pune - 411024

Performance Scale

5 - Outstanding, 4 – Very Good, 3 – Good, 2 - Satisfactory, 1 - Not Satisfactory

Service Aspect	Your Satisfaction with our Performance
1. Did we plan the job well?	1 2 3 4 5
2. Did our people behave well to your people?	1 2 3 4 5
3. Were we proactive in solving problem?	1 2 3 4 5
4. Did we respond promptly?	1 2 3 4 5
5. Did we work effectively?	1 2 3 4 5
6. Were we available when you needed us?	1 2 3 4 5
7. Did we keep you sufficiently informed about the progress?	1 2 3 4 5
8. Do you feel that we provided appropriate expertise?	1 2 3 4 5
9. Did we maintain an appropriate balance between services and value?	1 2 3 4 5
10. Did our status report provide the information you expected?	1 2 3 4 5
11. Did we deliver on time?	1 2 3 4 5
12. Did we meet your expectation? (Overall evaluation)?	1 2 3 4 5
13. Were accounts department serviced your promptly?	1 2 3 4 5
14. To what extant do you feel comfortable with recommending us to others .	1 2 3 4 5
15. How do you rate our services with those of our competitors?	1 2 3 4 5

General Comments / Feedback in work

Seal and signature of project authority

To,
Director,
Central Water & Power Research Station,
Sinhagad Road, Khadakwasla, Pune -24, Email: director@cwprs.gov.in

VISION

To be a world-class centre of excellence in hydraulic engineering research and allied areas; which is responsive to changing global scenario, and need for sustaining and enhancing excellence in providing technological solutions for optimal and safe design of water resources structures.

MISSION

- To meet the country's need for basic & applied research in water resources, power sector and coastal engineering with world-class standards
- To develop competence in deployment of latest technologies by networking with the top institutions globally, to meet the future needs for development of water resources projects in the country effectively
- To disseminate information, build skills and knowledge for capacity-building and mass awareness for optimization of available water resources

MAJOR FUNCTIONS

- Undertaking specific research studies relating to development of water resources, power and coastal projects
- Consultancy and advisory services to Central and State Governments, private sector and other countries
- Disseminating research findings and promoting/assisting research activities in other organizations concerned with water resources projects
- Contributions to Bureau of Indian Standards and International Standards Organization
- Carrying out basic and applied research to support the specific studies
- Contribution towards advancements in technology through participation in various committees at National and State Levels

The Director,

Central Water and Power Research Station

Khadakwasala, Sinhgad Road, Pune 411 024. Maharashtra

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रजिस्ट्री सं॰ डी॰ एल॰—(एन)04/0007/2003—21 REGISTERED NO. DL—(N)04/0007/2003—21

भारत का राजपत्र
The Gazette of India

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असाधारण
EXTRAORDINARY
भाग II — खण्ड 1
PART II — Section 1
प्राधिकार से प्रकाशित
PUBLISHED BY AUTHORITY

सं॰ 58] नई दिल्ली, मंगलवार, दिसम्बर 14, 2021/ अग्रहायण 23, 1943 (शक)
No. 58] NEW DELHI, TUESDAY, DECEMBER 14, 2021/AGRAHAYANA 23, 1943 (SAKA)

इस भाग में भिन्न पृष्ठ संख्या दी जाती है जिससे कि यह अलग संकलन के रूप में रखा जा सके।
Separate paging is given to this Part in order that it may be filed as a separate compilation.

MINISTRY OF LAW AND JUSTICE
(Legislative Department)

New Delhi, the 14*th December,* 2021/*Agrahayana* 23, 1943 (*Saka*)

The following Act of Parliament received the assent of the President on the 13th December, 2021, and is hereby published for general information:—

THE DAM SAFETY ACT, 2021

No. 41 OF 2021

[13*th December*, 2021.]

An Act to provide for surveillance, inspection, operation and maintenance of the specified dam for prevention of dam failure related disasters and to provide for institutional mechanism to ensure their safe functioning and for matters connected therewith or incidental thereto.

BE it enacted by Parliament in the Seventy-second Year of the Republic of India as follows:—

CHAPTER I

PRELIMINARY

1. (*1*) This Act may be called the Dam Safety Act, 2021. Short title, extent and commencement.

(*2*) It extends to the whole of India.

(*3*) It shall come into force on such date as the Central Government may, by notification in the Official Gazette, appoint.

2. It is hereby declared that it is expedient in the public interest that the Union should take under its control the regulation of uniform dam safety procedure for specified dam to the extent hereinafter provided. Declaration as to expediency of Union control.

Application.

3. Save as provided under this Act, it applies to the owner of every specified dam,—

(*a*) being a public sector undertaking or institution or a body owned or controlled by the Central Government or a State Government or jointly by one or more Governments, as the case may be; and

(*b*) being an undertaking or company or institution or a body other than those owned or controlled by the State Government or the Central Government, as the case may be.

Definitions.

4. In this Act, unless the context otherwise requires,—

(*a*) "alteration of dam" means alterations or repairs as may directly affect the safety of the dam or reservoir;

(*b*) "annual report" means a report giving the activities of the Authority and the State Dam Safety Organisation and the safety status of the specified dams falling under their jurisdiction during each financial year;

(*c*) "appurtenant structure" means the structure being—

(*i*) spillways, either in the dam or separate therefrom;

(*ii*) low level outlet structure and water conduits such as tunnels, pipelines or penstocks, either through the dam or its abutments or reservoir rim;

(*iii*) hydro-mechanical equipment including gate, valve, hoist, elevators;

(*iv*) energy dissipation and river training structure; and

(*v*) other associated structures acting integrally with the dam or its reservoir or reservoir rim;

(*d*) "Authority" means the National Dam Safety Authority established under section 8;

(*e*) "dam" means any artificial barrier and its appurtenant structure constructed across rivers or tributaries thereof with a view to impound or divert water which also include barrage, weir and similar water impounding structures but does not include—

(*a*) canal, aquaduct, navigation channel and similar water conveyance structures;

(*b*) flood embankment, dike, guide bund and similar flow regulation structures;

(*f*) "dam failure" means any failure of the structure or operation of a dam which leads to uncontrolled flow of impounded water resulting in downstream flooding, affecting the life and property of the people and the environment including flora, fauna and riverine ecology.

Explanation.—For the purposes of this clause, failure in the operation shall mean such faulty operations of the dam which are inconsistent with the operation and maintenance manual;

(*g*) "dam incident" means all such problems occurring to a dam that have not degraded into a dam failure, and includes—

(*i*) any structural damage to the dam and the appurtenant structure;

(*ii*) any unusual reading of any instrument in the dam;

(*iii*) any unusual seepage or leakage through the dam body;

(*iv*) any unusual change in the seepage or leakage regime;

(*v*) any boiling or artesian condition noticed below the dam;

(*vi*) any sudden stoppage or unusual reduction in seepage or leakage from the foundation or body of the dam or any of its galleries;

(*vii*) any malfunction or inappropriate operation of gates;

(*viii*) occurrence of flood, the peak of which exceeds the available flood discharge capacity of the dam or seventy per cent. of the approved design flood;

(*ix*) occurrence of flood, which resulted in encroachment on the available freeboard, or the approved design freeboard;

(*x*) any unusual erosion in the near vicinity up to five hundred metres downstream of the spillway or waste-weir; and

(*xi*) any other occurrence which a prudent dam engineer may relate to dam safety concerns;

(*h*) "dam safety unit" means a dam safety unit of any specified dam referred to in section 30;

(*i*) "distress condition" means the occurrence or potential development of such conditions in the dam or appurtenance structure or its reservoir or reservoir rim, which if left unattended to, may impede the safe operation of dam for its intended benefits or may pose serious risks to the life and property of people and the environment including flora, fauna and riverine ecology;

(*j*) "documentation" means all permanent records including electronic records concerning investigation, design, construction, operation, performance, maintenance, major repair, alteration, enlargement and safety of dams and includes design memorandum, construction drawings, geological reports, reports of specialised studies simulating structural and hydraulic response of the dam, changes made in design and drawings, quality control records, emergency action plan, operation and maintenance manual, instrumentation readings, inspection and testing reports, operational reports, and dam safety review reports and other similar reports;

(*k*) "enlargement of dam" means any change in the scope of an existing dam or reservoir, which raises water storage elevation or increases the volume of water impounded by the dam;

(*l*) "Government" means the Central Government or a State Government, as the case may be;

(*m*) "inspection" means on-site examination of any component of a dam and its appurtenant structure;

(*n*) "investigation" means collection of evidence, detailed examination, analysis or scrutiny of a specific problem pertaining to the dam and its appurtenant or a part thereof and includes laboratory testing, in-situ testing, geological exploration, model testing and mathematical simulation of the problem;

(*o*) "National Committee" means the National Committee on Dam Safety constituted under section 5;

(*p*) "notification" means a notification published in the Official Gazette and the term "notify" shall be construed accordingly;

(*q*) "operation of dam" means elements of the use, control and functioning of the dam which may primarily affect the storage, release of water and the structural safety of the dam;

(*r*) "operation and maintenance manual" means the written instructions that provide operation procedures, maintenance procedures, emergency procedures and any other features necessary for the safe operation of dam;

(*s*) "owner of specified dam" means the Central Government or a State Government or jointly by one or more Governments or public sector undertaking or local authority or company and any or all of such persons or organisations, who own, control, operate, or maintain a specified dam;

(*t*) "prescribed" means prescribed by rules made by the Central Government or, as the case may be, by the State Government;

(*u*) "regulations" means the regulations made by the Authority under this Act;

(*v*) "remedial measures" means such structural or non-structural measures, as may be required in relation to the specified dam or appurtenant structure or reservoir or reservoir rim or catchment area of reservoir for the purpose of removing or mitigating the distress condition of the specified dam;

(*w*) "reservoir" in relation to a dam shall mean any spread of water impounded by a specified dam;

(*x*) "specified dam" means a dam constructed before or after the commencement of this Act, which is,—

(*i*) above fifteen metres in height, measured from the lowest portion of the general foundation area to the top of dam; or

(*ii*) between ten metres to fifteen metres in height and satisfies at least one of the following, namely:—

(*A*) the length of crest is not less than five hundred metres; or

(*B*) the capacity of the reservoir formed by the dam is not less than one million cubic metres; or

(*C*) the maximum flood discharge dealt with by the dam is not less than two thousand cubic metres per second; or

(*D*) the dam has specially difficult foundation problems; or

(*E*) the dam is of unusual design;

(*y*) "State Committee" means the State Committee on Dam Safety constituted under sub-section (*1*) of section 11;

(*z*) "State Dam Safety Organisation" means the State Dam Safety Organisation established under section 14; and

(*za*) "vulnerability and hazard classification" means the system or systems of classifying dams on the basis of their condition, location, damage or hazard potential.

CHAPTER II

NATIONAL COMMITTEE ON DAM SAFETY

Constitution of National Committee.

5. (*1*) With effect from such date as the Central Government may, by notification, appoint, there shall be constituted, for the purposes of this Act, a National Committee to be known as the National Committee on Dam Safety consisting of the following members, namely:—

(*a*) the Chairman, Central Water Commission—Chairperson, *ex officio*;

(*b*) not exceeding ten representatives of the Central Government not below the rank of Joint Secretary to that Government or equivalent dealing with matters relating to dam engineering or dam safety, nominated by the Central Government —Members, *ex officio*;

(*c*) not exceeding seven representatives of the State Governments of the level of Engineer-in-Chief or equivalent by rotation, nominated by the Central Government —Members, *ex officio*; and

(*d*) not exceeding three specialists in the field of dam safety and allied fields nominated by the Central Government—Members.

(*2*) The National Committee shall be constituted within a period of sixty days from the date of commencement of this Act, and shall be reconstituted for every three years thereafter.

Functions of National Committee.

6. (*1*) The National Committee shall discharge such functions as specified in the First Schedule as may be necessary to prevent dam failure related disasters and to maintain standards of dam safety.

(*2*) The National Committee may, in discharge of its functions, constitute such sub-committees as it may consider necessary to assist it and the secretarial assistance to the National Committee and the sub-committees shall be provided by the Authority.

(*3*) The knowledge and information collected or generated by the National Committee shall be disseminated to all stakeholders by the Authority.

Meetings of National Committee.

7. (*1*) The National Committee shall meet at such times and places and shall observe such rules of procedure in regard to the transaction of business at its meetings in the manner as may be prescribed by the Central Government:

Provided that the National Committee shall meet twice in a year and one meeting shall be held before the onset of the monsoon season.

(*2*) The National Committee may invite the representative of the owner of any specified dam and such other experts in dam safety (including international experts) as it may consider appropriate for the discharge of its functions.

(*3*) The expenditure incurred on the National Committee shall be in such manner as may be prescribed by the Central Government.

CHAPTER III

NATIONAL DAM SAFETY AUTHORITY

Establishment of National Dam Safety Authority.

8. (*1*) With effect from such date as the Central Government may by notification, appoint, there shall be established for the purposes of this Act, a National Dam Safety Authority, within a period of sixty days from the date of commencement of this Act.

(*2*) The Authority shall be headed by an officer not below the rank of Additional Secretary to the Government of India or equivalent to be appointed by the Central Government who have knowledge of, and adequate qualification, experience and capacity in, dealing with problems relating to the dam engineering and dam safety management.

(*3*) The headquarters of the Authority shall be at the National Capital territory of Delhi and the Authority may establish offices at other places in India.

(*4*) The Authority shall comply with such directions as may, from time to time, be given to it by the Central Government.

Functions of Authority.

9. (*1*) The Authority shall discharge such functions as specified in the Second Schedule as may be necessary to implement the policy, guidelines and standards evolved by the National Committee for proper surveillance, inspection and maintenance of specified dams and for such purposes, it shall have the power to enforce the attendance of any person and call for any information as may be necessary.

(*2*) Without prejudice to the provisions contained in sub-section (*1*), the Authority shall make all endeavours to resolve any issue between the State Dam Safety Organisations of States or between a State Dam Safety Organisation and any owner of a specified dam in that State.

(*3*) Every decision of the Authority taken in respect of matters under this Act shall be final and binding upon all the parties to the issue.

Officers and Employees of Authority.

10. (*1*) The Central Government shall, for the purpose of enabling the Authority to perform functions under this Act, provide such number of officers and other employees as it may consider necessary:

Provided that the officers and other employees shall have such qualifications and experience in the field of dam safety including dam-design, hydro-mechanical engineering, hydrology, geo-technical investigation, instrumentation, dam-rehabilitation or such other fields as may be prescribed by the Central Government.

(*2*) The functions, powers, terms and conditions of service of the officers and other employees appointed under sub-section (*1*) shall be such as may be prescribed by the Central Government.

CHAPTER IV

STATE COMMITTEE ON DAM SAFETY

Constitution of State Committee on Dam Safety.

11. (*1*) With effect from such date as the State Government may, by notification, appoint, there shall be constituted, for the purposes of this Act, a State Committee on Dam Safety consisting of the following members, namely:—

(*a*) the Engineer-in-Chief or equivalent officer of the Department of the State responsible for Dam Safety—Chairperson, *ex officio;*

(*b*) technical and scientific officers of the rank of Chief Engineer, not exceeding six persons, from such Departments as may be decided by the State Government or from such other organisations owing specified dams—Members;

(*c*) the Chief Engineer or equivalent level officer of each such upstream States in cases where reservoir area of any of the specified dam of the State extends to another State—Members;

(*d*) the Chief Engineer or equivalent level officer of each such downstream State in cases where flood release of any of the specified dam of the State flows to a neighbouring State—Members;

(*e*) one representative of the Central Water Commission not below the rank of Director to be nominated by the Chairman, Central Water Commission—Member;

(*f*) experts in the field of hydrology or dam designs, not exceeding three, from engineering institutes—Members; and

(*g*) one representative of the Central Electricity Authority not below the rank of Director to be nominated by the Chairman, Central Electricity Authority—Member.

(*2*) The State Committee shall be constituted within a period of hundred and eighty days from the date of commencement of this Act, and reconstituted for every three years thereafter.

Functions of State Committee.

12. (*1*) The State Committee shall discharge such functions as specified in the Third Schedule as may be necessary to prevent dam failure related disasters under this Act as per guidelines, standards and other directions on dam safety issued by the Authority.

(*2*) The State Committee, in discharge of its functions, shall be assisted by such sub-committees as it may consider necessary, and the secretarial assistance to the State Committee as well as its sub-committees shall be provided by the concerned State Dam Safety Organisation.

Meetings of State Committee.

13. (*1*) The State Committee shall meet at such times and places and shall observe such rules of procedure in regard to the transaction of business at its meetings as may be prescribed by the State Government:

Provided that the State Committee shall meet twice in a year and one meeting shall be held before the onset of the monsoon season.

(2) The State Committee may invite the representative of the owner of any specified dam and such other experts in Dam Safety as it may consider appropriate, for the discharge of its functions.

(3) The expenditure incurred on the meetings of the State Committee shall be in the manner as may be prescribed by the State Government.

(4) The specialist members and other expert invitees who attend the meetings of the State Committee or its sub-committees shall be paid such fees and allowances as may be prescribed by the State Government.

CHAPTER V

STATE DAM SAFETY ORGANISATION

Establishment of State Dam Safety Organisation.

14. (1) The State Government shall, for the purposes of this Act, by notification, establish in the Department dealing with dam safety, a separate organisation, to be known as the State Dam Safety Organisation, within a period of hundred and eighty days from the date of commencement of this Act:

Provided that in States having more than thirty specified dams, the State Dam Safety Organisation shall be headed by an officer not below the rank of Chief Engineer or equivalent, and in all other cases, the State Dam Safety Organisation shall be headed by an officer not below the rank of Superintendent Engineer or equivalent.

(2) The State Dam Safety Organisation shall be responsible to, and report to, the technical head of the Department dealing with Dam Safety.

(3) The organisational structure and work procedures of the State Dam Safety Organisation shall be such as may be prescribed by the State Government.

(4) The administrative and other expenses of the State Dam Safety Organisation shall be borne by the respective State Government.

Officers and employees of State Dam Safety Organisation.

15. (1) The State Government shall, having regard to the number of specified dams in that State, provide such number of officers and employees to the State Dam Safety Organisation as it may consider necessary for the efficient functioning of the said Organisation:

Provided that the officers and employees shall have such qualifications and experience in the field of dam safety including dam-design, hydro-mechanical engineering, hydrology, geo-technical investigation, instrumentation, dam-rehabilitation or such other field as may be prescribed by the State Government.

(2) The functions and powers of the officers and employees appointed under sub-section (1) shall be such as may be prescribed by the State Government.

CHAPTER VI

DUTIES AND FUNCTIONS IN RELATION TO DAM SAFETY

Surveillance and inspection.

16. (1) Every State Dam Safety Organisation shall,—

(a) keep perpetual surveillance;

(b) carry out inspections; and

(c) monitor the operation and maintenance,

of all specified dams falling under their jurisdiction to ensure continued safety of such specified dams and take such measures as may be necessary to address safety concerns that are noticed with a view to achieve satisfactory level of dam safety assurance as per such guidelines, standards and other directions on dam safety as may be specified by the regulations.

(2) The State Dam Safety Organisation, for the purpose of enabling it to make decisions compatible with public safety, shall make or cause to be made such investigations and shall

gather or cause to be gathered such data as may be required for proper review and study of the various features of the design, construction, repair and enlargement of dams, reservoirs and appurtenant structures under their jurisdiction.

Vulnerability and hazard classification of dams.

17. The State Dam Safety Organisation shall classify each dam under their jurisdiction as per such vulnerability and hazard classification criteria as may be specified by the regulations.

Maintenance of log books.

18. (*1*) Every State Dam Safety Organisation shall maintain a log book or database for each specified dam under their jurisdiction recording therein all activities related to the surveillance and inspection and all important events related to dam safety and with such details and in such form as may be specified by the regulations.

(*2*) Every State Dam Safety Organisation shall furnish all such information to the Authority as and when required by them.

Records of dam failures and dam incidents.

19. (*1*) Every State Dam Safety Organisation shall report the event of any dam failure under their jurisdiction to the Authority, and furnish any information as and when required by them.

(*2*) Every State Dam Safety Organisation shall maintain the records of major dam incidents of each specified dams under their jurisdiction, and furnish all such information to the Authority as and when required by them.

Instructions on safety of specified dams.

20. (*1*) Every State Dam Safety Organisation shall render its instructions to the owner of a specified dam on the safety or the remedial measures required to be taken with respect to it.

(*2*) Every owner of the specified dam shall comply with the instructions issued by the State Dam Safety Organisation with regard to safety or remedial measures in relation to any specified dam owned by it.

Funds for maintenance and repairs.

21. Every owner of the specified dam shall earmark sufficient and specific funds for maintenance and repairs of the specified dam and to implement the recommendations of the State Dam Safety Organisation.

Technical documentation.

22. (*1*) Every owner of the specified dam shall compile all technical documentations concerning hydrology, dam foundation, structural engineering of dam, watershed upstream of dam, and nature or use of land downstream of dam along with information on all resources or facilities of economic, logistic or environmental importance which are likely to be affected due to dam failure.

(*2*) Every owner of the specified dam shall furnish all such information to the State Dam Safety Organisation and the Authority as and when required by them.

(*3*) Every owner of the specified dam shall equip its organisation with the state-of-the-art information technology tools to store, retrieve, and distribute the data related to the dam safety and dam performance.

Qualifications and experience of individuals responsible for safety of specified dams.

23. Every individual responsible for safety of specified dams and all activities related thereto shall possess such qualifications and experience and shall undergo such training as may be specified by the regulations.

Jurisdiction of State Dam Safety Organisation and Authority.

24. (*1*) Without prejudice to the provisions of this Act, all specified dams, shall fall under the jurisdiction of the State Dam Safety Organisation of the State in which such dam is situated in matters relating to dam inspections, analysis of information, investigation reports or recommendations regarding safety status, and remedial measures to be undertaken

to improve dam safety; and in all such matters, full co-operation shall be extended by the owner of the specified dam:

Provided that where a specified dam is owned by a Central Public Sector Undertaking or where a specified dam is extended over two or more States, or where the specified dam in one State is owned by another State, then the Authority shall be construed as the State Dam Safety Organisation for the purposes of this Act:

Provided further that in all such dams where the Authority takes up the role of State Dam Safety Organisation, the Governments of the States within the jurisdiction of which such dams are located shall have access to all information relating to these specified dams as available with the Authority.

(*2*) The authorised representative of the Authority or concerned State Dam Safety Organisation for the purposes of making any inspection or investigation necessary for the implementation of the provisions of this Act, may enter upon any part of the specified dam or its site as and when required and apply such investigation methods, as may be considered necessary.

(*3*) After making inspection or investigation under sub-section (*2*), the representative referred to in that sub-section is of the opinion that certain remedial measures are required to be taken, he shall report such remedial measures to the officer-in-charge of such specified dam and to the concerned State Dam Safety Organisation.

(*4*) The Authority and concerned State Dam Safety Organisation, in cases of specified dams being found to be distressed on account of their age, degeneration, degradation, structural or other impediments, shall suggest such remedial measures on such operational parameters (including maximum reservoir level, maximum spillway discharge and maximum discharges through other outlets) as it may consider necessary.

(*5*) Nothing contained in sub-sections (*1*), (*2*), (*3*) and (*4*) shall absolve the owner of specified dam or any other authority or person from any of the responsibilities or obligations entrusted upon it under the provisions of this Act and the provisions of sub-sections (*1*), (*2*), (*3*) and (*4*) shall be in addition to, and not in derogation of, any other provision of this Act.

Cost of investigation.

25. All the costs to be incurred by the Authority or State Dam Safety Organisation on any form of investigation done including payment given to any consultant or expert, shall be borne by the owner of the specified dam.

Construction or alteration of dams.

26. (*1*) Any construction or alteration of a specified dam shall be undertaken subject to investigation, design and construction being done by such agencies as may be accredited by the Authority or the State Government, as the case may be:

Provided that the Authority may disqualify any agency which violates any of the provisions of this Act or the rules or regulations made thereunder.

(*2*) Every agency referred to in sub-section (*1*) shall, for the purpose of designing or evaluating the safety of the specified dam, make use of the relevant standard codes and guidelines of the Bureau of Indian Standards, and furnish the reasons, if any departure is made in the design or dam safety evaluation.

(*3*) Every agency referred to in sub-section (*1*) shall for the purpose of investigation, design and construction employ such qualified, experienced and competent engineers, as may be specified by the regulations.

(*4*) Every agency referred to in sub-section (*1*) shall for the purpose of approval of dam design demonstrate the safety of the design, operational parameters and policies as per the provisions of relevant codes and guidelines to the Central Government or the State Government, as the case may be.

(*5*) Every agency referred to in sub-section (*1*) shall, for the purpose of dam construction, undertake such quality control measures, as may be specified by the regulations.

(*6*) The construction of any specified dam or the alteration or enlargement of any existing specified dam shall be undertaken with the approval of such competent authority, as may be specified by notification by the Central Government or the State Government, as the case may be.

Initial filling of reservoirs.

27. (*1*) Before initial filling of any reservoir of a specified dam, the agency responsible for its design shall draw the filling criteria and prepare an initial filling plan, with adequate time for monitoring and evaluating the performance of the dam and its appurtenant structures.

(*2*) Before initial filling of the reservoir is taken up, the State Dam Safety Organisation shall inspect or cause to be inspected the specified dam either through its own engineers or by an independent panel of experts, who shall also examine the initial filling programme and prepare a detailed report thereof duly certifying the fitness of dam for filling.

Operation and maintenance.

28. (*1*) Every owner of the specified dam shall provide operation and maintenance establishment for the specified dam, and shall ensure that sufficient number of trained operation and maintenance engineers or technical persons are posted at each such dam.

(*2*) Every owner of the specified dam shall ensure that a well-documented operation and maintenance manual is kept at each of the specified dams and are followed at all times.

Responsibility of owner of specified dam.

29. Nothing contained in this Act shall be construed to absolve an owner of a specified dam of the duties, obligations or liabilities incidental to the construction, operation, maintenance and supervision of the dam or reservoir.

CHAPTER VII

SAFETY, INSPECTION AND DATA COLLECTION

Dam safety unit.

30. For each specified dam, the owner shall, within the operation and maintenance establishment, provide a dam safety unit consisting of such competent levels of engineers as may be specified by the regulations.

Inspection.

31. (*1*) Every owner of a specified dam shall undertake every year, through their dam safety unit, a pre-monsoon and post-monsoon inspections in respect of each such dam.

(*2*) Without prejudice to sub-section (*1*), every owner of a specified dam shall inspect or cause to be inspected every specified dam by the dam safety unit, during and after every flood, earthquake or any other natural or man-made calamities, or if any sign of distress or unusual behaviour is noticed in the dam.

(*3*) Every owner of a specified dam shall,—

(*a*) carry out all inspections referred to in sub-section (*1*) and sub-section (*2*) in accordance with the guidelines and check-lists as may be specified by the regulations;

(*b*) station, at each of the specified dam site throughout the monsoon period, such engineers and other technical personnel, as may be decided, in consultation with the State Dam Safety Organisation:

Provided that the engineers and other technical personnel shall be required to be stationed at their respective dam sites during entire period of emergency following any other natural or man-made calamity that may create distress conditions in the dam; and

(*c*) forward the inspection report by the dam safety unit to the State Dam Safety Organisation, which shall analyse the report and submit comments on the deficiency and remedial measures, if any, to the owner of the specified dam.

Instrumentations to be installed in every specified dam.

32. (*1*) Every owner of a specified dam shall have a minimum number of such instrumentations at each specified dam, and installed in such manner as may be specified by the regulations for monitoring the performance of such dam.

(2) Every owner of the specified dam shall maintain a record of readings of the instrumentations referred to in sub-section (1) and forward the analysis of such readings to the State Dam Safety Organisation, in the form, manner and at such interval as may be specified by the regulations.

Establishment of hydro-meteorological station.

33. (1) Every owner of a specified dam shall establish a hydro-meteorological station in the vicinity of each specified dam capable of recording such data as may be specified by the regulations.

(2) Every owner of the specified dam shall collect, compile, process and store data referred to in sub-section (1) at a suitable location.

Installations of seismological station.

34. (1) In the case of every specified dam, having a height of thirty metres or above or falling under such seismic zone, as may be specified by the regulations, the owner of the specified dam shall establish a seismological station in the vicinity of each such dam for recording micro and strong motion earthquakes and such other data as may be specified by the regulations.

(2) Every owner of a specified dam shall collect, compile, process and store data referred to in sub-section (1) at such suitable location and in such manner as may be specified by the regulations.

CHAPTER VIII

EMERGENCY ACTION PLAN AND DISASTER MANAGEMENT

Obligation of owner of specified dam.

35. (1) Every owner of a specified dam, in respect of each specified dam, shall,—

(*a*) establish well designed hydro-meteorological network and an inflow forecasting system;

(*b*) establish an emergency flood warning system for the probable flood affected areas downstream of the dam;

(*c*) test or cause to be tested periodically the functioning of systems referred to in clauses (*a*) and (*b*);

(*d*) install such scientific and technical instruments which are invented or adopted from time to time for the purpose of ensuring the dam safety and the life and property of people downstream;

(*e*) make available the information relating to maximum anticipated inflows and outflows including flood warning and an adverse impact of the same, if any, on persons and property towards the upstream or downstream of the dam, to the concerned district authorities and also make available the information in public domain; and

(*f*) render necessary assistance to the Authority in establishment and running of the early warning system for the exchange of real time hydrological and meteorological data and information related to the operation of reservoirs.

(2) Every owner of a specified dam, for each of its dam shall, carry out risk assessment studies at such interval as may be specified by the regulations and the first such study shall be made within five years from the date of commencement of this Act.

Emergency action plan.

36. (1) Every owner of a specified dam, in respect of each of specified dam, shall,—

(*a*) prepare emergency action plan before allowing the initial filling of the reservoir and thereafter update such plans at regular intervals;

(*b*) in respect of the dam which is constructed and filled before the commencement of this Act, prepare emergency action plan within five years from the date of commencement of this Act and thereafter update such plans at regular intervals as may be specified by the regulations.

(2) The emergency action plan referred to in sub-section (1) shall,—

(a) set out the procedures to be followed for the protection of persons and property upstream or downstream of the specified dam in the event of an actual or imminent dam failure or to mitigate the effects of the disaster;

(b) include therein,—

(i) the type of emergencies which are likely to occur in the operation of any reservoir;

(ii) identification of the likely catastrophic flood in the event of any dam failure, along with probable areas, population, structures and installations likely to be adversely affected due to flood water released from the reservoir;

(iii) warning procedures, inundation maps and advance preparations for handling efficiently and in the best possible manner the likely adverse situations especially to avoid loss of human life;

(iv) such other matters which may having regard to the geographical conditions, size of the dam and other relevant factors as may be necessary.

(3) The emergency action plan under this section shall be put into action as and when conditions arise which are hazardous or likely to be hazardous to a specified dam or potentially hazardous to public safety, infrastructure, other property or to the environment.

(4) Every owner of the specified dam shall, while preparing and updating the emergency action plan, undertake a consultation process with all disaster management agencies and other Departments of the State entrusted with disaster management and relief in the area likely to be affected and owners of other dams in the immediate vicinity likely to be affected, so as to bring coordination and transparency and allay any unwarranted fear on dam safety issues.

Assistance to other disaster management authorities.

37. Without prejudice to the provisions of this Act or liability of the owner of the specified dam and other organisations and authorities under this Act, every owner, organisation and authority shall render necessary assistance, if so required by any authority under any law for the time being in force to meet or mitigate any disaster or emergency arising out of the specified dams.

CHAPTER IX

COMPREHENSIVE DAM SAFETY EVALUATION

Comprehensive dam safety evaluation.

38. (1) The owner of a specified dam shall make or cause to be made comprehensive dam safety evaluation of each specified dam through an independent panel of experts constituted as per regulations for the purpose of determining the conditions of the specified dam and its reservoir:

Provided that the first comprehensive dam safety evaluation for each existing specified dam shall be conducted within five years from the date of commencement of this Act, and thereafter the comprehensive dam safety evaluation of each such dam shall be carried out at regular intervals as may be specified by the regulations.

(2) The comprehensive dam safety evaluation shall consists of, but not be limited to,—

(a) review and analysis of available data on the design, construction, operation, maintenance and performance of the structure;

(b) general assessment of hydrologic and hydraulic conditions with mandatory review of design floods as specified by the regulations;

(c) general assessment of seismic safety of specified dam with mandatory site specific seismic parameters study in certain cases as specified by the regulations;

(*d*) evaluation of the operation, maintenance and inspection procedures; and

(*e*) evaluation of any other conditions which constitute a hazard to the integrity of the structure.

Compulsory evaluation in certain cases.

39. The comprehensive dam safety evaluation referred to in section 38 shall be compulsory in the case of,—

(*a*) major modification to the original structure or design criteria;

(*b*) discovery of an unusual condition at the dam or reservoir rim; and

(*c*) an extreme hydrological or seismic event.

Reports of comprehensive evaluation.

40. (*1*) The owner of a specified dam shall report the results of the dam safety evaluation undertaken under section 38 or section 39 to the State Dam Safety Organisation.

(*2*) The reports referred to in sub-section (*1*) shall include, but not be limited to,—

(*a*) assessment of the condition of the structure based on the visual observations and available data on the design, hydrology, construction, operation, maintenance and performance of the structure;

(*b*) recommendations for any emergency measures or actions, if required, to assure the immediate safety of the structure;

(*c*) recommendations for remedial measures and actions related to design, construction, operation, maintenance and inspection of the structure, if required;

(*d*) recommendations for additional detailed studies, investigations and analysis, if required; and

(*e*) recommendations for improvements in routine maintenance and inspection of dam, if required.

(*3*) Where the safety evaluations undertaken under section 38 or section 39, results in recommendations for a remedial action, the State Dam Safety Organisation shall pursue with the owner of the specified dam to ensure that remedial measures are carried out in time, for which the owner shall provide adequate funds.

(*4*) Where there is any unresolved matter emerging between an independent panel of experts referred to in sub section (*1*) of section 38 and the owner of the specified dam, the matter shall be referred to the State Dam Safety Organisation, and, in case no agreement is arrived at, the matter shall be referred to the Authority which shall render its advice and send recommendations to the State Government concerned for implementation.

CHAPTER X

OFFENCES AND PENALTIES

Punishment for obstruction, etc.

41. Whoever, without reasonable cause,—

(*a*) obstructs any officer or employee of the Central Government or the State Government, or a person authorised by the National Committee or the Authority or the State Committee or the State Dam Safety Organisation in the discharge of his functions under this Act; or

(*b*) refuses to comply with any direction given by or on behalf of the Central Government or the State Government or the National Committee or the Authority or the State Committee or the State Dam Safety Organisation under this Act,

shall be punishable with imprisonment for a term which may extend to one year or with fine, or with both, and if such obstruction or refusal to comply with directions results in loss of lives or imminent danger thereof, shall be punishable with imprisonment for a term which may extend to two years.

Offences by Departments of Government.

42. (*1*) Where an offence under this Act has been committed by a Department of the Government, the head of the Department shall be deemed to be guilty of the offence and shall be liable to be proceeded against and punished accordingly unless he proves that the offence was committed without his knowledge or that he exercised all due diligence to prevent the commission of such offence.

(*2*) Notwithstanding anything contained in sub-section (*1*), where an offence under this Act has been committed by a Department of the Government and it is proved that the offence has been committed with the consent or connivance of, or is attributable to any neglect on the part of, any officer, other than the head of the Department, such officer shall be deemed to be guilty of that offence and shall be liable to be proceeded against and punished accordingly.

Offence by companies.

43. (*1*) Where an offence under this Act has been committed by a company or body corporate, every person who at the time the offence was committed, was in charge of, and was responsible to, the company, for the conduct of the business of the company, as well as the company, shall be deemed to be guilty of the contravention and shall be liable to be proceeded against and punished accordingly:

Provided that nothing in this sub-section shall render any such person liable to any punishment provided in this Act, if he proves that the offence was committed without his knowledge or that he exercised due diligence to prevent the commission of such offence.

(*2*) Notwithstanding anything contained in sub-section (*1*), where an offence under this Act has been committed by a company, and it is proved that the offence was committed with the consent or connivance of, or is attributable to any neglect on the part of any director, manager, secretary or other officer of the company, such director, manager, secretary or other officer shall also, be deemed to be guilty of that offence and shall be liable to be proceeded against and punished accordingly.

Explanation.—For the purpose of this section—

(*a*) "company" means any body corporate and includes a firm or other association of individuals; and

(*b*) "director", in relation to a firm, means a partner in the firm.

Cognizance of offences.

44. (*1*) No court shall take cognizance of any offence punishable under this Act, except on a complaint made by the Central Government or the State Government or a person authorised in this behalf by the National Committee or the Authority or the State Committee or the State Dam Safety Organisation, as the case may be.

(*2*) No court inferior to that of a Metropolitan Magistrate or a Judicial Magistrate of the first class shall try any offence punishable under this Act.

CHAPTER XI

MISCELLANEOUS

Annual report of safety status of specified dam.

45. (*1*) Every State Dam Safety Organisation shall prepare annual report, within three months of the expiry of the preceding financial year, of its activities and safety status of specified dams in the State and such report shall be forwarded to the Authority and State Government and that Government shall cause the same to be laid before each House of the State Legislature, where it consists of two Houses or where such Legislature consists of one House, before that House.

(*2*) Every State Dam Safety Organisation and every owner of a specified dam shall provide to the Authority, documentation of the projects, report of enquiries into failure and any other data, as and when required in such format and in such manner as may be decided by the Authority.

(*3*) The Authority, shall prepare a consolidated annual report of the dam safety activities in the country and submit the same to the Central Government within six months of the

expiry of the preceding financial year and that Government shall cause the same to be laid before each House of Parliament.

(*4*) The Authority shall forward its annual report on the safety status of specified dams to the National Disaster Management Authority and also make available such report in public domain.

(*5*) The State Dam Safety Organisation of each State shall forward their annual report to the concerned State Disaster Management Authority and also make available such report in public domain.

Safety measures in respect of dams other than specified dams.

46. Every owner of the dam other than specified dams shall undertake such measures as may be necessary to ensure dam safety and shall comply with such measures as may be specified by the regulations.

Safety measures in respect of dams located outside territory of India.

47. Where a dam, including a dam created due to landslides or glacial moraine, is located outside the territory of India and the Authority *suo motu* or on receipt of information from any person or organisation or authority or source *prima facie* is of the opinion that measures are required to be taken to ensure safety of such dams and failure of which may endanger the life and property of people located in India, it shall in writing submit an intimation thereof to the Central Government indicating therein the likely damages which may arise due to failure of such dams and the safety measures required to be taken in respect of such dam and the Central Government shall take all suitable measures to mitigate any possible threat.

Act to have overriding effect.

48. The provisions of this Act shall have effect notwithstanding anything inconsistent therewith contained in any other law for the time being in force.

Power to amend Schedules.

49. (*1*) If the Central Government is satisfied that it is necessary or expedient so to do, it may, by notification, amend the First Schedule, the Second Schedule or the Third Schedule and thereupon the Schedules, shall be deemed to have been amended accordingly.

(*2*) A copy of every notification made under sub-section (*1*) shall be laid before each House of Parliament as soon as may be after it is made.

Power of Central Government to give directions.

50. The Central Government may give such directions, as it may consider necessary, to the State Government where that Government is the owner of the specified dam and to the owner of a specified dam in any other case for the effective implementation of the provisions of this Act.

Vacancies, etc., not to invalidate proceedings of National Committee on Dam Safety Authority and State Committee on Dam Safety.

51. No act or proceedings of the National Committee, the Authority and the State Committee shall be invalid merely by reason of—

(*a*) any vacancy in, or any defect in the constitution of, the Authority; or

(*b*) any defect in the appointment of a person acting as a member of the Authority; or

(*c*) any irregularity in the procedure of the Authority not affecting the merits of the case.

Power of Central Government to make rules.

52. (*1*) The Central Government may, by notification, make rules to carry out the provisions of this Act.

(*2*) In particular, and without prejudice to the foregoing power, such rules may provide for all or any of the following matters, namely:—

(*a*) the time and place of the meetings of the National Committee and the procedure to be followed at such meetings under sub-section (*1*) of section 7 and the expenditure incurred on the meetings of the National Committee under sub-section (*3*) of section 7;

(*b*) the qualifications and experience of the officers and other employee of the Authority in the field of dam safety or such other field under sub-section (*1*) of section 10;

(*c*) the functions, powers, and terms and conditions of service of other officers and other employees of the Authority under sub-section (*2*) of section 10;

(*d*) any other matter which is to be, or may be, prescribed or in respect of which provision is to be made by the Central Government by rules.

Power of State Government to make rules.

53. (*1*) The State Government may, by notification, make rules to carry out the provisions of this Act.

(*2*) In particular, and without prejudice to the foregoing power, such rules may provide for all or any of the following matters, namely:—

(*a*) the times and places of the meetings of the State Committee and the procedure to be followed at such meetings under sub-section (*1*) of section 13;

(*b*) the expenditure incurred on the meetings of the State Committee under sub-section (*3*) of section 13;

(*c*) the fee and allowances paid to the specialist members or expert invitees of the State Committee or its sub-committees under sub-section (*4*) of section 13;

(*d*) the organisational structure and work procedure of State Dam Safety Organisation under sub-section (*3*) of section 14;

(*e*) the qualifications and experience of the officers and other employees of the State Dam Safety Organisation in the field of dam safety or such other field under sub-section (*1*) of section 15;

(*f*) the functions, powers, and terms and conditions of service of the employees of the State Dam Safety Organisation under sub-section (*2*) of section 15;

(*g*) the dam safety measures in respect of dams other than specified dams under section 46;

(*h*) any other matter which is to be, or may be, prescribed or in respect of which provision is to be made by the State Government by rules.

(*3*) Every rule made by a State Government under this Act shall be laid, as soon as may be after it is made, before the State Legislature, where it consists of two Houses, or where such legislature consists of one House, before that House.

Power to make regulations by Authority.

54. (*1*) The Authority on the recommendations of the National Committee may make regulations consistent with this Act and the rules made thereunder to carry out the provisions of this Act.

(*2*) In particular, and without prejudice to the generality of the foregoing power, such regulations may provide for all or any of the following matters, namely:—

(*a*) the guidelines, standards and other directions for achieving the satisfactory level of dam safety assurance under sub-section (*1*) of section 16;

(*b*) the vulnerability and hazard classification criteria of specified dams under section 17;

(*c*) the details and form pertaining to the maintenance of log books or database under sub-section (*1*) of section 18;

(*d*) the qualifications, experience and training of the individuals responsible for safety of specified dams under section 23;

(*e*) the employment of competent engineers and their qualifications and experience for the purpose of investigation, design and construction of specified dams under sub-section (*3*) of section 26;

(*f*) the quality control measures for the purpose of dam construction under sub-section (*5*) of section 26;

(*g*) the level of competent engineers for the dam safety units under section 30;

(*h*) the guidelines and check-lists for inspection of specified dams under clause (*a*) of sub-section (*3*) of section 31;

(*i*) the minimum number of set of instrumentations in the specified dams and the manner of their installation under sub-section (*1*) of section 32;

(*j*) the form, manner and time interval for forwarding the analysis of readings to the State Dam Safety Organisation under sub-section (*2*) of section 32;

(*k*) the data requirements of hydro-meteorological stations in the vicinity of specified dams under sub-section (*1*) of section 33;

(*l*) the data requirements of seismological stations in the vicinity of specified dams under sub-section (*1*) of section 34;

(*m*) the suitable location and manner of collection, compliance, process and storage of data under sub-section (*2*) of section 34;

(*n*) the time interval of risk assessment studies to be carried out under sub-section (*2*) of section 35;

(*o*) time interval for updating the emergency action plan under clause (*b*) of sub-section (*1*) of section 36;

(*p*) the time interval for the comprehensive safety evaluation of specified dams under sub-section (*1*) of section 38;

(*q*) the mandatory review of design flood of existing specified dams under clause (*b*) of sub-section (*2*) of section 38;

(*r*) the mandatory site specific seismic parameter studies of existing specified dams under clause (*c*) of sub-section (*2*) of section 38;

(*s*) the measures necessary to ensure dam safety by every owner of dam other than specified dams under section 46;

(*t*) any other matter which is to be specified or in respect of which provision is to be made by the Authority.

Rules and regulations to be laid before Parliament.

55. Every rule and every regulation made by the Central Government under this Act shall be laid, as soon as may be after it is made, before each House of Parliament, while it is in session, for a total period of thirty days which may be comprised in one session or in two or more successive sessions, and if, before the expiry of the session immediately following the session or the successive sessions aforesaid, both Houses agree in making any modification in the rule or regulation or both Houses agree that the rule or regulation should not be made, the rule or regulation shall thereafter have effect only in such modified form or be of no effect, as the case may be; so, however, that any such modification or annulment shall be without prejudice to the validity of anything previously done under that rule or regulation.

Power to remove difficulties.

56. (*1*) If any difficulty arises in giving effect to the provisions of this Act, the Central Government may, by order, published in the Official Gazette, make such provisions not inconsistent with the provisions of this Act, as may appear it to be necessary or expedient for removing the difficulty:

Provided that no order shall be made under this section after the expiry of three years from the date of commencement of this Act.

(*2*) Every order made under this section shall, as soon as may be after it is made, be laid before each House of Parliament.

THE FIRST SCHEDULE

[*See* section 6(*1*)]

FUNCTIONS OF NATIONAL COMMITTEE ON DAM SAFETY

1. For the purposes of maintaining standards of dam safety and prevention of dam failure related disasters, evolve dam safety policies and recommend necessary regulations as may be required;

2. act as a forum for exchange of views on techniques to be adopted for remedial measures to relieve distress conditions in specified dams and appurtenant structures;

3. analyse the causes of major dam incidents and dam failures and suggest changes in the planning, specifications, construction, operation and maintenance practices in order to avoid recurrence of such incidents and failures;

4. evolve comprehensive dam safety management approach as an integration of dam safety evaluation, risk assessment and risk management for the desired level of safety assurance; and also explore compensations, by means of insurance coverage for the people affected by dam failures;

5. render advice on any specific matter relating to dam safety which may be referred to it by the Central Government or the State Government, as the case may be;

6. make recommendations on a request by the Central Government on safety measures in respect of dams located outside the territory of India;

7. make recommendations on the rehabilitation requirements of ageing dams;

8. provide strategic supervision for such dam rehabilitation programmes that are executed in States through central or externally aided funding;

9. identify areas of research and development for dam safety and recommend for provision of funds;

10. make recommendations on the coordinated reservoir operations of cascading dams; and

11. any other specific matter relating to dam safety which may be referred to it by the Central Government.

THE SECOND SCHEDULE

[*See* section 9(*1*)]

FUNCTIONS OF NATIONAL DAM SAFETY AUTHORITY

1. For the purpose of maintaining standards of dam safety and prevention of dam failure related disasters, discharge such functions as related to implementation of the policies made by the National Committee including making regulations on the recommendations of the National Committee;

2. resolve any issue between the State Dam Safety Organisations of States or between a State Dam Safety Organisation and any owner of a specified dam in that State;

3. provide the state-of-the-art technical and managerial assistance to the State Dam Safety Organisations;

4. maintain a national level database of all specified dams in the country, including serious distress conditions, if any, noticed therein;

5. maintain liaison with the State Dam Safety Organisations and the owners of the specified dams for standardisation of dam safety related data and practices, and related technical or managerial assistance;

6. lay down guidelines and check-lists for the routine inspection and detailed investigation of the specified dams and appurtenant structures;

7. maintain the records of major dam failures in the country;

8. examine, as and when necessary, either through its own engineers or through a panel of experts, the cause of any major dam failure, and submit its report to the National Committee;

9. examine whenever required, either through its own engineers or through a panel of experts, the cause of any major public safety concern in respect of any specified dam, and issue appropriate instructions relating to further investigations, operational parameters or remedial measures;

10. lay down the uniform criteria for vulnerability and hazard classification of the specified dams in the country, and review such criteria as and when necessary;

11. give directions regarding maintenance of log books or database;

12. give directions regarding qualifications and experience requirements of individuals responsible for safety of the specified dams;

13. accord accreditations to the agencies that may be entrusted with the investigation, design, construction and alteration of the specified dams;

14. disqualify any agency for taking up investigation, design, construction or alteration of the specified dams, if it violates any of the regulations made under this Act;

15. give directions regarding qualification and experience requirements of individuals responsible for investigation, design and construction of the specified dams;

16. give directions regarding quality control measures to be undertaken during construction of the specified dams;

17. lay down guidelines for preventive measures in the areas vulnerable to landslides in the vicinity of a specified dam under construction;

18. give directions regarding competent levels of engineers in the dam safety units of the specified dams on the basis of vulnerability and hazard classification of such dams;

19. give directions regarding instrumentation requirements and manner of their installation for monitoring the performance of the specified dams;

20. give directions regarding data requirements of hydro-meteorological stations in the vicinity of the specified dams;

21. give directions regarding data requirements of seismological stations in the vicinity of the specified dams;

22. give directions regarding time interval for the risk assessment studies of the specified dams on the basis of vulnerability and hazard classification of such dams;

23. give directions regarding time interval for updating the emergency action plans of the specified dams on the basis of vulnerability and hazard classification of such dams;

24. give directions regarding constitution of independent panel of experts for comprehensive dam safety evaluation of the specified dams;

25. give directions regarding time interval for the comprehensive safety evaluation of the specified dams on the basis of vulnerability and hazard classification of such dams;

26. lay down guidelines for review of design floods of existing the specified dams;

27. lay down guidelines for review of site specific seismic parameter studies of the specified dams;

28. establishment of an early warning system incorporating appropriate framework for the exchange of real time hydrological and meteorological data and information related to operation of reservoirs by the owner of a dam;

29. promote general education and awareness in relation to dam safety;

30. provide secretarial assistance to the National Committee and its sub-committees;

31. provide coordination and overall supervision of dam rehabilitation programmes that are executed in States through central or externally aided funding; and

32. any other specific matter relating to dam safety which may be referred to it by the Central Government.

THE THIRD SCHEDULE

[*See* section 12(*1*)]

FUNCTIONS OF STATE COMMITTEE ON DAM SAFETY

1. For the purpose of maintaining standards of dam safety and prevention of dam failure related disasters, discharge such functions as may be necessary as per the guidelines, standards and other directions issued by the Authority;

2. review the work done by the State Dam Safety Organisation;

3. establish priorities for investigations in case of specified dams under distress condition;

4. in cases where investigations with respect to safety of any specified dam in the State had already been undertaken, to order further investigations in relation to safety of such specified dam and assign responsibilities for execution including the use of non-departmental resources, and association of independent experts where necessary;

5. recommend the appropriate measures to be taken in relation to the safety of the specified dam which is under distress condition;

6. establish priorities among projects requiring remedial safety works;

7. review the progress on measures recommended in relation to dam safety;

8. assess potential implication of reservoir filling of a specified dam in the State on any upstream State, and coordinate mitigation measures with such upstream States;

9. assess potential implication of failure of a specified dam in the State on any downstream State, and coordinate mitigation measures with such downstream States;

10. assess probability of cascading dam failure, and coordinate mitigation measures with all concerned, including bordering States;

11. recommend provision of funds for the purpose of planned and appropriately phased rehabilitation of ageing dams in the State;

12. provide strategic supervision for such dam improvement and rehabilitation programmes that are executed through State funding; and

13. any other specific matter relating to dam safety which may be referred to it by the State Government.

DR. REETA VASISHTA,
Secretary to the Govt. of India.

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MGIPMRND—1589GI(S3)—14-12-2021.

Annexure -IV

सी एस आइ आर - राष्ट्रीय भूभौतिकीय अनुसंधान संस्थान
(वैज्ञानिक तथा औद्योगिक अनुसंधान परिषद्)
पो.ब. सं. 724 उप्पल रोड़, हैदराबाद-500 007, तेलंगाणा, भारत
CSIR - NATIONAL GEOPHYSICAL RESEARCH INSTITUTE
(Council of Scientific & Industrial Research)
Post Bag # 724, Uppal Road, Hyderabad - 500 007, T.S., INDIA

डॉ. प्रकाश कुमार, एफ एन ए एससी
निदेशक
Dr. Prakash Kumar, FNASc
Director

February 29, 2024

To

The Engineer-in Chief
2nd Floor, Integrated Office Complex
Sangapoor Road, Gajwel,
Siddipet District 502278

DEE

Sub: Kaleshwaram Project – Formation of Sri Komaravelli Mallanna Sagar Reservoir- Seismic study -Reg.

Ref: Lr. No. SE/IC/GJL/DCE/DEE-4/AEE-1/SKMS/2023-24/369 dated 21-2-2024

Dear Sir,

AEE)

With reference to the letter cited, it is recommended to carry out continuous seismic monitoring of the reservoir as per CWC guidelines. CSIR-NGRI has submitted a detailed proposal to Mallanna Sagar Reservoir authorities in this regard.

In addition, it is also recommended to carry out a seismic safety audit of the structure by a team of Civil Engineering / Structural Engineering experts.

Best Regards,

29/2/2024

(Dr. Prakash Kumar)
डॉ. प्रकाश कुमार - निदेशक
Dr. Prakash Kumar - Director
सी एस आई आर - राष्ट्रीय भूभौतिकीय अनुसंधान संस्थान
CSIR - National Geophysical Research Institute
उप्पल रोड, हैदराबाद - 500 007, तेलंगाणा, भारत
Uppal Road, Hyderabad-500 007, Telangana, India

[P.T.O]

फोन / Phone: 040-2343 4600
फैक्स / Fax : 040-2343 4651, 2717 1564
वेब साइट / Web site: www.ngri.org.in
ई-मेल / E mail : director@ngri.res.in
pk.ngri.csir@gmail.com

GOVERNMENT OF TELANGANA
IRRIGATION &CAD DEPARTMENT

From
Sri G.Anil Kumar,M.Tech
Engineer-in-Chief (General), FAC
I & CAD Dept, ErrumManzil,
Hyderabad, Telangana.

To
The Secretary to Government,
I&CAD Department, 4th Floor-24,
Dr.B.R.Ambedkar Telangana Secretariat,
Hyderabad.

Lr.No.ENC(G)/Dy.ENC(G)/DCE KB/OT6/AEE15/SKMS Dt:25.05.2024

Sir

Sub:- I & CAD Department - Kaleshwaram Project - "Formation of Sri Komaravelli Mallanna Sagar Reservoir with a Capacity of 50 TMC - Formation of Earth Bund with all associated components for Reach-4 from Km 16.700 to Km 22.900 along with its structures and adjoining with Reach-3 at Km 16.700 and saddle bund of 1.600 KM length" - Request for permission for depositing the required funds towards seismic monitoring of Sri Komaravelli Mallanna Sagar Reservoir by CSIR-NGRI- Reg.

Ref:- 1.ENC(I), Gajwel Lr.No.ENC(I)/GJL/DCE/DEE4/AEE1/SKMS/Vol-IV/2024/995, Dt:10.05.2024
2.Chief Scientist, CSIR-NGRI proposal dt:20.02.2024

&&&&

The Engineer-in-Chief (Gajwel) vide reference cited has requested to communicate orders of the Government for depositing an amount of Rs.534.325 Lakhs to CSIR-NGRI, Hyderabad towards Seismic Monitoring of Sri Komaravelli Mallanna Sagar Reservoir for a period of five years by CSIR-NGRI from available provision of Rs.639.5763 Lakhs in sanctioned estimate of Sri Komaravelli Mallanna Sagar Reach-4.

The Engineer-in-Chief(I), Gajwel reported as below:

As per the suggestion of Chief Engineer, Central designs organization, Hyderabad, the Executive Engineer, Irrigation Division No.6, Gajwel has addressed the Director, CSIR-NGRI, Hyderabad for conducting the site-specific seismic studies pertaining to Sri Komaravelli Mallanna sagar Reservoir. Subsequently, the Chief Scientist, NGRI, Hyderabad along with his team visited the site and conducted Ground Penetration Radar (GPR) studies. As per the results, the Chief Scientist, NGRI has submitted a Preliminary Seismo-tectonic and GPR studies Appraisal (Overview) around Mallanna sagar Project vide their letter dt: 23.08.2018 and concluded as follows:

"The above preliminary data clearly suggests; it is a deep seated vertical fault with significant strike slip motion. The rocks in the fault zone are highly sheared and fractured. Further there is at least three sets of dominant lineaments with distinct geomorphic signatures are observed in the region. To characterize their effect on shallow subsurface and understand their mutual relationship, it will be appropriate to conduct detailed survey with planned profile orientations. The same is proposed for future work for the region".

Further, the NGRI has reported that it has carried out GPR survey at site and as per the latitude and longitude of the location (aa' @ N 17°57.451', E 78°47.915'; 65m length and bb' @ N 17°57.469', E 78°47.942'; 68 m length) it falls nearby FRL at (+)557.000M and away from the bund alignment of the SKMS reservoir, where the ground level is almost (+)557.000m. The water column at the location where GPR survey conducted by NGRI is zero for the reservoir full capacity of 50 TMC (+ 557.000 m).

The excavation of the Cut-off Trench (COT) is taken up along the center line of the bund alignment based on the bore hole data. COT is excavated up to hard strata as per the COT guidelines issued by Chief Engineer, CDO, Hyderabad. On completion of excavation, Geologist from Geological Survey of India (GSI) has inspected regularly and conducted mapping of COT strata. The Geologist from GSI has also suggested the actual COT depth, grouting depth and its pattern based on the mapping.

It is to inform that, as per I.S.Code 1893-Part-I Sri Komaravelli Mallannasagar Reservoir falls under Seismic Zone-II category (lowest seismicity level). During the design of earth bund, basic horizontal seismic coefficients (ao=0.02 as per Table-2 of I.S: 1893- 1984) is considered and designed accordingly by Chief Engineer, Central Designs Organization, Hyderabad.

Subsequently the Executive Engineer, Irrigation Division No.6, Gajwel has requested the Director NGRI, Hyderabad vide letter 05.07.2022 to depute the concerned to finalize the location of installation of seismometer. Accordingly, the Chief Scientist, Head, Seismology, CSIR-NGRI, Hyderabad had visited the site on August 16, 2022 for selection of suitable site for installation of seismic instruments and made the following recommendations which was forwarded by the Senior Principal Scientist, Seismological Observatory, CSIR-NGRI to the

Executive Engineer, Irrigation Division No.6, Gajwel through email dated 23rd August 2022.

1. Installation of four Strong Motion Accelerographs (SMA) for continuous seismic monitoring of the Earth bund; three SMAs may be installed in the Earth bund at locations Km.2.90, km.11.62 and km.19.05 and one SMA at the free field location away from the Earth bund
2. Installation of one Seismograph near the earth bund for continuous monitoring of seismicity around the earth bund and delineation of active faults/ lineaments
3. A suitable site has been selected near the Guest house (under construction) in the Department premises for the installation of a seismograph. A seismic vault and a recording room should be constructed for installation and operation of seismograph.

The Executive Engineer, vide letter 29.01.2024 had requested the Director CSIR-NGRI, Hyderabad to furnish the proposal for Supplying and installation of recommended seismic instruments for monitoring the seismic activity excluding the civil works of Sri Komaravelli Mallanna Sagar.

At this juncture, it is to submit that as per Dam Safety Act- December-2021 Part-II- Section-I-Chapter-VII Clause no.34(1), every specified dam having a height of **thirty meters** and above or falling under such seismic zone, as may be specified by the regulations, the owner of the specified dam shall establish a seismological station in the vicinity of each such dam for recording micro and strong motion earthquakes and such other data as may be specified by the regulations.

During the performance audit of Kaleshwaram Project, the Comptroller and Auditor General of India has pointed out the aspect of seismic studies and as per their report for the year 2024 has recommended to conduct detailed seismic studies for Sri Komaravelli Mallanna Sagar.

The Director, NGRI, Hyderabad was requested vide letter 21.02.2024 to furnish the expert opinion on seismic studies for Sri Komaravelli Mallanna Sagar. In response to the above, the NGRI vide their letter dt:29.02.2024 has recommended to carry out continuous seismic monitoring of the reservoir as per

CWC guidelines and stated that a detailed proposal has been submitted to the Mallanna sagar authorities in this regard.

In view of the guidelines of Dam Safety Act-2021 and the recommendations of CSIR-NGRI, Hyderabad scientists, a proposal was requested from CSIR-NGRI, Hyderabad by the Executive Engineer, Irrigation Division No.6, Gajwel for Supplying and Installation of recommended seismic instruments for monitoring the seismic activity.

In response, CSIR-NGRI, Hyderabad has submitted a detailed proposal for an amount of Rs.534.325 lakhs towards Seismic Monitoring of Sri Komaravelli Mallanna Sagar Reservoir for five years. The scope of works includes the following:

- Monitoring of Seismicity of the region.
- Delineation of seismically active faults/lineaments.
- Determination of Peak Ground Acceleration (PGA) levels of the dam structure during the occurrence of near field earthquakes.

The Programme of work with phasing, milestones and deliverable envisaged from CSIR-NGRI are

- Procurement of Broadband Seismographs and Strong Motion Accelero-graphs
- Site preparation
- Installation of one Broad band Seismograph(BBS) in the Dam premises and
- three more seismographs around the reservoir.
- Installation of three Strong Motion Accelerographs (SMA)in the Earth bund structure and one in the free field.
- Operation and Maintenance of seismological instruments.
- Seismological Data collection.
- Operation and maintenance of Central Recording Station at CSIR-NGRI, Hyderabad.
- Monitoring the state of health of the seismic network periodically
- Seismic Data Processing and Interpretation
- Submission of preliminary earthquake report of significant events.
- Submission of Annual event report.

The total cost for the Seismic Monitoring of Sri Komaravelli Mallanna Sagar Reservoir as worked out by CSIR-NGRI is Rs.534.325 Lakhs.

In the sanctioned estimate of SKMS Reach-4 a provision was made in Part-III item no.(a) towards Detail investigation, design preparation of drawings and estimates, sub-soil exploration etc. for Rs.680.54 Lakhs.

From the above provision, an amount of Rs.40.964 Lakhs was utilized for Detailed Investigation, Geotechnical Seepage & stability studies and preparation of Emergency Action Plan of SKMS respectively. Thus, the balance available provision is Rs.639.5763 Lakhs.

It is proposed for utilization of Rs.534.325 Lakhs from the above available provision towards the payment for the purpose of Seismic Monitoring of Sri Komaravelli Mallanna Sagar Reservoir by CSIR-NGRI for five years.

In view of the above, the Engineer-in-Chief(I), Gajwel has requested to obtain permission from the Government to deposit an amount of Rs.534.325 Lakhs to CSIR-NGRI, Hyderabad towards Seismic Monitoring of Sri Komaravelli Mallanna Sagar Reservoir for a period of five years by CSIR-NGRI as per the preliminary report of Chief scientist, CSIR-NGRI from balance available provision of Rs.639.5763 Lakhs in sanctioned estimate of Sri Komaravelli Mallanna Sagar Reach-4.

As per the suggestions for further study in the preliminary report of CSIR-NGRI and as per the suggestions of Chief scientist, CSIR-NGRI for continuous Seismic Monitoring of Sri Komaravelli Mallanna Sagar Reservoir for a period of five years, it is requested to accord permission for depositing an amount of Rs.534.325 Lakhs as per the schedule of payments; from the balance available provision of Rs.639.5763 Lakhs in sanctioned estimate of Sri Komaravelli Mallanna Sagar Reach-4 at an early date.

Encl: Engineer-in-Chief Letter cited

Yours faithfully
Sd/-G.Anil Kumar, dt:25.05.2024
Engineer-in-Chief(General)

Copy to the Engineer-in- Chief (I), Gajwel for information and necessary action.

DISPATCHED
ENGG IRRIGATION

T. Vijay Bhaskar 27/5/24
For Engineer-in-Chief(General)
27/5/24

Annexure -V

	PROFORMA FOR APPROVAL OF CONTRACT R&D PROJECT	

1. Project

a) Title : **Seismic Monitoring of Sri Komaravelli Mallanna Sagar Reservoir, Telangana**

b) Number & Accounting Code :

c) Type (Sponsored/Collaborative/Grant-in-aid) :

2. Client / Customer

a) Name and Address	The Executive Engineer, Irrigation Division No.6, Gajwel, Siddipet District. Telangana PIN 502278
b) Category* (Type & size) (*Govt.Dept./Agency/Voluntary/ Cooperative Agency, Research Organization, Foreign Firm/Agency, Public/Private Sector, Large/Medium/ Small / Cottage Unit)	Govt. Dept
c) Status	New
d) If it is 'repeat', please provide a brief statement of past experience	NA

3. Objectives, Scope and Duration of the project :

Objectives: Seismic Monitoring of Sri Komaravelli Mallanna Sagar Reservoir, Telangana

Scope

- Monitoring of Seismicity of the region
- Delineation of seismically active faults/lineaments
- Determination of Peak Ground Acceleration (PGA) levels of the dam structure during the occurrence of near field earthquakes.

Duration: No. of Years:	Date of Start	Date of Completion
5 years	Date of work order	

4. Does the activity fall within the approved research areas of the laboratory:	Yes (Seismology)

5. Present state of knowledge available with lab in the area including IPR position:

- CSIR-NGRI is a pioneering institute in seismic monitoring of Dams.
- It is operating seismic Networks around Koyna-Warna Reservoirs in Maharashtra for the past five decades.
- It also operating seismic stations at Nagarjunasagar, Srisailam and Sriramsagar reservoirs in

Andhra Pradesh and Telangana states, since 1981.

- An aftershock study was carried out by installing a four-station seismic network around Pulichintala Reservoir after an M4.6 magnitude earthquake that occurred on January 26, 2020 near the Pulichintala reservoir, felt in Andhra Pradesh and Telangana states.
- CSIR-NGRI operates a seismic network with 15 seismic stations in Andhra Pradesh and Telangana States to monitor the regional seismicity.
- CSIR-NGRI is monitoring the Dhamni and Bhatsa Dams in Maharashtra by installing four Strong Motion Accelerographs in Dhamni dam and Six Strong Motion Accelerographs in Bhatsa dam. These are continuously operated from November 2019. In addition to that, a five station Broadband Seismograph network is continuously operated to monitor seismicity in the Palghar region from January 2019 onwards.
- An aftershock study was carried out by installing a five-station seismic network after the M4.5 magnitude earthquake that occurred on June 20, 1988 near Idukki reservoir in Kerala state.
- A digital seismograph was procured for Kerala State Electricity Board for installation at Idukki dam and also training on the operation of the seismograph and seismic data analysis was provided in 2001.
- CSIR-NGRI is carrying out seismic monitoring of Periyar, Sholayar and Mettur dams maintained by Tamil Nadu Water Resources Department (TNWRD) and 16 other dams maintained by Tamilnadu Generation and Distribution Company (TANGEDCO) through a network of five Broadband Seismographs and twenty-eight Strong Motion Accelerographs in the dam structures in Tamilnadu state.
- CSIR-NGRI also operates more than ten different seismic networks comprising more than 200 seismic stations under various projects in India.

6. Specify the S&T inputs being provided by client:

a) Programme of work with phasing, milestones and deliverables envisaged from CSIR-NGRI:	1. Procurement of Broadband Seismographs and Strong Motion Accelerographs. 2. Site preparation 3. Installation of one Broadband Seismograph (BBS) in the Dam premises and three more seismographs around the reservoir. 4. Installation of three Strong Motion Accelerographs (SMA) in the Earth bund structure and one in the free field. 5. Operation and Maintenance of seismological instruments. 6. Seismological Data collection. 7. Operation and maintenance of Central Recording Station at CSIR-NGRI, Hyderabad. 8. Monitoring the state of health of the seismic network periodically 9. Seismic Data Processing and Interpretation 10. Submission of preliminary earthquake report of significant events. 11. Submission of Annual event report.

b) Vesting of Intellectual Property Rights:	Lies with CSIR-NGRI

7. Project Team (S& T Staff) :

Name	Designation	PL / Co-PL / Member
i. Er. R. Vijayaraghavan	Chief Scientist	Project Leader
ii. Dr. M. Shekar	Principal Scientist	Co-Project Leader
iii. Dr. Nitin Sharma	Scientist	Member
iv. Dr. Pavan Kumar	Scientist	Member
v. Dr. G Suresh	Senior Tech. Officer (1)	Member
vi. Dr. D. Srinivas	Senior Tech. Officer (1)	Member

8. Financial Aspects

Particulars	Cost (₹. in Lakhs)
Project cost (five years period) (The project cost includes Manpower, TA /DA for field staff, Field expenses, Consumables, Laboratory share and Project Fee as per CSIR Guidelines)	**285.126**
GST 18%	**51.323**
Capital cost (The capital cost includes Field Seismic Equipment (five Broadband Seismographs, four Strong Motion Accelerographs and accessories) to be installed in and around Mallanna Sagar Reservoir and Data Processing and Storage Equipment to be installed at CSIR-NGRI, Hyderabad and Procurement and handling charges 5% as listed in Annexure I	**197.876**
Total cost	**534.325**

Schedule of payments to be received: (Link the payments receivable to deliverables, specify the deliverables, vis-à-vis time frame and the amount of installment receivable from client)	Amount to be paid by Demand Draft / RTGS 1. Along with the work order- 25% of the project cost + GST + Capital cost 2. After submission of 1st Annual Event Report – 15 % of the project cost + GST 3. After submission of 2nd Annual Event Report – 15 % of the project cost + GST 4. After submission of 3rd Annual Event Report – 15 % of the project cost + GST 5. After submission of 4th Annual Event Report – 15 % of the

	project cost + GST 6. After submission of 5th Annual Event Report – 15 % of the project cost + GST

- If any concession is provided on Project Fee, a note of justification may be enclosed.

9. Utilization of Intellectual Property / Knowledgebase generated :

Licensing :	
a) Exclusive/Non-Exclusive	
b) Period	
c) Envisaged Fee/Charges	
i. Lumpsum (instalments, amount, time, mode)	
ii. Recurring royalty (Period and basis)	

Remarks :

Project Leader	MLP-PL	BDG	CoFA/FAO

DECISION OF COMPETENT AUTHORITY
Director / Management Council / DG, CSIR

Copy to:	1. Project Leader	2. CoA / AO
	3. CoFA / FAO	4. BDG&PME
	5. CoSP/SPO	6. Director

Annexure-I

Seismic Monitoring of Sri Komaravelli Mallanna Sagar Reservoir

Part A. Cost estimate of Field seismological equipment

Sl.No	Item	Quantity	Unit cost (₹.in Lakhs)	Total cost (₹. in Lakhs)
Imported				
1.	Broadband Seismometer	5 Nos.	11.00	55.000
2.	Data Acquisition System	5 Nos.	6.00	30.000
3.	Strong Motion Accelerograph	4 Nos.	6.00	24.000
Indigenous				
4.	Battery (12V-100AH)	56 Nos.	0.10	5.600
5.	Solar Panel 100W	16 Nos.	0.10	1.600
6.	Solar charge controller 20A	20 Nos.	0.10	2.000
7.	Power supply / Battery charger	20 Nos.	0.20	4.000
8.	Cellular Modem	8 Nos.	0.30	2.400
9.	Data Charges	60 months	0.05	3.000
10.	Consumables	1 Lot	2.00	2.000
			Total	129.600
			GST 18%	23.328
Customs Duty + Freight + Insurance (approx.) 15% for Imported Items Sl. Nos.1 to 3				16.350
			Total A	**169.278**

Note: The cost of the field seismological equipment to be installed in and around the Mallanna sagar Reservoir. It is proposed to install one Broadband seismograph in the dam premises and three more Broadband seismographs around Mallanna sagar Reservoir (one spare unit) and also three strong motion accelerographs in the dam structure and one strong motion accelerograph at the free field site.

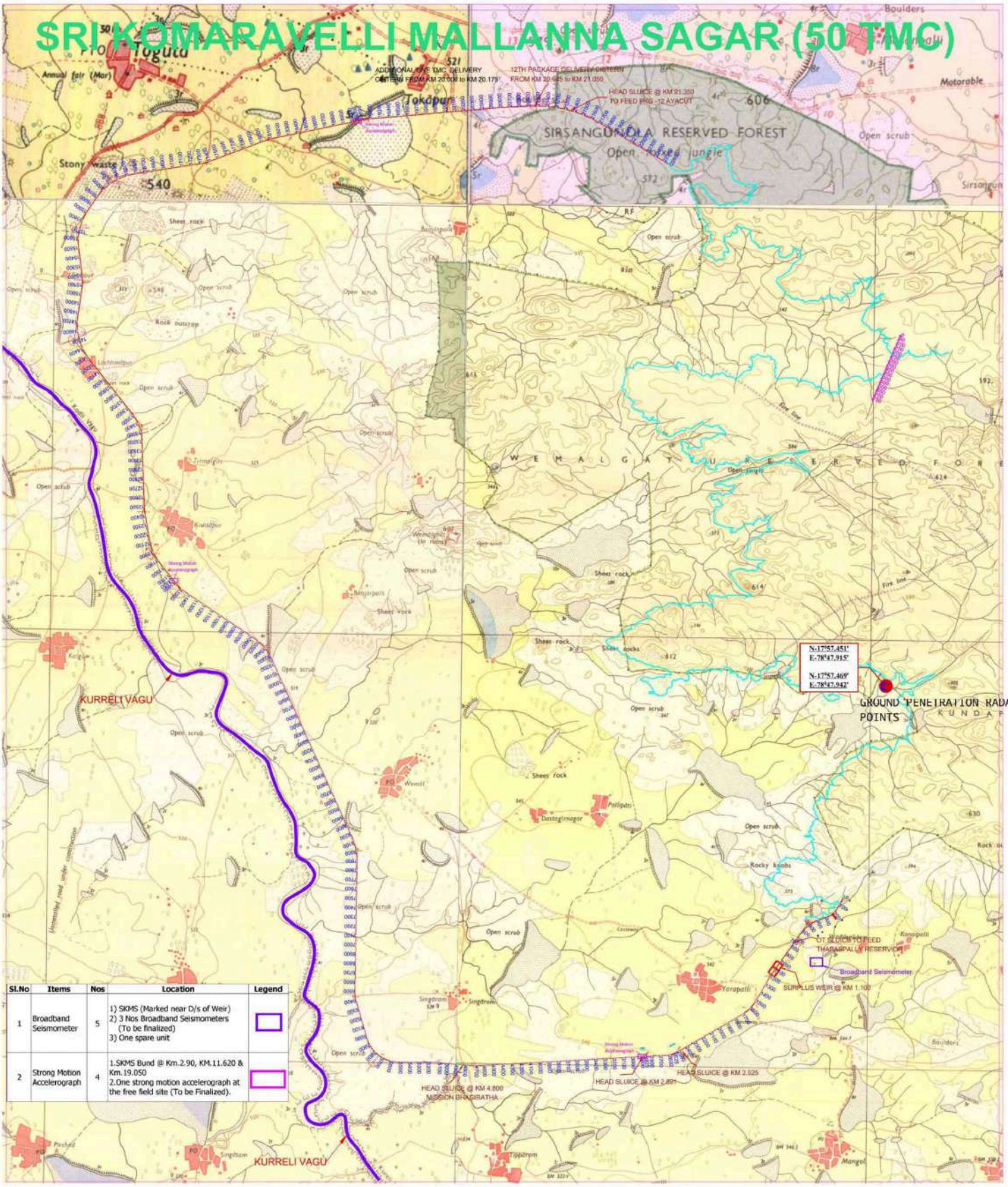
Part B. Cost estimate of Data Processing and Storage equipment

Sl.No	Item	Quantity	Unit cost (₹.in Lakhs)	Total cost (₹. in Lakhs)
Indigenous				
1.	Data Retrieval computer (Laptop computer)	1 No.	2.00	2.000
2.	Data Analysis computer (Desktop computer)	1 No.	2.00	2.000
3.	Data Analysis computer (Workstation computer)	1 No.	4.00	4.000
4.	Printer	1 No.	0.75	0.750
5.	External Storage media	10 Nos.	0.15	1.500
6.	Data Storage (NAS server)	1 No.	6.00	6.000
			Total	16.250
			GST 18%	2.925
			Total B	**19.175**

Note: The cost of the Data Processing and Data storage equipment to be installed at CSIR-NGRI.

Total (A+B)	**188.453**
Procurement and handling charges 5%	**9.423**
Total Capital cost	**197.876**

Annexure-VI



Sl.No	Items	Nos	Location	Legend
1	Broadband Seismometer	5	1) SKMS (Marked near D/s of Weir) 2) 3 Nos Broadband Seismometers (To be finalized) 3) One spare unit	
2	Strong Motion Accelerograph	4	1.SKMS Bund @ Km.2.90, KM.11.620 & Km.19.050 2.One strong motion accelerograph at the free field site (To be Finalized).	

Annexure -VII

Government of India
Ministry of Water Resources,
River Development and
Ganga Rejuvenation

भारत सरकार
जल संसाधन, नदी विकास
और गंगा संरक्षण मंत्रालय

केन्द्रीय जल और विद्युत अनुसंधान शाला

CENTRAL WATER AND POWER RESEARCH STATION

तकनीकी रिपोर्ट संख्या : 5537

अक्तूबर, 2017

TECHNICAL REPORT NO. 5537
OCTOBER, 2017

श्री कॉमरावेली मल्लन्ना सागर, सिद्दीपेट, तेलंगाना के लिए बांध सेंध अध्ययन और आपातकालीन क्रिया योजना

DAM BREAK ANALYSIS AND EMERGENCY ACTION PLAN FOR SRI KOMARAVELLI MALLANNA SAGAR, SIDDIPET, TELANGANA.

डॉ (श्रीमती) वी.वी.ओसेकर

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भारत सरकार
Government of India

संख्या. : पु.ज.व.इ/ Kaleshwaram/2017/ दि:

श्री के एन आनंद
अधिशाषी अभियंता
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आईबी बिल्डिंग की पहली मंजिल, भरत नगर
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विषय : Final report on 'Dam Break Analysis and Emergency Action Plan for Sri Komaravelli Mallanna Sagar, Siddipet, Telangana'

महोदय,

Please find enclosed the Final Technical Report No. 5537 on 'Dam Break Analysis and Emergency Action Plan for Sri Komaravelli Mallanna Sagar, Siddipet, Telangana' in duplicate for your kind perusal.

Kindly acknowledge the receipt of report along with the feedback in the prescribed format.

Thanking you,

भवदीय,

31-10-2017

(रा. सु. जगताप)
संयुक्त निदेशक

संलग्न: यथा उपरोक्त

भारत सरकार

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नदी तथा जलाशय प्रणाली प्रतिमानन
RIVER AND RESERVOIR SYSTEM MODELLING

तकनीकी रिपोर्ट संख्या 5537

अक्तूबर, 2017

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DAM BREAK ANALYSIS AND EMERGENCY ACTION PLAN FOR SRI KOMARAVELLI MALLANNA SAGAR, SIDDIPET, TELANGANA

REPORT DOCUMENT SHEET

Technical Report No.: 5537 Month and Year: October, 2017

TITLE: DAM BREAK ANALYSIS AND EMERGENCY ACTION PLAN FOR SRI KOMARAVELLI MALLANNA SAGAR, SIDDIPET, TELANGANA

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Synopsis

Irrigation and Command Area Development (I&CAD) Department of Government of Telangana State has taken up the execution of a prestigious lift irrigation project to meet various irrigation requirements of backward and drought prone areas covering uplands. The project is named as Kaleshwaram Project. One of the main components of Kaleshwaram project is Sri Komaravelli Mallana Sagar online Storage having capacity of about 50 TMC. The study is carried out to estimate the effect of flooding in the downstream of the proposed project in the case of eventuality of failure of the dam. A generalized flood routing model (unsteady flow simulation), HEC-RAS has been used to simulate the problem. Dam breach of Sri Komaravelli Mallana Sagar dam and further routing of flood through Kurelli Vaagu River for a length of about 47 km downstream is simulated in the mathematical model. It was assumed that the dam breaks when the level of water reaches top of the dam and start over topping so as to cover vulnerable senarios. Three different dam break simulations with different breach timings (18 min, 30 min and 60 min) have been carried out. Dam breach flood hydrographs and likely maximum flood water surface elevations are computed. The results estimated using 1-D mathematical model in HEC-RAS were further imported in ARC-GIS and Q-GIS for the preparation of inundation map for likely worst scenario. The villages affected nearby the right bank and left bank of study reach coming under inundation zone were marked on Toposheet using Q-GIS, which can be utilized as a key input for preparation of Emergency Action Planning

Key words: Dam Break, HEC-RAS, Cross-section of channel, 1-D mathematical model, Flood routing, Inundation map, Toposheet.

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Dam Break Analysis and Emergency Action Plan for Sri Komaravelli Mallanna Sagar, Siddipet, Telangana

1.0 INTRODUCTION

Irrigation and Command Area Development (I&CAD) Department of Government of Telangana State has taken up the execution of a prestigious lift irrigation project to meet various irrigation requirements of backward and drought prone areas covering uplands (Figure 1). The project is named as Kaleshwaram Project. Out of the total 225 TMC of water requirement, 180 TMC of water is proposed to be lifted for this scheme at Medigadda village, below the point of confluence of Pranhitha and Godavari River, 20 km downstream of Kaleshwaram village. Kaleshwaram project envisages of various components like Barrages (03 numbers), Water conveyance system (gravity canal and tunnels), Online storages (17 numbers) and Distributory Network System etc.

One of the main components of Kaleshwaram project is Sri Komaravelli Mallana Sagar online Storage having capacity of about 50 TMC. It is reported that Sri Komaravelli Mallanna Sagar online storage will be having capacity of about 25-30 % of overall water demand and has been kept at higher elevation to act as mother online storage and also as carryover storage in case there is a water shortage in the system. The proposed Sri Komaravelli Mallanna Sagar will be having its F.R.L at RL 557.00 m. The length of Bund will be 22.90 km and maximum height of 61.5 m. I&CAD Department of Telangana state has requested Central Water & Power Research Station (CWPRS), Pune to carry out Dam Break Analysis (DBA) for preparation of guidelines for Emergency Action Plan for proposed Sri Komaravelli Mallana Sagar. Dam Break Studies has been carried out at CWPRS using 1-Dimensional (1-D) Dynamic mathematical model for different breach parameters. The flood hydrograph due to breach have been routed through existing natural stream Kurelli Vaagu. This report presents the results of model study carried out for dam break flood discharge, predicted water levels along the stream and likely flood inundation area marked on Survey of India (SOI) toposheets.

Sri Komaravelli Mallanna Sagar reservoir has been proposed to act as balancing type of reservoir and kept at higher elevation, therefore the storage will be through lifting of water from Godavari River. In the downstream of proposed Mallanna reservoir, there exist a natural stream Kurelli Vaagu flowing parallel to bund of proposed Sri Komaravelli Mallanna reservoir. Figure 2 shows the location and alignment of the proposed bund and

stream Kurelli Vaagu on the Google image. In the eventuality of dam break, the most likely path of flooding will be along this stream because of its lower elevation.

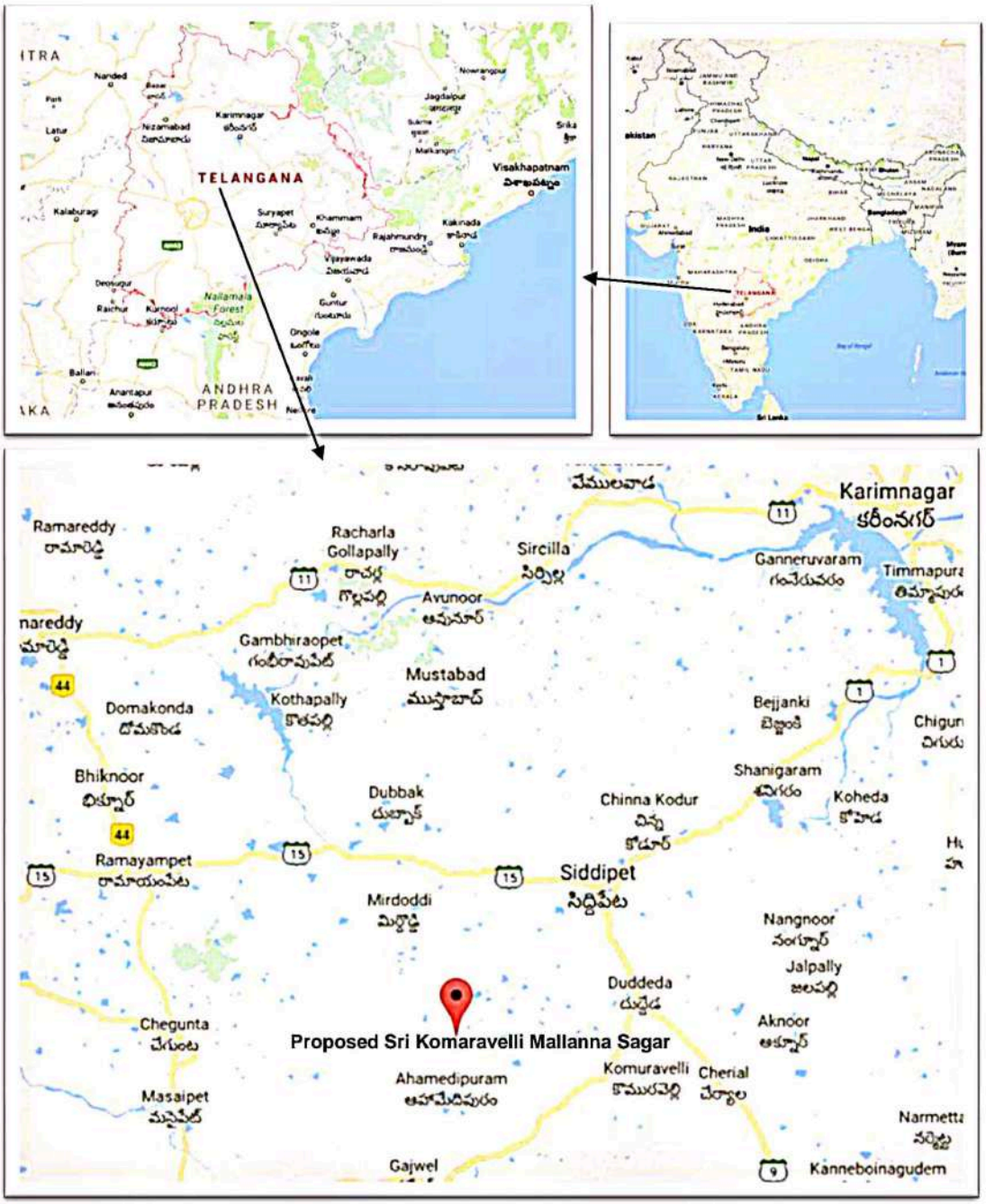

Figure 1: VICINITY MAP OF STUDY AREA

Figure 2: Imagery showing the location and alignment of the proposed bund with existing Kurelli Vaagu stream

2.0 SCOPE OF STUDY

Based on the data made available by project authorities and other relevant data which CWPRS could collect, the scope of work for this study are as below:

1) Estimation of Dam Breach flood hydrographs due to breach of proposed dam under different scenarios of breaking
2) Computation of flood level in the downstream channels by routing dam breach flood hydrographs, independently for different conditions of breaking.
3) To demarcate the area of inundation at important locations and installation for disaster management and Emergency Action Planning.
4) Providing inputs for the Development of Emergency Action Plan in case Dam break.

3.0 METHODOLOGY

For prediction of the reservoir outflow hydrograph due to Dam Break and routing it through the downstream valley, 1-D mathematical model capable of handling unsteady state flow condition has been used. Predicting the outflow hydrograph can be further subdivided into predicting the breach characteristics (e.g., shape, depth, width, rate of breach formation) and routing the reservoir storage through the breach and downstream. Various steps involved in the analysis are described below:

1. Review of salient features of the proposed Sri Komaravelli Mallanna Sagar for identification of most likely vulnerable location of breach.
2. Estimation of breach parameters using appropriate methods.
3. Extract topographic data from RASTER image (ASTER DEM) using ARC-GIS.
4. Development of 1-D mathematical model using appropriate software
5. Simulate the Kurelli Vaagu stream reach from Sri Komaravelli Mallanna Sagar upto Upper Maniar reservoir considering appropriate roughness factor for Dam Break flood condition.
6. Prediction of Inundation levels and demarcation on toposheets for the locations downstream of proposed dam for worst scenarios of breaching.

4.0 DATA USED FOR THE STUDY

Following data have been utilized for carrying out the studies

1. Toposheets from Survey of India (SOI) covering the study area (Scale 1:50,000)
2. Salient features of the Sri Komaravelli Mallanna Sagar and Upper Maniar reservoir.
3. Elevation – Area - Capacity curve / table of the Sri Komaravelli Mallanna Sagar.
4. ASTER DEM downloaded from USGS website.
5. Google Earth Pro imageries

5.0 SITE VISIT

A joint site visit and meeting were conducted by I&CAD Department, Telangana and CWPRS officials at the proposed location of Sri Komaravelli Mallanna sagar and some locations along the stream reach downstream upto Upper Maniar reservoir. During the visit, various locations along the alignment of proposed bund for Sri Komaravelli Mallanna Sagar reservoir were inspected. Sri Komaravelli Mallanna Sagar reservoir is proposed to be a balancing type of reservoir, where the storage will be through lifting of

water from Godavari River. Natural flow in catchment may be minimal due to typical and isolated topographic site of the bund. In the downstream of proposed Mallanna reservoir, there exist a natural stream Kurelli Vaagu flowing parallel to bund of proposed Sri Komaravelli Mallanna reservoir. In the eventuality of dam break, the most likely path and possibility of flooding will be along this stream. Some of the locations along this stream were also visited and it was observed that the downstream reach is having rocky bed. It was also noticed that the river bed near Upper Maniar reservoir the reach is of mainly alluvial type. Some of the photos for taken during the site visit are given in Photos 1 to 5. During the discussion it was opined and agreed upon by the project authorities that the simulation of the break in the model will be made at the most likely vulnerable section of the structure at the deepest portion of the dam body i:e at the location where bund is having maximum height.

Photo 1: Location of the submergence area of the proposed dam

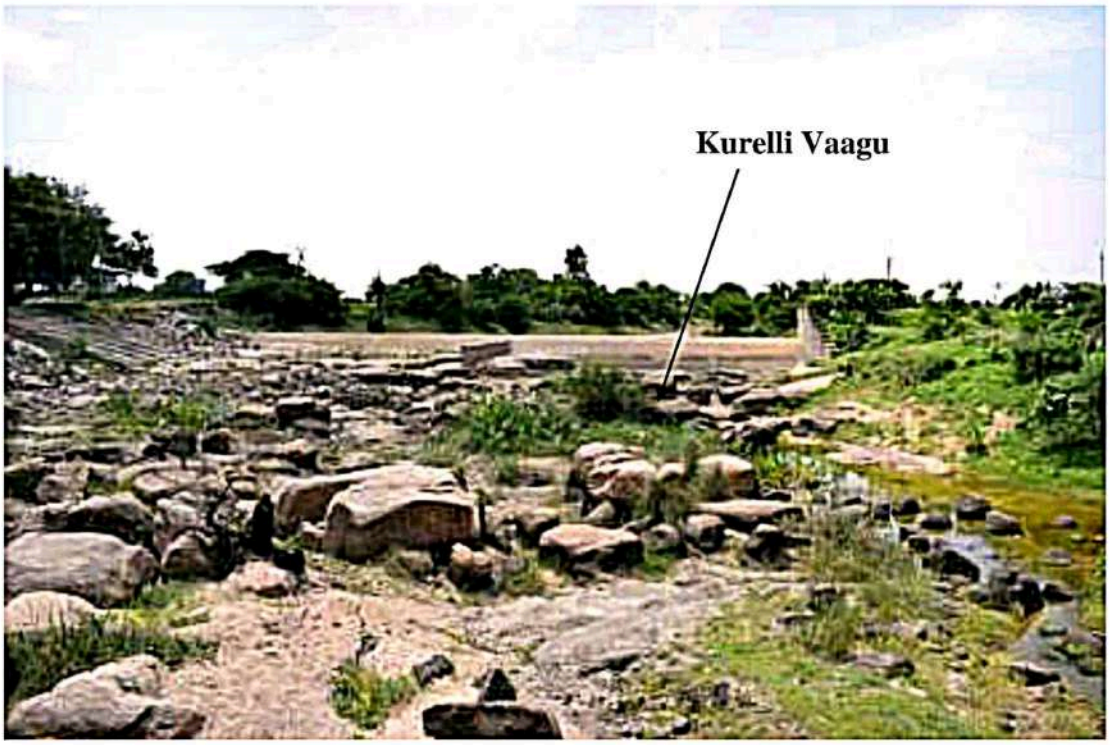

Photo 2: Rocky reach of Kurelli Vaagu stream downstream of proposed dam

Photo 3: Existing bridge on Kurelli Vaagu stream.

Photo 4: View of Kurelli Vaagu at upstream reach of Upper Maner reservoir

Photo 5: View of existing dam of Upper Maner reservoir

6.0 THE STUDY APPROACH

Dam breach of Sri Komaravelli Mallana Sagar and further routing of flood through Kurelli Vaagu stream for a length of about 47 km downstream upto Upper Maniar reservoir has been simulated in the study using mathematical model, Hydraulic Engineering Center River Analysis System (HEC RAS) model. Storage (level-pool) routing is used within the reservoir with the tail water elevations computed via the Saint-Venant equations, by dynamic routing through the 47 km routing reach downstream of the proposed reservoir. 109 cross sections of the Kurelli Vaagu Stream and 3 sections close to the proposed bund of dam on the upstream were provided in the model. The task of estimation of maximum water level at selected locations in river Kurelli Vaagu Stream has been carried out by routing the dam break flood hydrograph generated due to the breach of Sri Komaravelli Mallana Sagar. The breach is the opening formed in the structure as it fails. User-specified breach parameters and a description of the reservoir enable HEC- RAS to compute the outflow hydrograph. The breach is assumed to develop over a finite interval of time and will have a final size determined by a terminal bottom width parameter and shape parameter. Such a parametric representation of the breach is utilized in HEC-RAS for reasons of simplicity, generality, wide applicability, and the uncertainty in the actual failure mechanism.

The time for breach formation is in the range of a few minutes to hours depending upon the composition of dam, height, width, the cause of breach etc. The breach up to the bottom of the dam which will cause maximum damage resulting in highest flood is assumed. In general, the dam can fail either by over toping or by piping. In the present studies Sri Komaravelli Mallana Sagar failure is assumed to be due to over toping. It is assumed that reservoir is filled up to top of dam when failure commences. The breaching scenario considered for the study is that Dam breaks at Level Pool Condition (FRL) to simulate the worst scenario.

7.0 HEC-RAS MODEL FOR DAM BREAK ANALYSIS

Dam break modelling can be carried out by either i) scaled physical hydraulic models or ii) mathematical simulation using a computer. A modern tool to deal with this problem is the mathematical model, which is most cost effective and approximately solves the governing flow equations of continuity and momentum by computer simulation. Mathematical modelling of Dam Breach floods can be carried out by either one dimensional analysis or two dimensional analysis. In one dimensional analysis, the information about the magnitude of flood, i.e., discharge and water levels, variation of

these with time and velocity of flow through breach can be obtained in the direction of flow. HEC-RAS software is assimilated system of Graphical User Interface (GUI), Separate analysis components, Data storage and Management capabilities and Graphics and Reporting capabilities.

Analysis components for the river system comprise:

1) Unsteady flow simulations: This component of modelling is based on law of conservation of mass and law of conservation of momentum. These laws are expressed in the form of partial differential equation known as continuity equation and momentum equation.

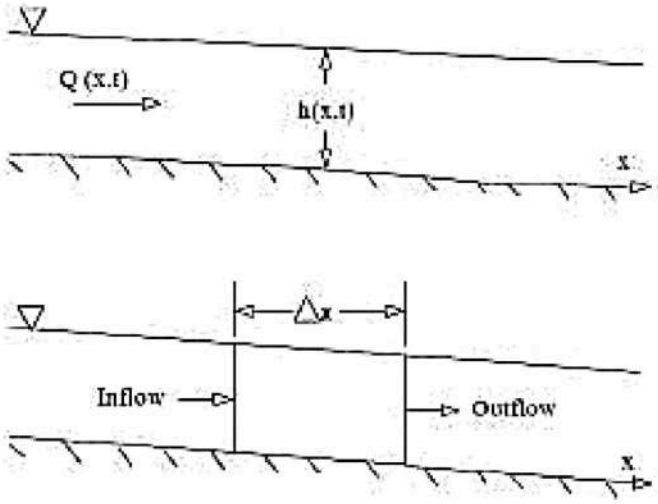

Figure3: ELEMETARY CONTROL VOLUME FOR MOMENTUM EQUATION

The special features like dam break analysis, levee breaching, overtopping etc. are also included in this component of modelling.

2) Graphics and Reporting: Graphics part includes X-Y plotting, cross-section profile, hydrographs, rating curves, etc. Reporting part involved the printed output and input data.

The governing equations of the model are the complete one-dimensional Saint-Venant equations of unsteady flow which are coupled with internal boundary equations representing the rapidly varied (broad-crested weir) flow through structures such as dams and bridge/embankments which can develop a user specified time-dependent breach. Also, appropriate external boundary equations at the upstream and downstream ends of the routing reach are utilized. The basic theory for dynamic routing in one dimensional analysis consists of two partial differential equations originally derived by Barre De Saint Venant in 1871. The equations are:

Conservation of mass (continuity) equation

$$(\partial Q/\partial X) + \partial(A + A0) / \partial t - q = 0$$

Conservation of momentum equation

$$(\partial Q/\partial t) + \{ \partial(Q2/A)/\partial X \} + g\, A\, ((\partial h/\partial X) + Sf + Sc) = 0$$

where

Q = discharge;
A = active flow area;
A0 = inactive storage area;
h = water surface elevation;
q= lateral outflow;
x = distance along waterway;
t = time;
Sf = friction slope;
Sc = expansion contraction slope and
g = gravitational acceleration.

Breach outflow is computed as broad-crested weir flow equation:

$$Qb = c_v k_s [3.1 b_i (h - h_b)^{1.5} + 2.45 z (h - h_b)]^{2.5}$$

In which

b_i = computed instantaneous breach bottom width

$= b.t_b / \tau \qquad if\ t_b < \tau$

where

b = terminal width of the bottom of the breach

τ = time interval until the terminal width is attained

t_b = time since beginning of breach formation

h = reservoir water surface elevation

h_b = computed elevation of breach bottom

$= h_d - \frac{(h_d - h_{bm}) t_b}{\tau}$ if $0 < t_b < \tau$

$= h_{bm}$ if $t_b > \tau$

where

h_{bm} = final elevation of breach bottom

h_d = height of the dam

z = user specified side-slope of the breach

k_s = computed submergence correction due to downstream tailwater

elevation (h_t)

$= 1.0 - 27.8[\frac{h_t - h_b}{h - h_b} - 0.67]^3 \qquad if\ (h_t - h_b) / (h - h_b) > 0.67$

= 1.0 otherwise

c_v = small computed correction for velocity of approach

$$c_v = 1.0 + 0.023(Q_b{}^2/[B_d{}^2(h - h_{bm})^2(h - h_b)]$$

where

B_d = width of reservoir at the dam

User is required to enter boundary conditions at all external boundaries of the system, as well as at any desired internal locations, and set the initial flow and storage area conditions at the beginning of simulation. The upstream boundary conditions for unsteady flow state can be given as the lateral inflow hydrograph for a reservoir (storage area), or gate openings in case of presence of gates as controlled structure in the system. Downstream boundary conditions for unsteady flow state can be given as the stage/flow hydrographs, rating curves or friction slope of the channel. In addition to the boundary conditions, the user must establish the initial conditions of the system at the beginning of the unsteady flow simulation. Initial conditions consist of flow and stage information at each of the cross sections, as well as elevations for any storage areas defined in the system.

7.1 Breach Parameters

The physical description of the breach will consist of the bottom elevation, bottom width, and side slopes in H:V (side slopes are expressed in units of distance horizontal to every one unit in the vertical). These values represent the breach size as shown in figure 4 below. In addition to this, it is mandatory to specify breach weir coefficient and the breach formation time and the breach trigger condition- whether on a particular elevation or at a particular time interval along with the mode of failure. HEC RAS can be used for overtopping as well as piping as mode of failure for the different dams. The resulting flood wave is routed through the downstream river channel using the unsteady flow simulations.

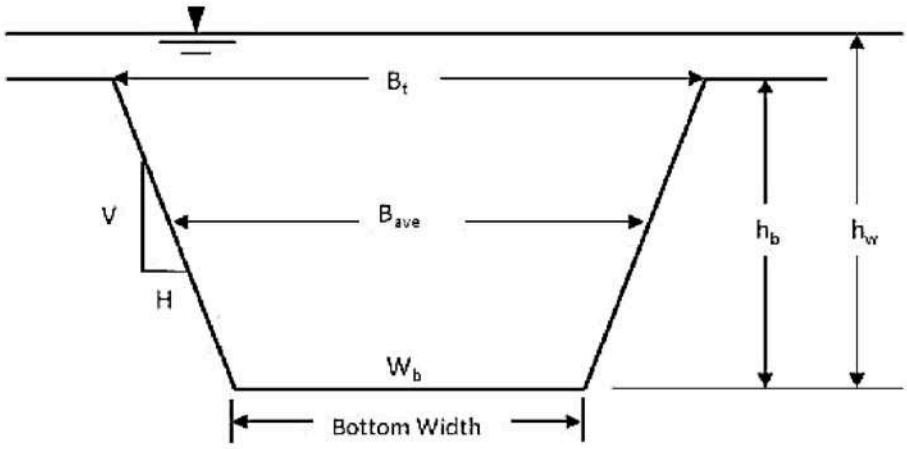

Figure 4: BREACH GEOMETRY

8.0 DAM BREAK ANALYSIS FOR SRI KOMARAVELLI MALLANNA SAGAR

The failure of an embankment dam can be viewed as a two-stage process. First, the actual breach of the dam that must be analyzed, and second, the outflow from the breach to be routed through the downstream valley to determine the resulting flood at population centers. Predicting the outflow hydrograph can be subdivided into predicting the breach characteristics (e.g., shape, depth, width, rate of breach formation) and routing the reservoir storage due to the outflow through the breach. The models do not directly simulate the breach; rather the user determines the breach characteristics independently and provides that information as input to the routing model.

One dimensional mathematical model (HEC-RAS) under unsteady flow condition is used for Dam break analysis of the present study. Dam break flood hydrographs have been simulated under different conditions of breaking when the reservoir is full. Unsteady flow component of this model has been used for routing the generated flood hydrograph due to dam break. The Unsteady flow component is based on law of conservation of mass and law of conservation of momentum.

The dam break studies for Sri Komaravelli Mallanna Sagar have been carried out considering rectangular breach with maximum width of 300m. This optimum size of breach has been derived as per the standard guidelines with reference to the nature of bund and height of the dam. The most vulnerable point of breach could be the location where bund is having maximum height. This location was identified with the help of toposheet (SOI) and satellite imageries. The failure of this section of bund was considered due to overtopping.

For this study CWPRS used the data provided by the project authority like salient features of bund, Area Elevation Capacity curve of reservoir. As mentioned above, the 1-D model required topographical data as well as the boundary condition for running the model. In the absence of actual topographical survey data of the stream downstream of proposed Shri K. Mallanna Sagar, a Digital Elevation Model (DEM) of 30 m resolution available at USGS website (figure 5) was downloaded and processed using ARC-GIS software for topographical data of the stream on the downstream of the proposed Sri Komaravelli Mallanna Sagar. The geometric data required for development of 1-D mathematical model were extracted from ASTER DEM using ARC-GIS and MS-Excel software. The cross sections extracted were compared with few cross sections provided

by project authority for validation purpose, and were found to be matching fairly. About 47 km of channel reach from proposed Sri Komaravelli Mallanna Sagar upto Upper Maniar reservoir was considered in the study. 109 cross sections of the Kurelli Vaagu Stream and 3 sections close to the proposed bund of dam on the upstream were provided in the model. The schematic geometry in the HEC-RAS model showing the reservoir and cross sections upto 47 kms as given in model are shown in figure 6. The cross sections were appropriately extended beyond both the banks of the stream varying from 2 to 8 km in length, to know the maximum extent of inundation. Storage (level pool) routing was carried out within the reservoir with F.R.L of Upper Maniar reservoir as downstream boundary. Dynamic routing was carried out in downstream reach and water surface elevations were computed in HEC-RAS using Saint Venant equations by numerical simulations. For the worst possible case, the shape of break was considered as rectangular. Three simulations with the breaching time as 18 minutes, 30 minutes and 1 hour (as per the standard methods for the failure of earthen dams) with the level at F.R.L of the Dam have been considered. Since, this is a pumped storage type of reservoir, catchment flow addition to the reservoir will be negligible. Therefore, the worst breaching scenario may be dam breaching at F.R.L and having minimum breaching time.

Boundary conditions for controlling the simulations were assigned to the model as upstream boundary condition (FRL of proposed bund), downstream boundary condition (FRL of existing reservoir 47 km downstream). With above conditions unsteady simulations under mix flow regime were carried out. The flood levels computed with breach generated flood hydrograph routed through the stream have been analyzed at every cross section.

8.1 Schematization of Kurelli Vaagu stream Reach under Study

The Kurelli Vaagu stream reach of 47 km from proposed Sri Komaravelli Mallanna Sagar upto Upper Maniar reservoir had been simulated in the mathematical model study. Figure 6 shows schematization of this reach. The model grid points indicate the location of river cross sections used for the study. The topography of river was reproduced using the extracted river cross-section data. As mentioned above all these cross sections were appropriately extended on either side of the bank beyond highest natural bank level in order to estimate the flooding effect resulting from dam break flood. These cross sections were provided at about 500m interval in the model.

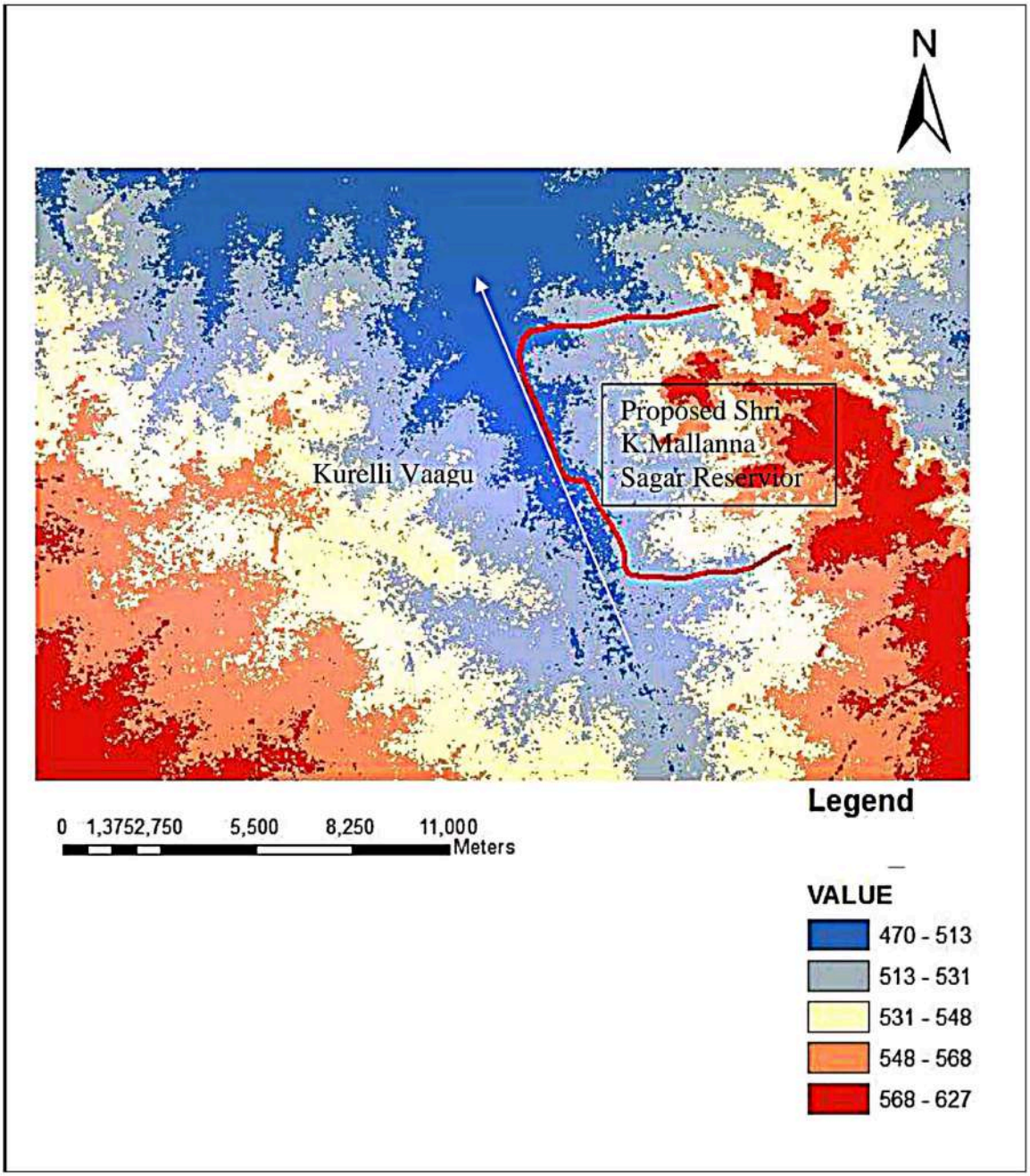

Figure 5: Digital Elevation Model (DEM) used for extraction of cross sections of stream near proposed Sri Komaravelli Mallanna Sagar Reservior

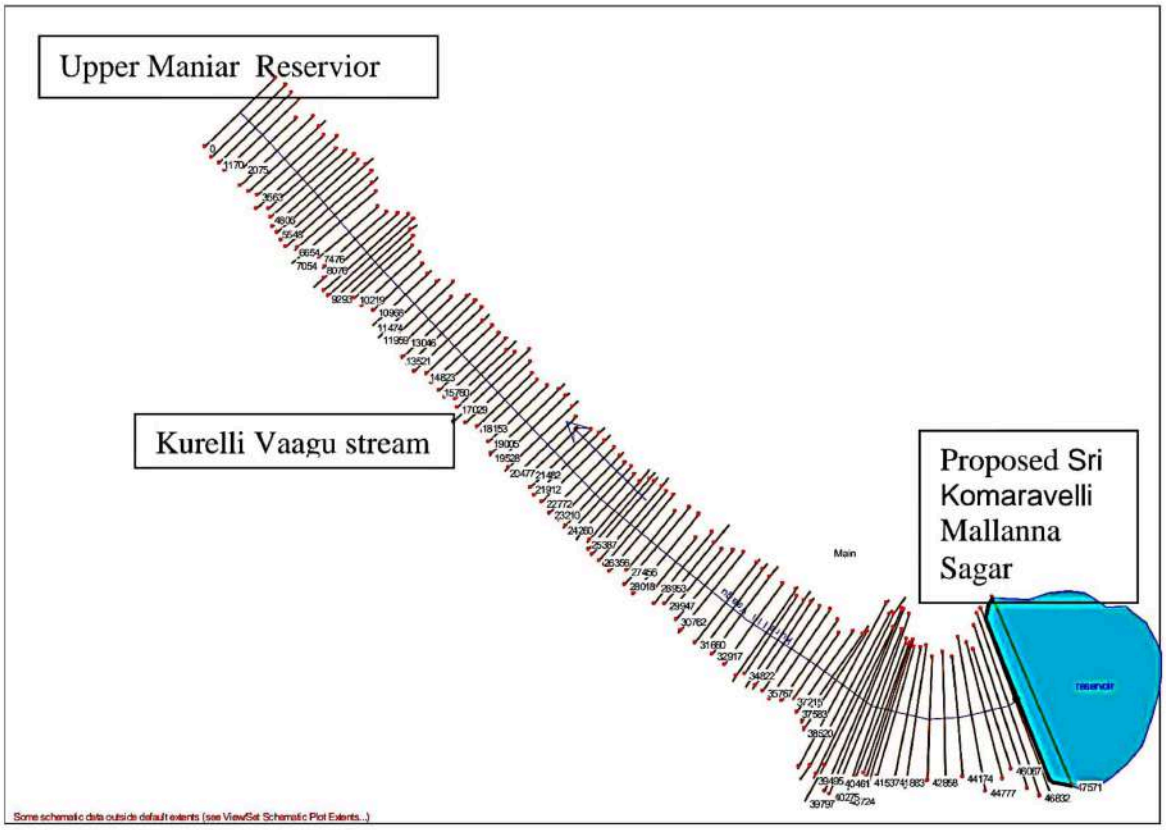

Figure 6 : Schematic Geometry used in HEC-RAS model for proposed Sri Komaravelli Mallanna Sagar with Kurelli Vaagu stream

9.0 MATHEMATICAL MODEL SIMULATION AND RESULTS

The details of the extracted cross sections with reference to chainage (from Upper Maner reservoir) are given in Table 1.These cross sections were used as geometric data for the development of 1-D mathematical model in HEC-RAS. In addition to this, the details of in-line structure i.e. geometric details of the dam and storage area were also provided to the HEC- RAS. The Dam break simulations were carried out for the time to breach of 18 min, 30 min and 60 min. The mode of failure was taken as overtopping for this study.

It was considered that the breaching of dam was initiated when the reservoir is at FRL. Consequently, FRL was used as upstream boundary condition under level pool scenario. FRL of Upper Maniar reservoir was used as a downstream boundary condition for dam break model runs using HEC- RAS model. The initial condition for all cross sections of the study reach was considered as 100 cum/s as per approximately observed lean period flow data noticed during the site inspection. The initial elevation of reservoir was taken as FRL for the unsteady flow simulations using HEC-RAS.

The dam break flood hydrograph and maximum water level profile were estimated and used for plotting inundation map for the study reach of river Kurelli Vaagu.

TABLE 1: Cross section details (w.r.t zero chainage at Upper Maner Reservoir)

Chainage 0 from existing Upper Maner reservoir (m)	*Cross Section No.*	Chainage 0 from existing Upper Maner reservoir (m)	*Cross Section No.*	Chainage 0 from existing Upper Maner reservoir (m)	*Cross Section No.*
47571	C/S 1	31218	C/S 42	13521	C/S 83
47196	C/S 2	30762	C/S 43	13046	C/S 84
46832	C/S 3	30341	C/S 44	12545	C/S 85
46436	C/S 4	29947	C/S 45	11959	C/S 86
46432	C/S 5	29540	C/S 46	11474	C/S 87
46067	C/S 6	28953	C/S 47	10968	C/S 88
45437	C/S 7	28389	C/S 48	10501	C/S 89
44777	C/S 8	28018	C/S 49	10219	C/S 90
44174	C/S 9	27456	C/S 50	9898	C/S 91
43494	C/S 10	27085	C/S 51	9623	C/S 92
42858	C/S 11	26771	C/S 52	9293	C/S 93
42431	C/S 12	26356	C/S 53	8908	C/S 94
41883	C/S 13	26096	C/S 54	8531	C/S 95
41663	C/S 14	25826	C/S 55	8076	C/S 96
41537	C/S 15	25387	C/S 56	7476	C/S 97
41407	C/S 16	25012	C/S 57	7054	C/S 98
41207	C/S 17	24672	C/S 58	6654	C/S 99
40984	C/S 18	24260	C/S 59	6270	C/S 100
40724	C/S 19	23771	C/S 60	5872	C/S 101
40461	C/S 20	23210	C/S 61	5548	C/S 102
40275	C/S 21	22772	C/S 62	5148	C/S 103
40003	C/S 22	22372	C/S 63	4806	C/S 104
39797	C/S 23	21912	C/S 64	4424	C/S 105
39495	C/S 24	21482	C/S 65	3990	C/S 106
39119	C/S 25	21007	C/S 66	3563	C/S 107
38719	C/S 26	20477	C/S 67	3078	C/S 108
38520	C/S 27	20012	C/S 68	2564	C/S 109
38080	C/S 28	19528	C/S 69	2075	C/S 110
37583	C/S 29	19005	C/S 70	1594	C/S 111
37215	C/S 30	18639	C/S 71	1170	C/S 112
36697	C/S 31	18153	C/S 72	615	C/S 113
36217	C/S 32	17747	C/S 73	0	C/S 114
35767	C/S 33	17374	C/S 74		
35455	C/S 34	17029	C/S 75		
35075	C/S 35	16640	C/S 76		
34822	C/S 36	16235	C/S 77		
34126	C/S 37	15760	C/S 78		
33407	C/S 38	15269	C/S 79		
32917	C/S 39	14823	C/S 80		
32480	C/S 40	14390	C/S 81		
31660	C/S 41	13981	C/S 82		

9.1 Dam Break Simulation under Level Pool Scenario:

In all the 3 cases, a Rectangular Breach shape of width 300 m and bottom elevation at R.L. 512.73 m as feasible at the most vulnerable location of the proposed bund was taken for Dam Break Simulations. Breach weir coefficient was considered as 1.44 for all the cases as suggested in the manual of HEC-RAS software. The unsteady flow simulations were carried out for the simulation time of 24 hours and the maximum water level profile of the study reach was estimated. In addition to this, discharges and velocities corresponding to maximum water level were estimated for all cases.

Also, the dam break flood hydrograph and stage hydrograph for cross section just immediate downstream of proposed Mallanna Sagar Reservior was estimated. The details are shown in Figure 7, Figure 8 for 18 minute breach time, Figure 9, Figure 10 for 30 minute breach time and Figure 11, Figure 12 for 60 minute breach time.

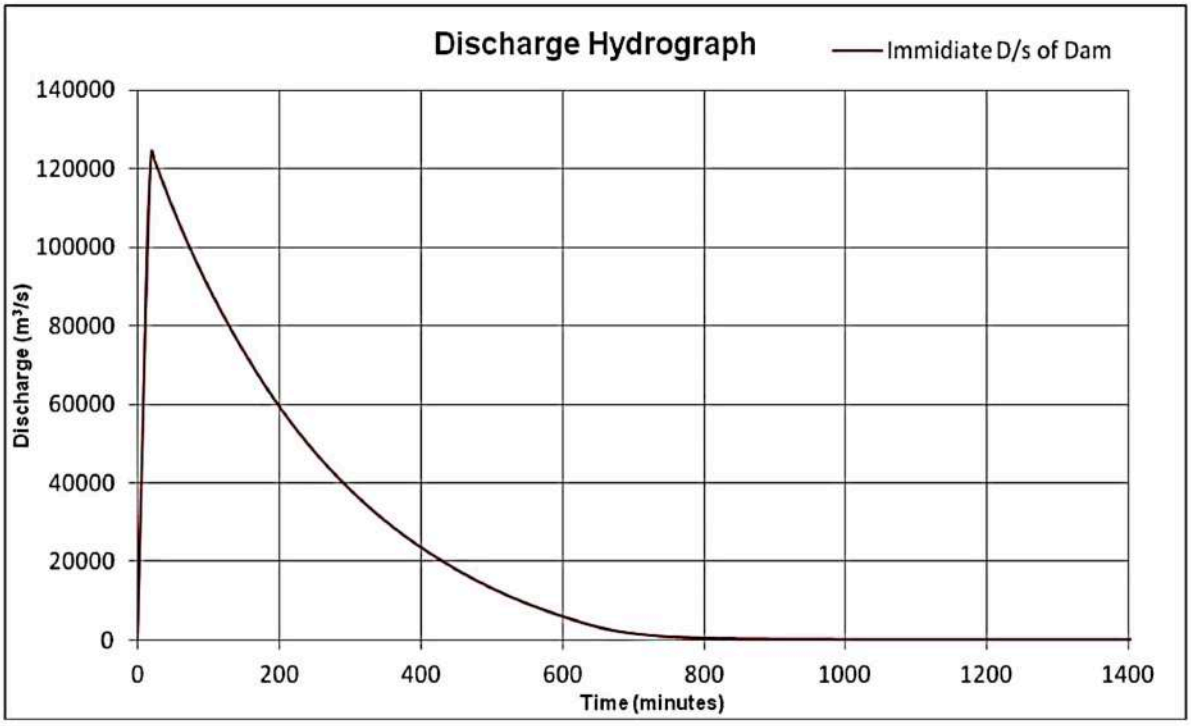

Figure 7: DAM BREAK HYDROGRAPH IMMEDIATE DOWNSTREM OF DAM FOR 18 MINUTES BREACH TIME

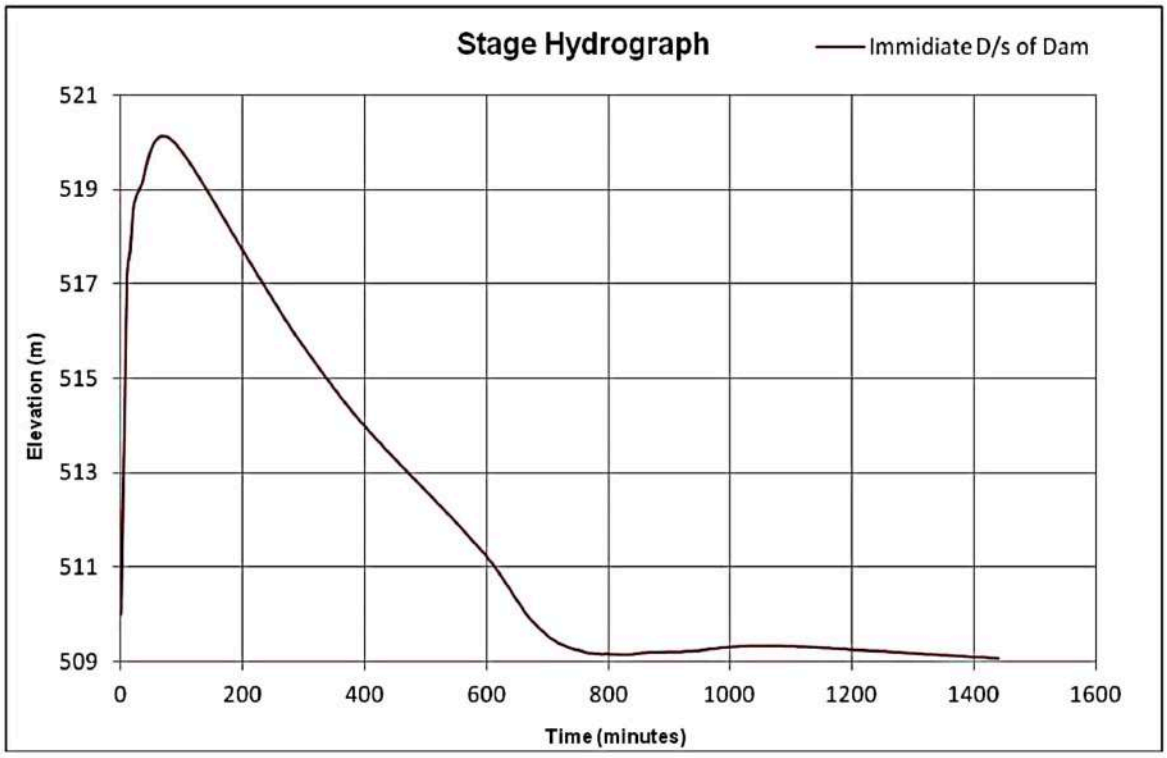

Figure 8: STAGE HYDROGRAPH IMMEDIATE DOWNSTREM OF DAM FOR 18 MINUTES BREACH TIME

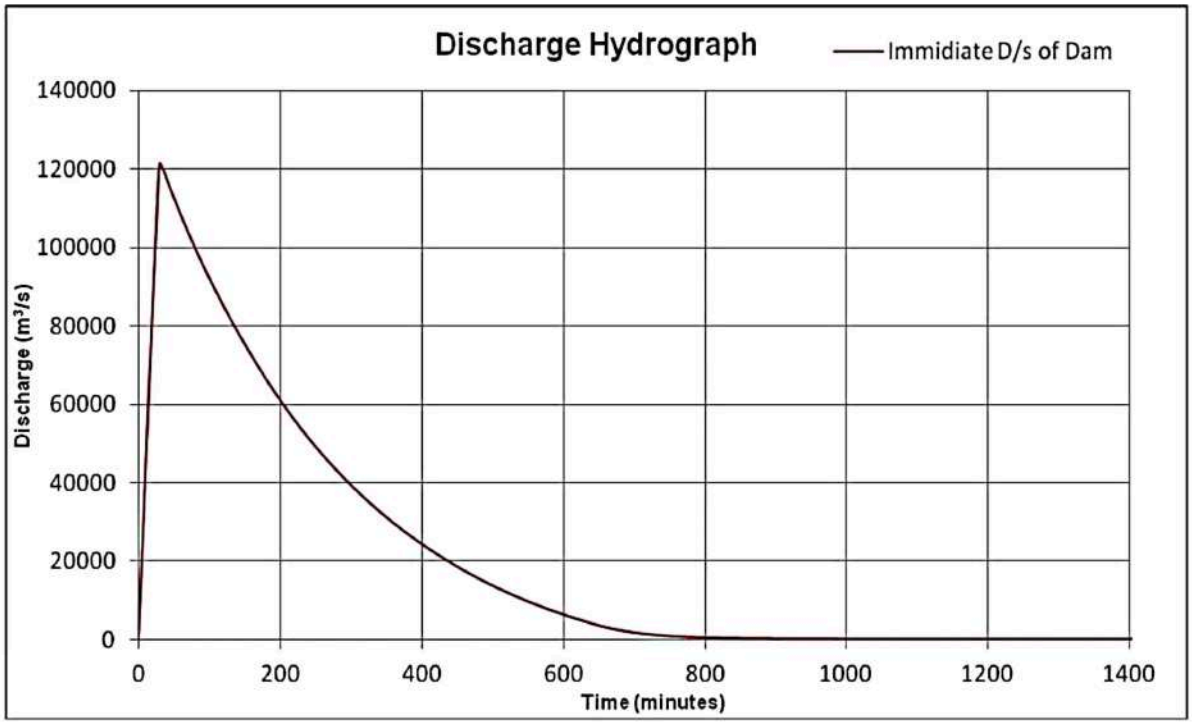

Figure 9: DAM BREAK HYDROGRAPH IMMEDIATE DOWNSTREM OF DAM FOR 30 MINUTES BREACH TIME

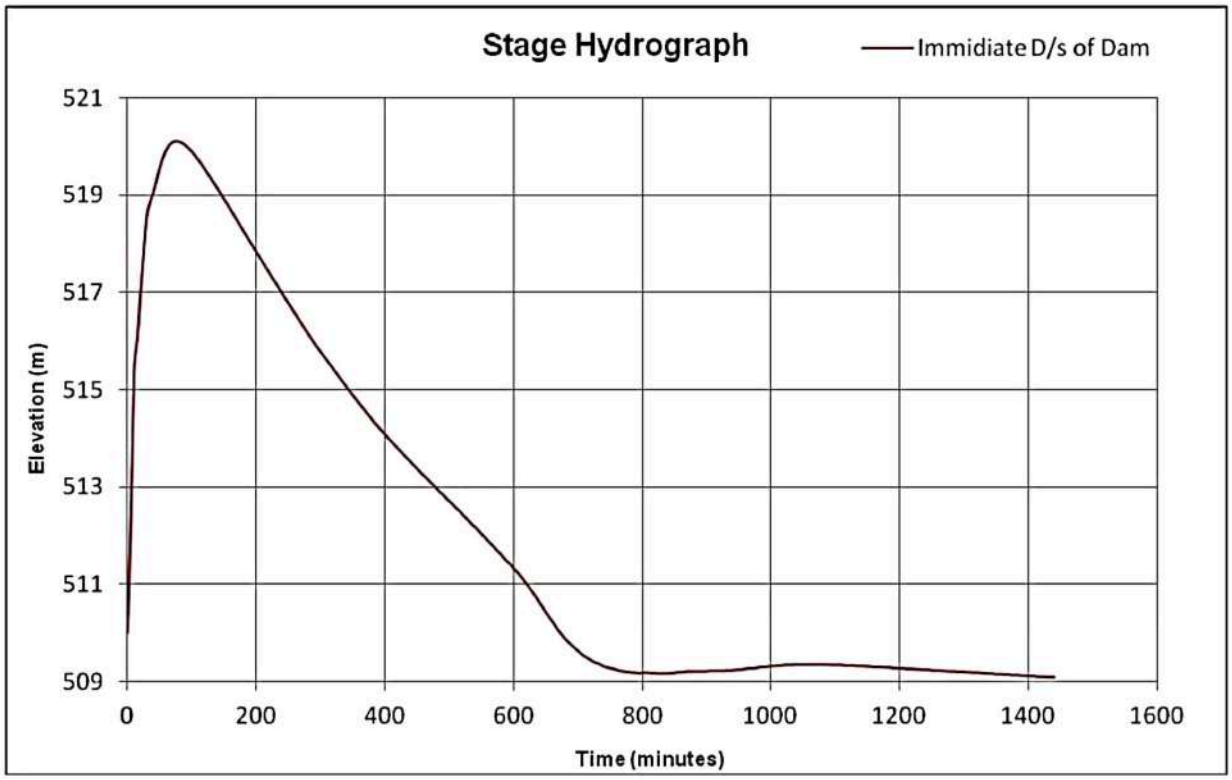

Figure 10: STAGE HYDROGRAPH IMMEDIATE DOWNSTREM OF DAM FOR 30 MINUTES BREACH TIME

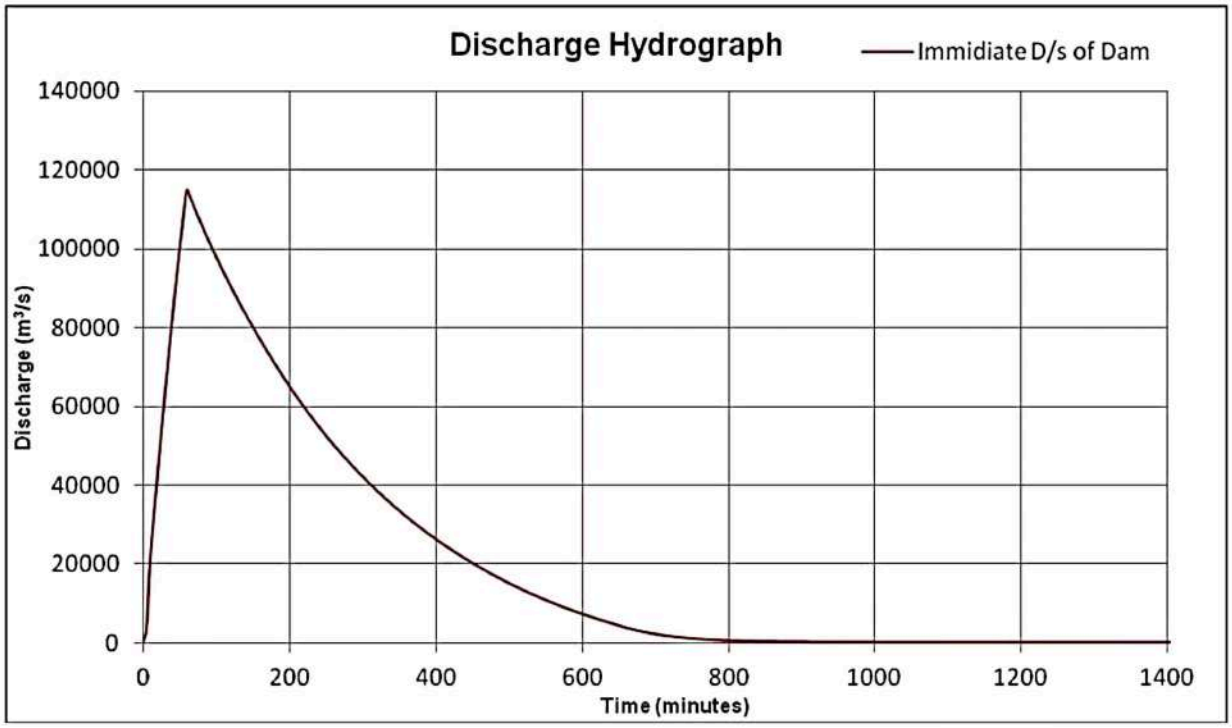

Figure 11: DOWNSTREM OF DAM BREAK HYDROGRAPH IMMEDIATE DAM FOR 60 MINUTES BREACH TIME

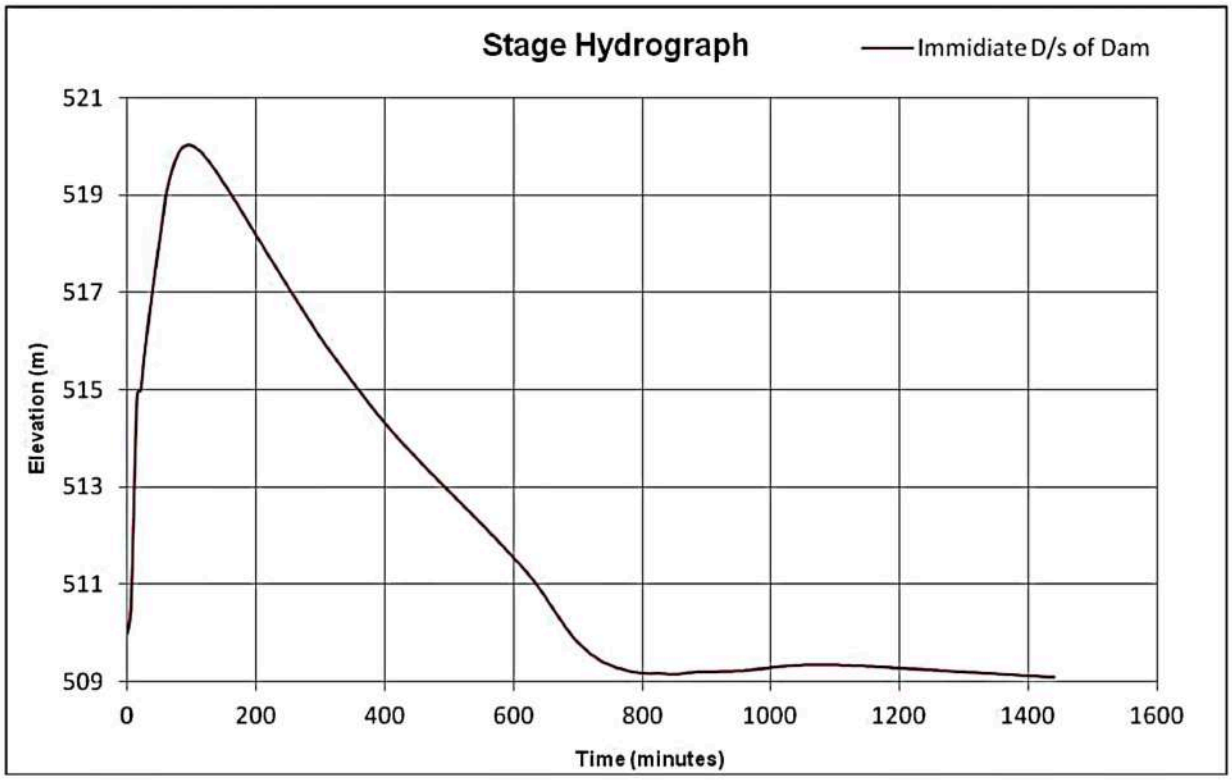

Figure 12: STAGE HYDROGRAPH IMMEDIATE DOWNSTREM OF DAM FOR 60 MINUTES BREACH TIME

The details of the Maximum Water Surface Elevation with corresponding discharge and velocities at each cross section for all the 3 cases are given in the Table 2, Table 3 and Table 4 for breaching time of 18minutes,30 minutes and 60 minutes respectively.

Table 2: Predicted maximum Water Levels with corresponding Discharge and Velocity at each cross section for breach time 18 minutes

Chainage / Distance (m)		Water level (m)	Discharge (m^3/s)	Velocity (m/s)	Remark
From proposed Dam	From Upper Maniar Dam				
0	47571	562.04	100	0	Within proposed reservior
375	47196	562.04	100	0	
739	46832	562.04	100	0	
1135	46436	562.04	100	0	
1139	46432				At Dam
1504	46067	520.14	102086.5	3.05	D/s of Dam
2134	45437	520	101785.0	2.31	
2794	44777	519.75	101508.8	1.97	
3397	44174	519.31	101103.5	2.55	
4077	43494	519.15	100991.0	2.14	
4713	42858	518.69	100871.1	2.73	
5140	42431	518.28	100809.6	2.83	

Chainage / Distance (m)		Water level (m)	Discharge (m^3/s)	Velocity (m/s)	Remark
From proposed Dam	From Upper Maniar Dam				
5688	41883	517.7	100763.2	3.51	
5908	41663	515.84	100714.4	6.01	
6034	41537	515.35	100660.4	5.33	
6164	41407	514.99	100644.5	5.39	
6364	41207	514.41	100655.5	6.4	
6587	40984	513.35	100586.5	7.04	
6847	40724	512.41	100501.6	5.05	
7110	40461	511.34	100445.5	6.03	
7296	40275	510.97	100140.9	3.89	
7568	40003	510.72	100085.1	3.49	
7774	39797	510.27	99951.47	3.63	
8076	39495	509.6	99827.1	4.53	
8452	39119	508.82	99427.38	4.53	
8852	38719	508.03	98834.77	4.07	
9051	38520	507.1	98303.41	4.44	
9491	38080	506.51	97970.63	4.8	
9988	37583	505.61	97177.27	4.54	
10356	37215	503.87	96052.55	5.89	
10874	36697	503.53	94591.63	3.4	
11354	36217	503.3	94373.09	2.46	
11804	35767	503.04	94181.13	2.56	
12116	35455	502.48	93783.78	3.35	
12496	35075	502.15	93571.6	3.4	
12749	34822	501.87	93410.68	3.21	
13445	34126	501.9	93445.05	2.55	
14164	33407	501.44	93312.36	2.76	
14654	32917	500.63	93129.41	3.43	
15091	32480	500.28	93061.95	3.07	
15911	31660	499.99	93041.14	3.02	
16353	31218	498	92873.68	4.7	
16809	30762	497.22	92789.06	3.83	
17230	30341	496.53	92735.89	3.92	
17624	29947	495.15	92674.02	5.28	
18031	29540	493.66	92498.93	5.57	
18618	28953	492.78	92171.73	4.44	
19182	28389	492.39	92029.78	2.99	
19553	28018	491.16	91655.71	4.12	
20115	27456	490.68	91507.53	3.53	
20486	27085	490.24	91390.13	3.04	
20800	26771	489.36	91218.98	4.21	
21215	26356	488.51	90898.49	4.74	
21475	26096	487.66	90495.43	4.61	

Chainage / Distance (m)		Water level (m)	Discharge (m^3/s)	Velocity (m/s)	Remark
From proposed Dam	From Upper Maniar Dam				
21745	25826	487.44	90312.42	3.88	
22184	25387	486.74	89932.97	4.56	
22559	25012	485.97	89305.1	4.42	
22899	24672	485.41	88903.26	4.19	
23311	24260	485.02	88570.14	3.89	
23800	23771	484.47	88200.97	3.74	
24361	23210	483.98	87952.13	3.4	
24799	22772	483.56	87755.27	3.13	
25199	22372	483.34	87695.55	2.85	
25659	21912	482.12	87229.82	4.08	
26089	21482	481.63	86892.31	3.94	
26564	21007	481.63	86890.78	2.81	
27094	20477	481.31	86778.02	2.81	
27559	20012	480.2	86355.16	4.35	
28043	19528	479.75	86100.74	3.71	
28566	19005	479.18	85790.36	3.62	
28932	18639	477.45	85298.27	5.7	
29418	18153	477.35	84580.44	2.87	
29824	17747	477.27	84513.95	2.16	
30197	17374	477.1	84454.06	2.2	
30542	17029	476.34	84096.39	3.68	
30931	16640	475.97	83931.5	3.46	
31336	16235	476.04	83953.41	2.24	
31811	15760	475.84	83905.51	2.48	
32302	15269	475.32	83759.88	3.25	
32748	14823	474.37	83522.75	4.28	
33181	14390	473.71	83310.71	4.19	
33590	13981	473.05	83091.26	4.03	
34050	13521	472.59	82938.85	3.64	
34525	13046	471.8	82750.13	3.51	
35026	12545	470.92	82377.45	4.27	
35612	11959	470.59	82259.93	2.88	
36097	11474	469.74	82075.92	3.12	
36603	10968	469.68	82071.17	2.5	
37070	10501	469.52	82035.12	2.35	
37352	10219	468.93	81965.41	3.43	
37673	9898	467.9	81867.8	5.26	
37948	9623	467.62	81791.45	4.24	
38278	9293	467.73	81803.12	2.82	
38663	8908	467.79	81799.47	1.82	
39040	8531	467.45	81776.9	2.57	
39495	8076	466.55	81753.63	4.2	

Chainage / Distance (m)		Water level (m)	Discharge (m^3/s)	Velocity (m/s)	Remark
From proposed Dam	From Upper Maniar Dam				
40095	7476	465.9	81731.84	4	
40517	7054	464.73	81701.8	4.44	
40917	6654	463.88	81668.08	4.39	
41301	6270	462.62	81644.01	4.8	
41699	5872	461.11	81599.92	5.29	
42023	5548	459.99	81539.91	4.67	
42423	5148	458.74	81507.35	5.54	
42765	4806	458.23	81456.52	3.71	
43147	4424	457.75	81433.36	3.77	
43581	3990	457.02	81431.77	4.11	
44008	3563	455.86	81423.39	4.75	
44493	3078	455.26	81422.17	4.06	
45007	2564	454.49	81420.65	4.11	
45496	2075	452.68	81411.24	5.92	
45977	1594	452.28	81294.16	3.91	
46401	1170	452.05	81051.45	2.71	
46956	615	452.04	81309.22	1.84	
47571	0	451.85			D/s W.S El

Table 3 : Predicted maximum Water Levels with corresponding Discharge and Velocity at each cross section for breach time 30 minutes (case 2)

Chainage / Distance (m)		Water level (m)	Discharge (m^3/s)	Velocity (m/s)	Remark
From proposed Dam	From Upper Maniar Dam				
0	47571	562.04	100	0	Within proposed reservior
375	47196	562.04	100	0	
739	46832	562.04	100	0	
1135	46436	562.04	100	0	
1139	46432				At Dam
1504	46067	520.12	101805.5	3.05	D/s of Dam
2134	45437	519.98	101503.7	2.31	
2794	44777	519.73	101226.4	1.97	
3397	44174	519.29	100762.6	2.55	
4077	43494	519.14	100704.2	2.13	
4713	42858	518.67	100581.1	2.73	
5140	42431	518.26	100496.4	2.83	
5688	41883	517.68	100454.8	3.5	
5908	41663	515.82	100409.7	6.01	
6034	41537	515.33	100367.5	5.32	
6164	41407	514.98	100323.7	5.38	

Chainage / Distance (m)		Water level (m)	Discharge (m^3/s)	Velocity (m/s)	Remark
From proposed Dam	From Upper Maniar Dam				
6364	41207	514.39	100363.1	6.39	
6587	40984	513.34	100296	7.04	
6847	40724	512.39	100212.5	5.05	
7110	40461	511.33	100137.7	6.02	
7296	40275	510.96	99854.55	3.88	
7568	40003	510.71	99747.08	3.48	
7774	39797	510.25	99641.32	3.63	
8076	39495	509.59	99540.57	4.53	
8452	39119	508.81	99150.39	4.52	
8852	38719	508.01	98566.52	4.06	
9051	38520	507.09	98044.22	4.43	
9491	38080	506.5	97758.19	4.79	
9988	37583	505.6	97025.35	4.54	
10356	37215	503.86	95870.08	5.88	
10874	36697	503.52	94530.66	3.4	
11354	36217	503.3	94257.8	2.46	
11804	35767	503.03	94066.61	2.56	
12116	35455	502.48	93673.94	3.35	
12496	35075	502.14	93463.06	3.4	
12749	34822	501.86	93302.11	3.21	
13445	34126	501.9	93336.86	2.55	
14164	33407	501.44	93176.78	2.76	
14654	32917	500.62	93021.66	3.43	
15091	32480	500.27	92955.2	3.07	
15911	31660	499.98	92934.1	3.02	
16353	31218	497.99	92768.59	4.7	
16809	30762	497.21	92672.06	3.83	
17230	30341	496.52	92632.36	3.92	
17624	29947	495.14	92559.3	5.28	
18031	29540	493.66	92398.21	5.57	
18618	28953	492.78	92074.13	4.44	
19182	28389	492.39	91933.39	2.99	
19553	28018	491.15	91561.62	4.12	
20115	27456	490.67	91414.63	3.52	
20486	27085	490.23	91319.28	3.04	
20800	26771	489.35	91128.59	4.21	
21215	26356	488.5	90836.79	4.74	
21475	26096	487.65	90380.38	4.61	
21745	25826	487.44	90258.93	3.88	
22184	25387	486.74	89884.7	4.56	
22559	25012	485.97	89227.91	4.42	

Chainage / Distance (m)		Water level (m)	Discharge (m^3/s)	Velocity (m/s)	Remark
From proposed Dam	From Upper Maniar Dam				
23311	24260	485.02	88534.27	3.89	
23800	23771	484.47	88132.08	3.74	
24361	23210	483.98	87887.25	3.4	
24799	22772	483.56	87724.97	3.13	
25199	22372	483.34	87638.06	2.85	
25659	21912	482.12	87172.81	4.08	
26089	21482	481.63	86867.42	3.94	
26564	21007	481.63	86865.3	2.81	
27094	20477	481.31	86727.02	2.81	
27559	20012	480.2	86333.05	4.35	
28043	19528	479.75	86080.52	3.71	
28566	19005	479.18	85771.76	3.62	
28932	18639	477.45	85252.37	5.69	
29418	18153	477.35	84568.91	2.87	
29824	17747	477.27	84532.47	2.16	
30197	17374	477.1	84441.88	2.2	
30542	17029	476.34	84086.23	3.68	
30931	16640	475.97	83922.38	3.46	
31336	16235	476.04	83943.91	2.24	
31811	15760	475.84	83875.32	2.48	
32302	15269	475.32	83751.49	3.25	
32748	14823	474.37	83535.95	4.28	
33181	14390	473.71	83326.2	4.19	
33590	13981	473.05	83086.38	4.03	
34050	13521	472.59	82935.17	3.64	
34525	13046	471.8	82725.97	3.51	
35026	12545	470.92	82400.44	4.27	
35612	11959	470.59	82260.1	2.88	
36097	11474	469.75	82077.23	3.12	
36603	10968	469.68	82073.13	2.5	
37070	10501	469.52	82051.46	2.35	
37352	10219	468.93	81968.52	3.43	
37673	9898	467.9	81871.14	5.26	
37948	9623	467.63	81795.25	4.24	
38278	9293	467.73	81807.12	2.82	
38663	8908	467.79	81803.74	1.82	
39040	8531	467.45	81782.14	2.57	
39495	8076	466.55	81759.29	4.2	
40095	7476	465.9	81737.71	4	
40517	7054	464.73	81702.96	4.44	
40917	6654	463.88	81684.59	4.39	

Chainage / Distance (m)		Water level (m)	Discharge (m^3/s)	Velocity (m/s)	Remark
From proposed Dam	From Upper Maniar Dam				
41301	6270	462.62	81650.3	4.8	
41699	5872	461.11	81599.55	5.29	
42023	5548	459.99	81546.01	4.67	
42423	5148	458.74	81521.51	5.54	
42765	4806	458.23	81463.38	3.71	
43147	4424	457.75	81453.41	3.77	
43581	3990	457.03	81439.53	4.11	
44008	3563	455.86	81431.38	4.75	
44493	3078	455.26	81430.5	4.06	
45007	2564	454.49	81428.41	4.11	
45496	2075	452.68	81411.98	5.92	
45977	1594	452.28	81305.63	3.91	
46401	1170	452.05	81087.75	2.71	
46956	615	452.04	81308.4	1.84	
47571	0	451.85			D/s W.S El

Table 4 : Predicted maximum Water Levels with corresponding Discharge and Velocity at each cross section for breach time 60 minutes (case 3)

Chainage / Distance (m)		Water level (m)	Discharge (m^3/s)	Velocity (m/s)	Remark
From proposed Dam	From Upper Maniar Dam				
0	47571	562.04	100	0	Within proposed reservior
375	47196	562.04	100	0	
739	46832	562.04	100	0	
1135	46436	562.04	100	0	
1139	46432				At Dam
1504	46067	520.03	100252.7	3.04	D/s of Dam
2134	45437	519.89	99955.84	2.3	
2794	44777	519.63	99611.33	1.97	
3397	44174	519.19	99233.07	2.53	
4077	43494	519.04	99173.52	2.12	
4713	42858	518.58	99048.73	2.71	
5140	42431	518.16	98962.23	2.81	
5688	41883	517.59	98920.74	3.49	
5908	41663	515.73	98877.53	5.98	
6034	41537	515.25	98825.54	5.29	

Chainage / Distance (m)		Water level (m)	Discharge (m^3/s)	Velocity (m/s)	Remark
From proposed Dam	From Upper Maniar Dam				
6164	41407	514.9	98811.3	5.35	
6364	41207	514.31	98833.63	6.37	
6587	40984	513.25	98755.28	7.01	
6847	40724	512.31	98689.81	5.02	
7110	40461	511.25	98618.74	5.99	
7296	40275	510.88	98347.91	3.88	
7568	40003	510.63	98270.02	3.47	
7774	39797	510.18	98143.87	3.61	
8076	39495	509.53	98041.05	4.5	
8452	39119	508.74	97816.04	4.51	
8852	38719	507.94	97272.47	4.05	
9051	38520	507.02	96793.89	4.42	
9491	38080	506.43	96569.65	4.78	
9988	37583	505.54	95938.18	4.52	
10356	37215	503.8	94952.39	5.87	
10874	36697	503.47	93605.47	3.39	
11354	36217	503.24	93350.05	2.45	
11804	35767	502.98	93214.33	2.55	
12116	35455	502.42	92803.88	3.34	
12496	35075	502.09	92604.92	3.39	
12749	34822	501.81	92453.91	3.2	
13445	34126	501.84	92522.15	2.54	
14164	33407	501.38	92367.17	2.75	
14654	32917	500.57	92201.63	3.42	
15091	32480	500.22	92159.38	3.06	
15911	31660	499.93	92124.47	3	
16353	31218	497.95	91982.72	4.69	
16809	30762	497.17	91904.13	3.82	
17230	30341	496.48	91854.75	3.91	
17624	29947	495.1	91796.79	5.27	
18031	29540	493.62	91646.94	5.55	
18618	28953	492.74	91316.45	4.42	
19182	28389	492.35	91201.94	2.98	
19553	28018	491.11	90845.63	4.12	
20115	27456	490.63	90704.27	3.52	
20486	27085	490.19	90612.91	3.03	
20800	26771	489.31	90429.96	4.2	
21215	26356	488.46	90178.28	4.73	
21475	26096	487.62	89771.4	4.6	
21745	25826	487.4	89625.96	3.87	
22184	25387	486.7	89302.64	4.55	

Chainage / Distance (m)		Water level (m)	Discharge (m^3/s)	Velocity (m/s)	Remark
From proposed Dam	From Upper Maniar Dam				
22559	25012	485.93	88711.98	4.41	
22899	24672	485.37	88330.02	4.18	
23311	24260	484.98	87977.72	3.88	
23800	23771	484.43	87662.19	3.74	
24361	23210	483.95	87394.23	3.4	
24799	22772	483.52	87210.67	3.13	
25199	22372	483.3	87181.77	2.84	
25659	21912	482.09	86735.72	4.07	
26089	21482	481.6	86470.25	3.93	
26564	21007	481.6	86466.11	2.81	
27094	20477	481.28	86306.97	2.81	
27559	20012	480.18	85925.32	4.35	
28043	19528	479.73	85681.42	3.71	
28566	19005	479.15	85436.8	3.62	
28932	18639	477.42	84908.46	5.69	
29418	18153	477.33	84243.63	2.86	
29824	17747	477.25	84208.87	2.16	
30197	17374	477.08	84120.94	2.2	
30542	17029	476.32	83775.25	3.68	
30931	16640	475.94	83615.88	3.46	
31336	16235	476.02	83660.48	2.24	
31811	15760	475.82	83591.53	2.48	
32302	15269	475.29	83470.62	3.25	
32748	14823	474.35	83241.56	4.27	
33181	14390	473.69	83037.63	4.19	
33590	13981	473.04	82826.32	4.03	
34050	13521	472.57	82699.6	3.64	
34525	13046	471.79	82476.02	3.5	
35026	12545	470.91	82134.43	4.27	
35612	11959	470.57	82021.33	2.88	
36097	11474	469.73	81842.26	3.12	
36603	10968	469.66	81839.28	2.5	
37070	10501	469.51	81804.88	2.35	
37352	10219	468.91	81750.09	3.42	
37673	9898	467.88	81655.2	5.25	
37948	9623	467.61	81566.16	4.24	
38278	9293	467.72	81578.57	2.82	
38663	8908	467.77	81586.41	1.81	
39040	8531	467.44	81563.27	2.57	
39495	8076	466.53	81533.66	4.19	

Chainage / Distance (m)		Water level (m)	Discharge (m^3/s)	Velocity (m/s)	Remark
From proposed Dam	From Upper Maniar Dam				
40095	7476	465.89	81512.98	3.99	
40517	7054	464.72	81483.96	4.44	
40917	6654	463.87	81461.05	4.38	
41301	6270	462.6	81421.86	4.8	
41699	5872	461.09	81390.01	5.29	
42023	5548	459.97	81332.3	4.67	
42423	5148	458.73	81300.78	5.54	
42765	4806	458.22	81251.37	3.71	
43147	4424	457.73	81234.41	3.77	
43581	3990	457.01	81221.55	4.11	
44008	3563	455.84	81218.27	4.74	
44493	3078	455.25	81213.99	4.05	
45007	2564	454.48	81212.57	4.11	
45496	2075	452.68	81197.73	5.91	
45977	1594	452.28	81083.93	3.9	
46401	1170	452.04	80844.17	2.7	
46956	615	452.04	81085.83	1.83	
47571	0	451.85			D/s W.S El

Reviewing the results, it was noticed that among the 3 cases, the maximum discharge of 102086.5 m^3/s was attained on the immediate downstream of proposed Mallanna Sagar reservoir for Case 1. Further, discharge decreased towards the downstream cross sections of the study reach of river Kurelli Vaagu and the water level varied between 520.14m at first cross section downstream of proposed reservior to 451.85m at Upper Maniar Reservior. As more emphasis in the analysis is given for estimation of maximum water surface elevation for preparation on 'Inundation map', Maximum water surface elevation and corresponding discharge and velocity are only extracted. However, the maximum discharge and maximum velocity need not be occurring simultaneously at the time of maximum level.

9.2. Water Surface Profiles

The maximum water surface profile for each scenarios has been estimated and shown in Figures 13, 14 & 15. Reviewing all the estimated water surface profiles, it was noticed that the dam break model runs for 18 min breaching time with rectangular shape of breach 300 m wide under level pool scenario generated maximum inundation.

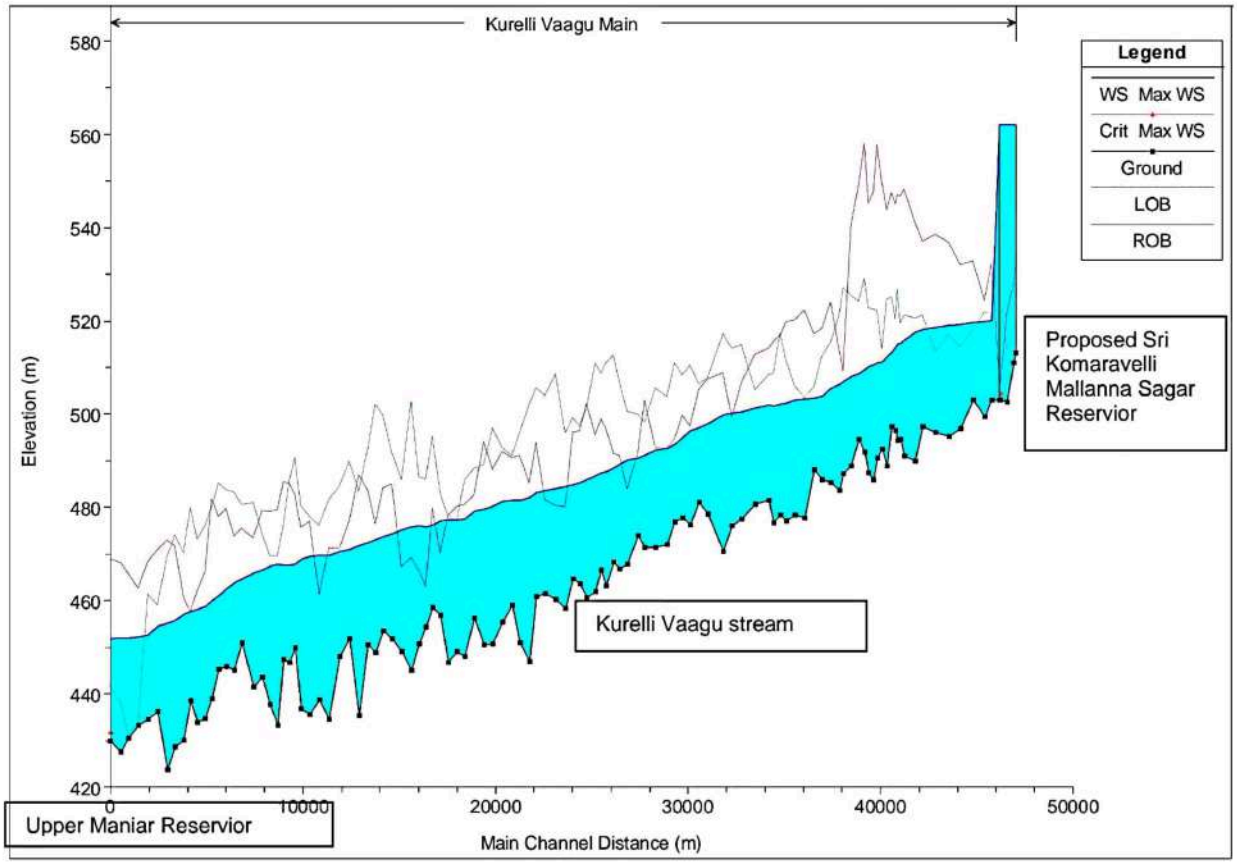

Figure 13 : Longitudinal water surface profile alongwith bed and banks for downstream channel of proposed Sri Komaravelli Mallanna Sagar for 18 minutes breach time.

***(Note : LOB and ROB shown in the figure are extended bank levels as given in the mathematical model)**

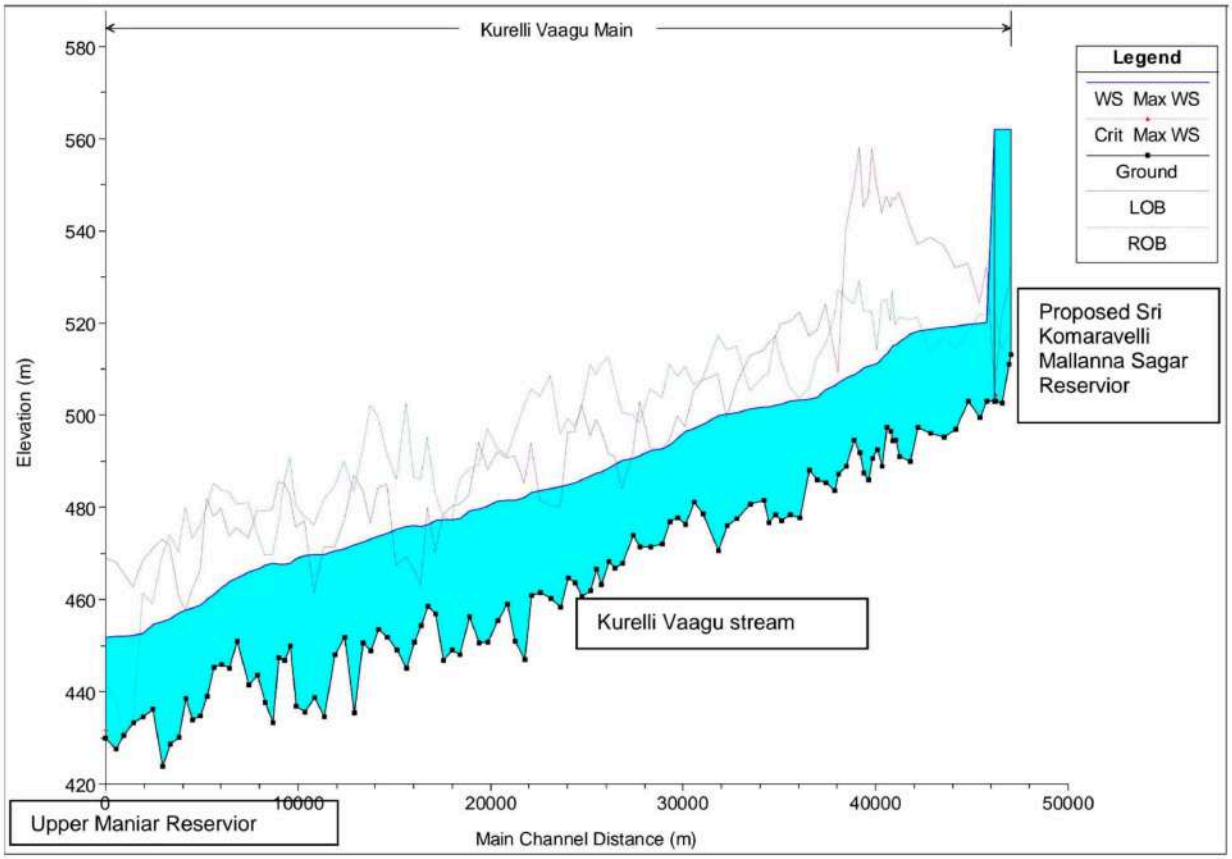

Figure 14 : Longitudinal water surface profile alongwith bed and banks for downstream channel of proposed Sri Komaravelli Mallanna Sagar for 30 minutes breach time.

***(Note : LOB and ROB shown in the figure are extended bank levels as given in the mathematical model)**

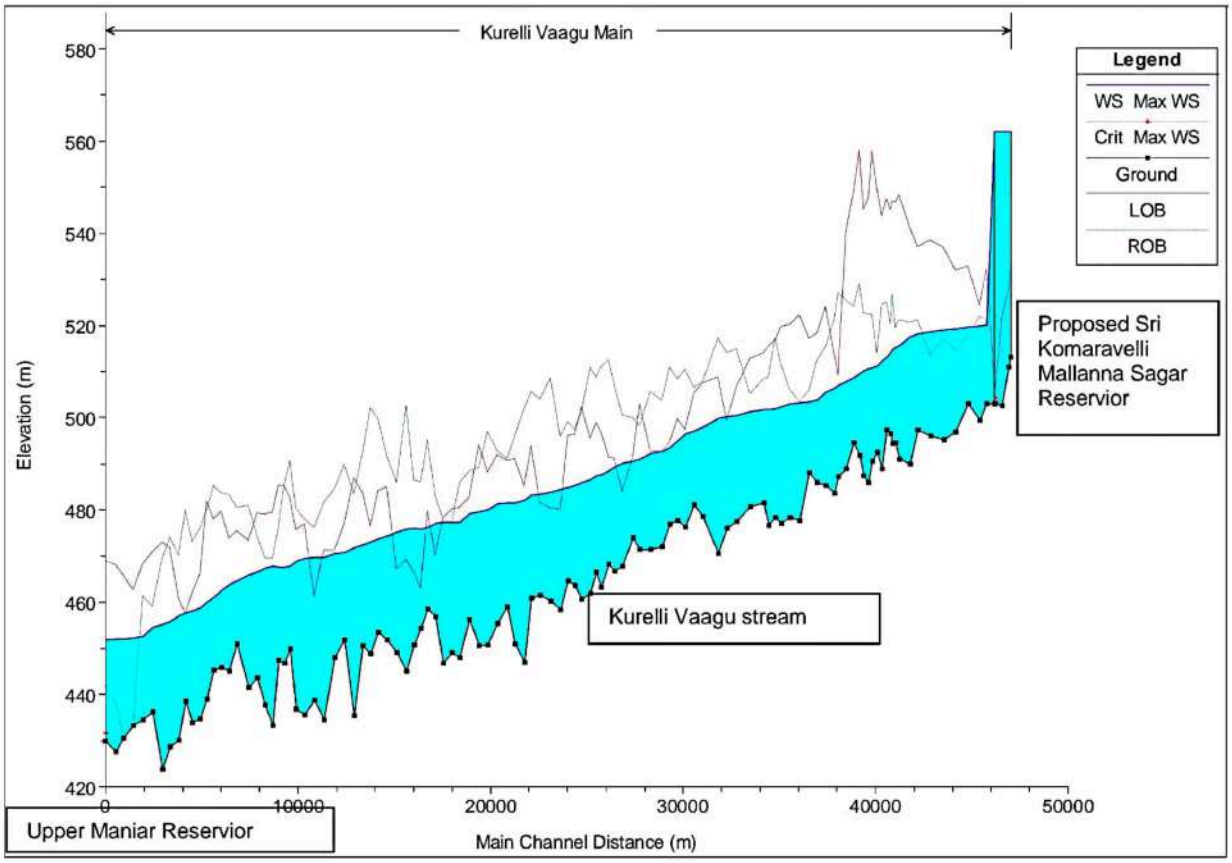

Figure 15 : Longitudinal water surface profile alongwith bed and banks for downstream channel of proposed Sri Komaravelli Mallanna Sagar for 60 minutes breach time.

***(Note : LOB and ROB shown in the figure are extended bank levels as given in the mathematical model)**

Some typical cross sections of Kurelli Vaagu stream at selected locations on the downstream showing maximum water levels (flood inundation levels) are given in figure 16 to figure 21. These figures show the extent of maximum water level and inundation on both the sides of the stream under worst scenario of breach of Shri K. Mallanna sagar.

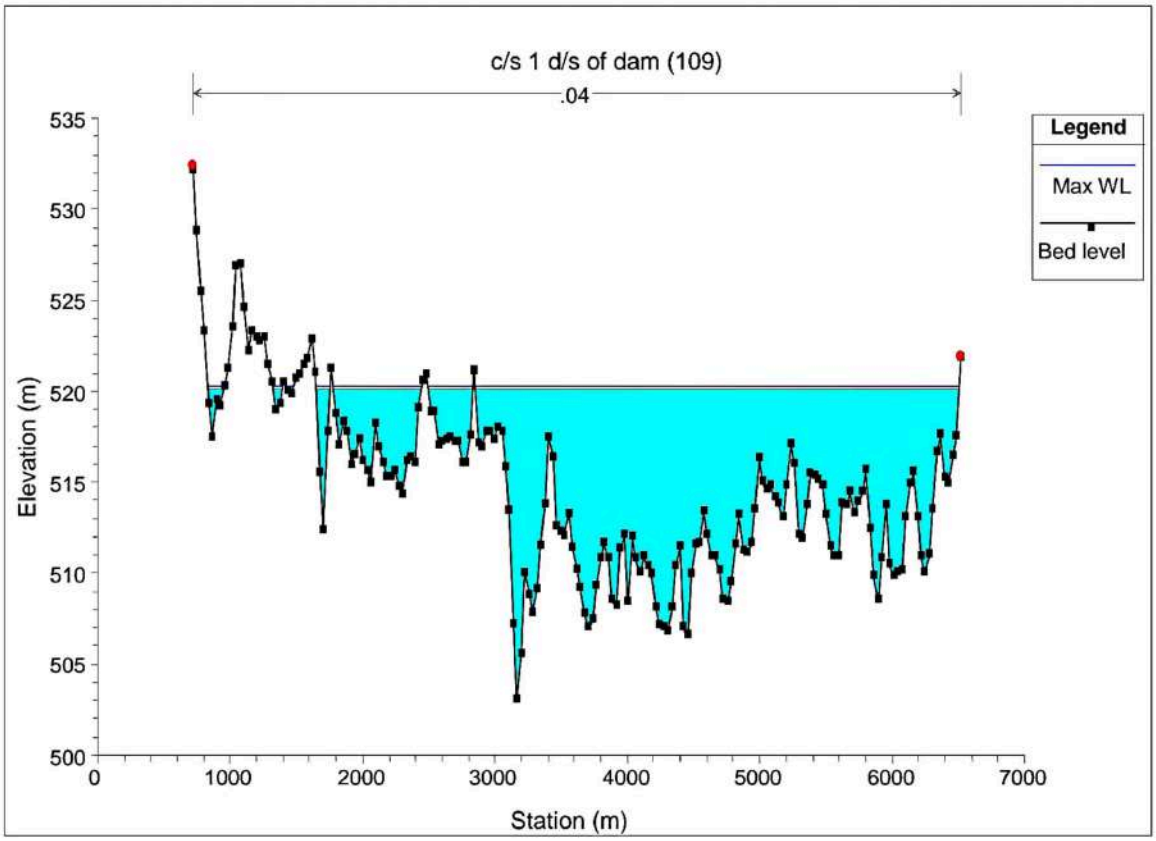

Figure 16: Cross Section of Kurelli Vaagu at 369 m downstream of proposed dam showing maximum water level

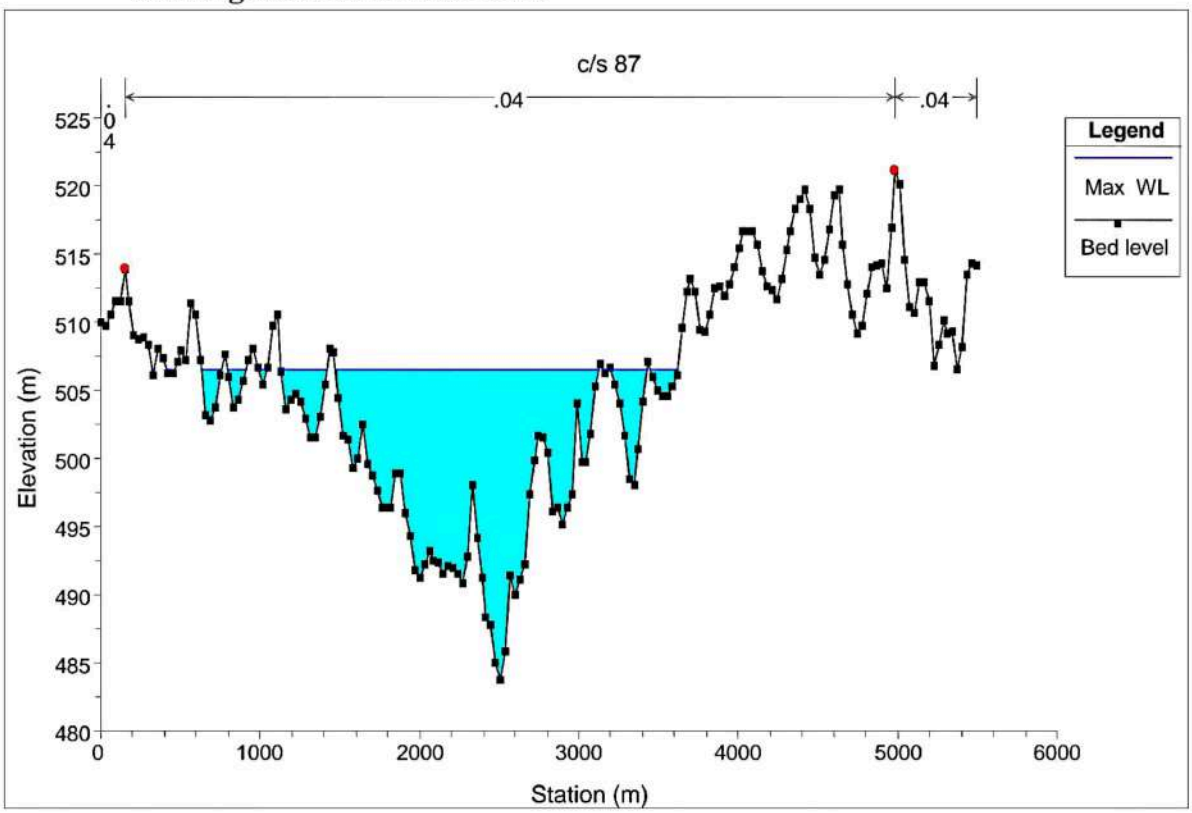

Figure 17: Cross Section of Kurelli Vaagu at 8356 m downstream of proposed dam showing maximum water level

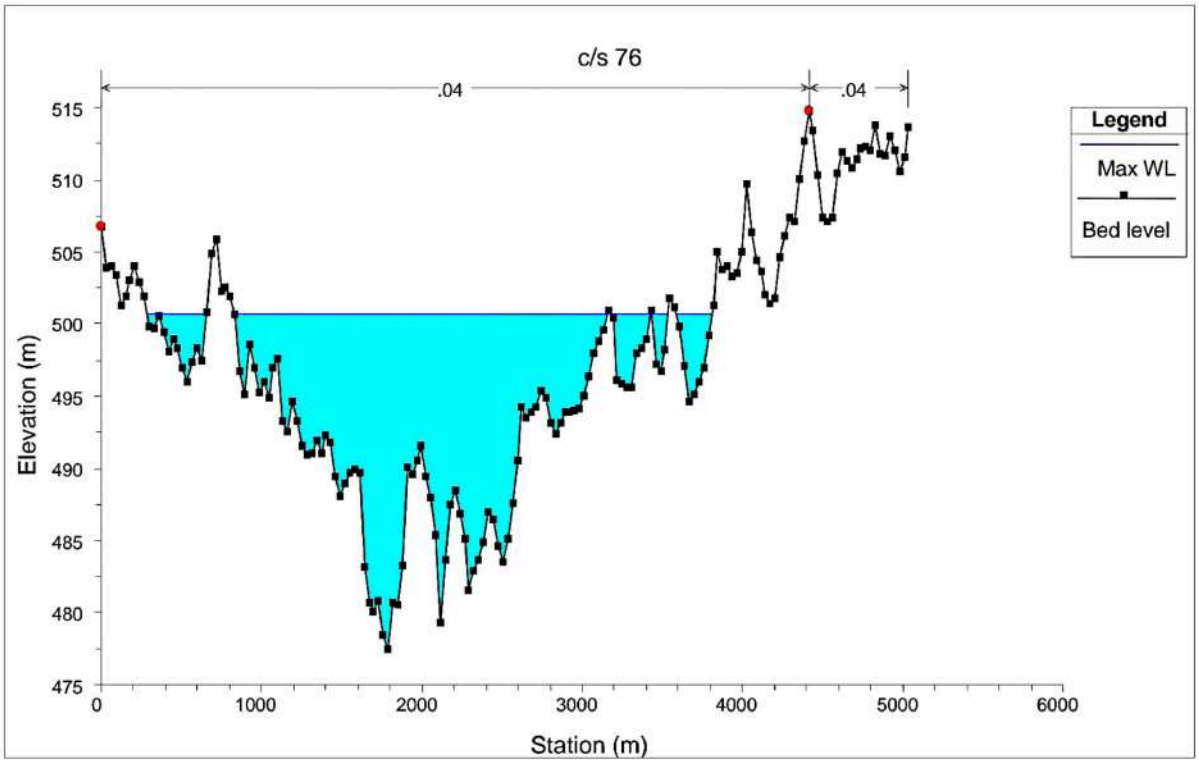

Figure 18: Cross Section of Kurelli Vaagu at 13519 m downstream of proposed dam showing maximum water level

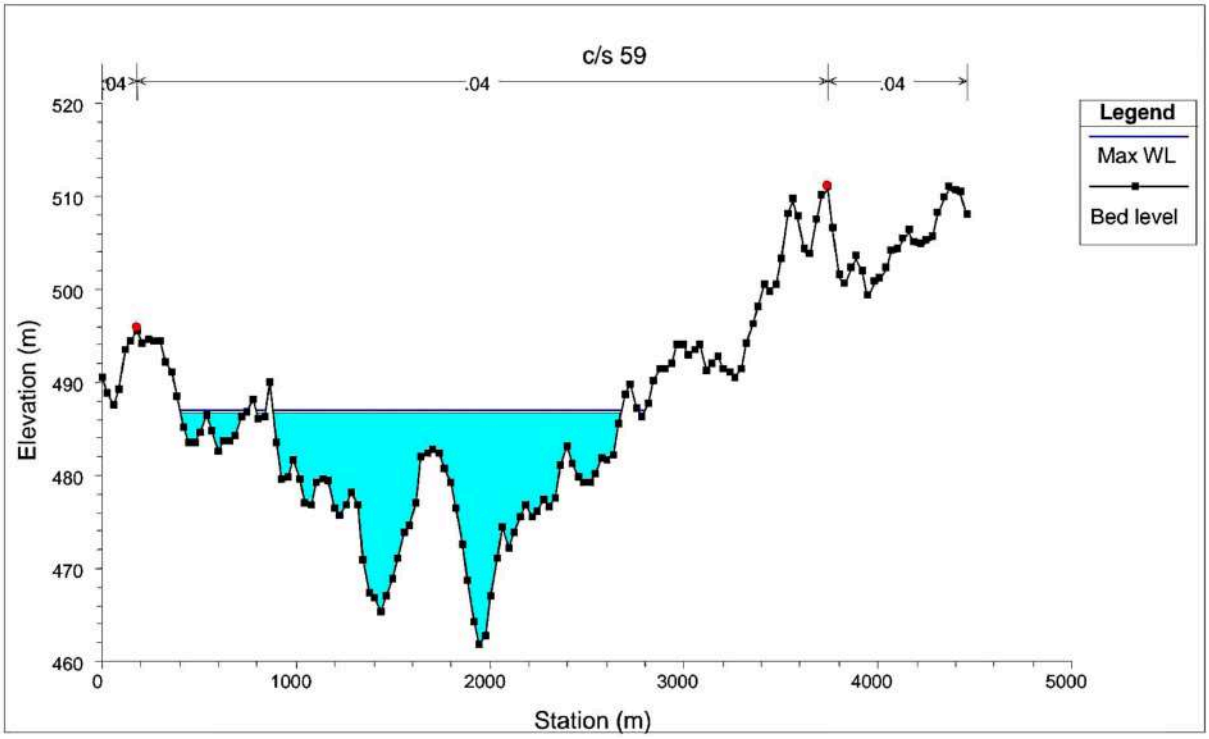

Figure 19: Cross Section of Kurelli Vaagu at 21049 m downstream of proposed dam showing maximum water level

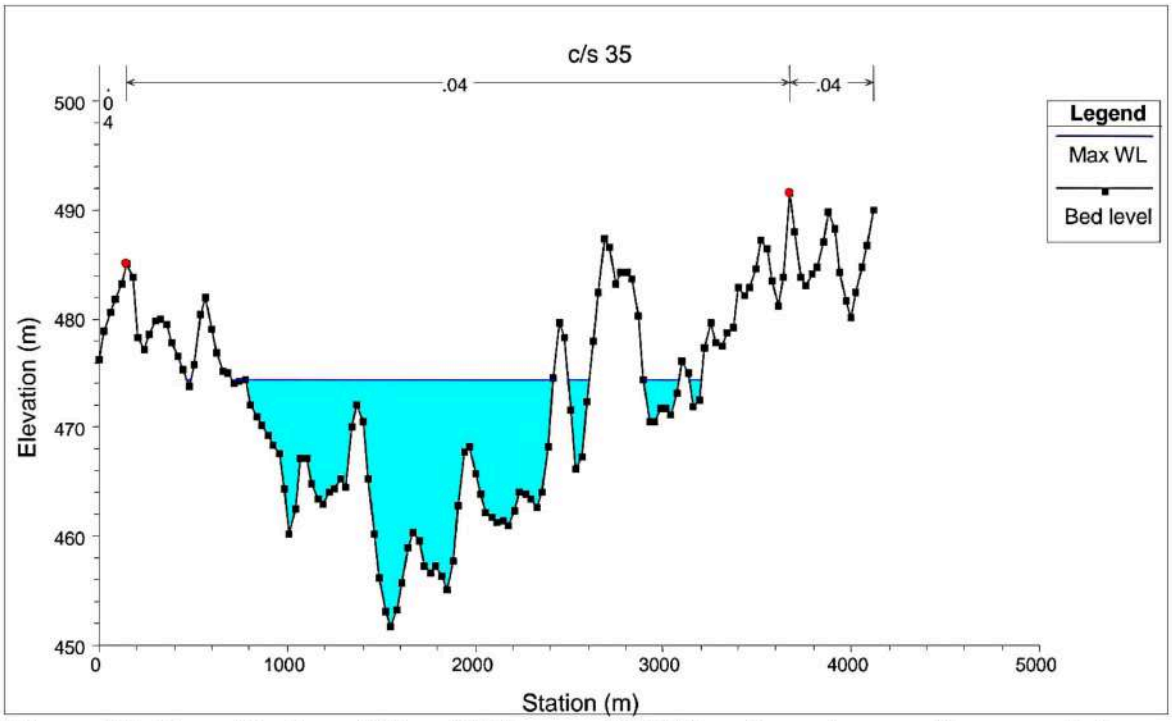

Figure 20: Cross Section of Kurelli Vaagu at 31613 m downstream of proposed dam showing maximum water level

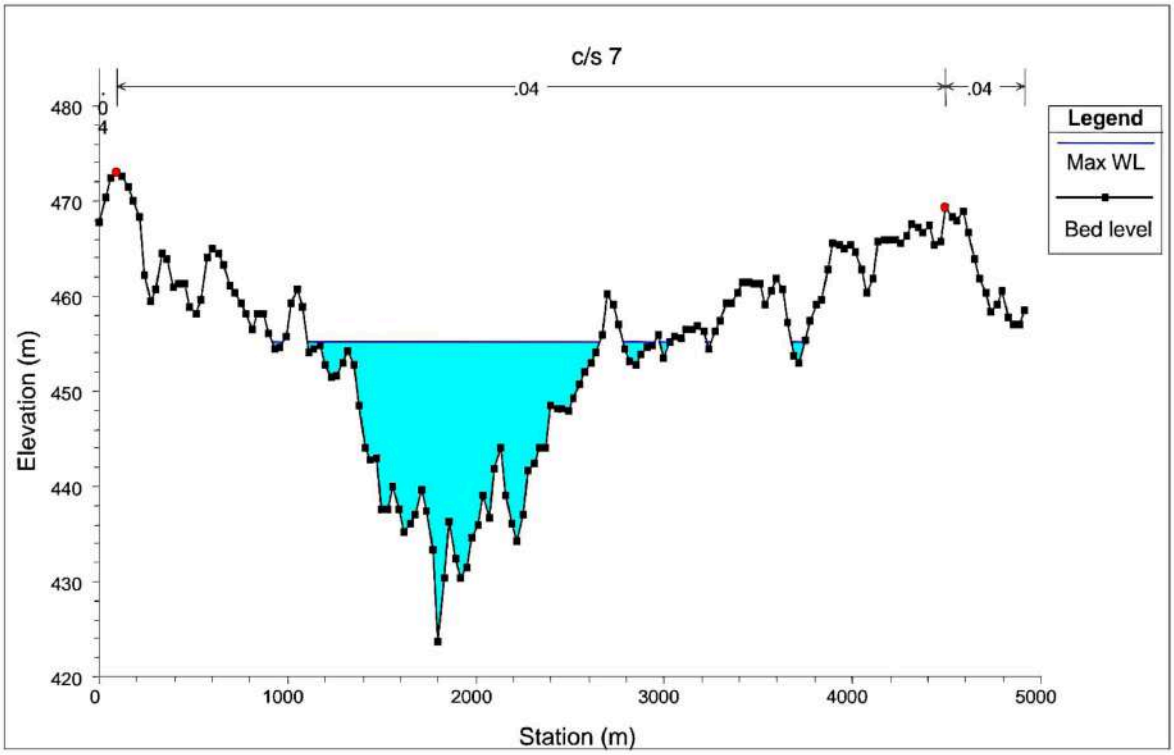

Figure 21: Cross Section of Kurelli Vaagu at 43358 m downstream of proposed dam showing maximum water level

10.0 INUNDATION MAP FOR THE WORST SCENARIO

The results estimated using 1-D mathematical model in HEC-RAS were further imported in ARC-GIS and Q-GIS for the preparation of inundation map for worst scenarios. The flood levels extracted from the water surface profiles were marked on the respective cross sections with reference to the contours using ARC-GIS. The flood levels were marked on the cross sections along the left and right banks of study reach of river Kurelli Vaagu. All marked flood points and cross sections of study reach were imported in to Q-GIS for the preparation of inundation map. The villages nearby the right bank and left bank of study reach were identified on topo map (1:50,000 scale). The locations of importance for flood rescue and evacuation had been identified and marked on flood inundation maps for emergency action planning for disaster management purpose. The details of the inundation maps for case1 is shown in Figure 22 and bifurcated into 4 parts A to D are shown in Figure 23 to fig 26 for more detail.

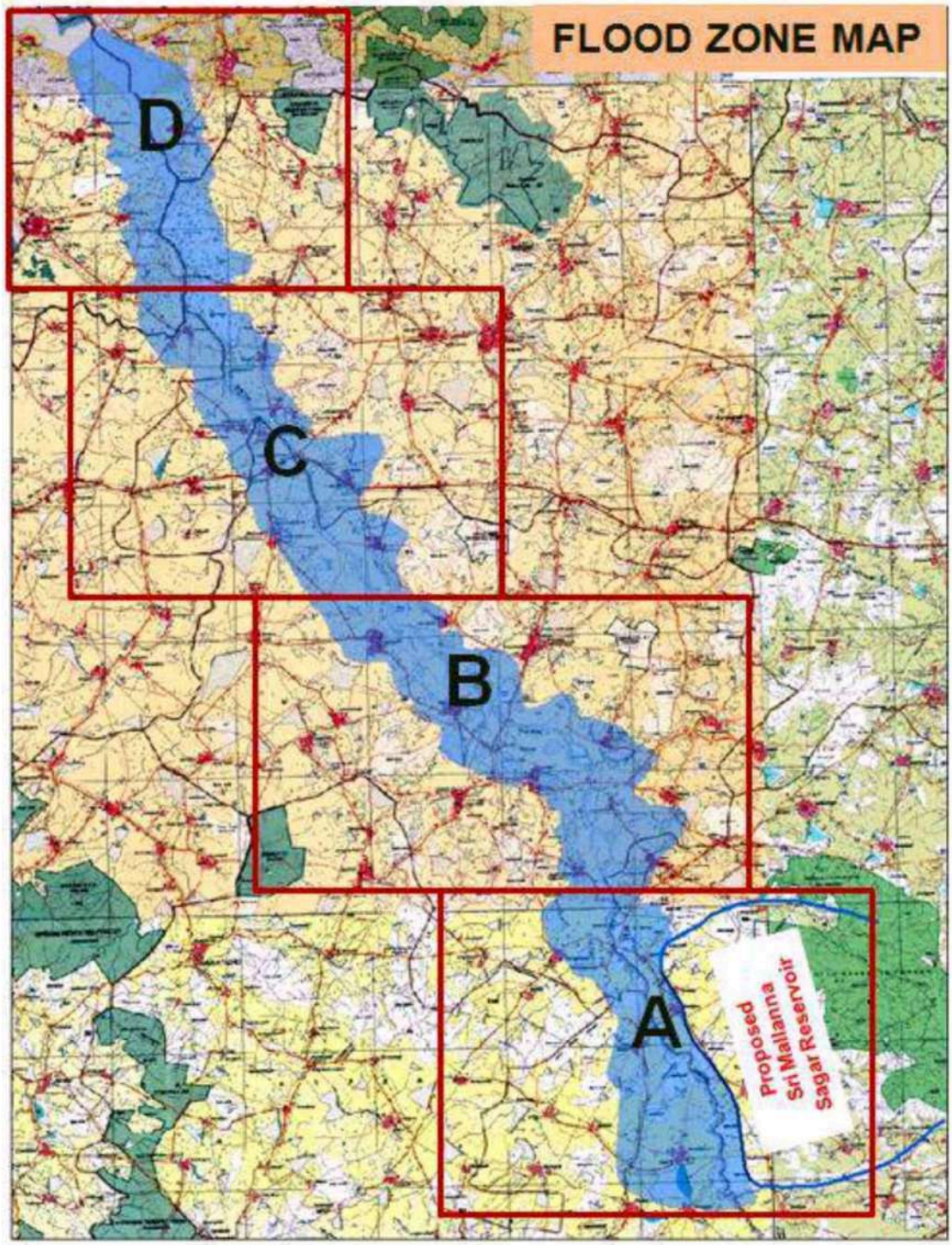

FIGURE 22: INUNDATION MAP OF MOST LIKELY FLOODING AREA UNDER STUDY FOR CASE 1

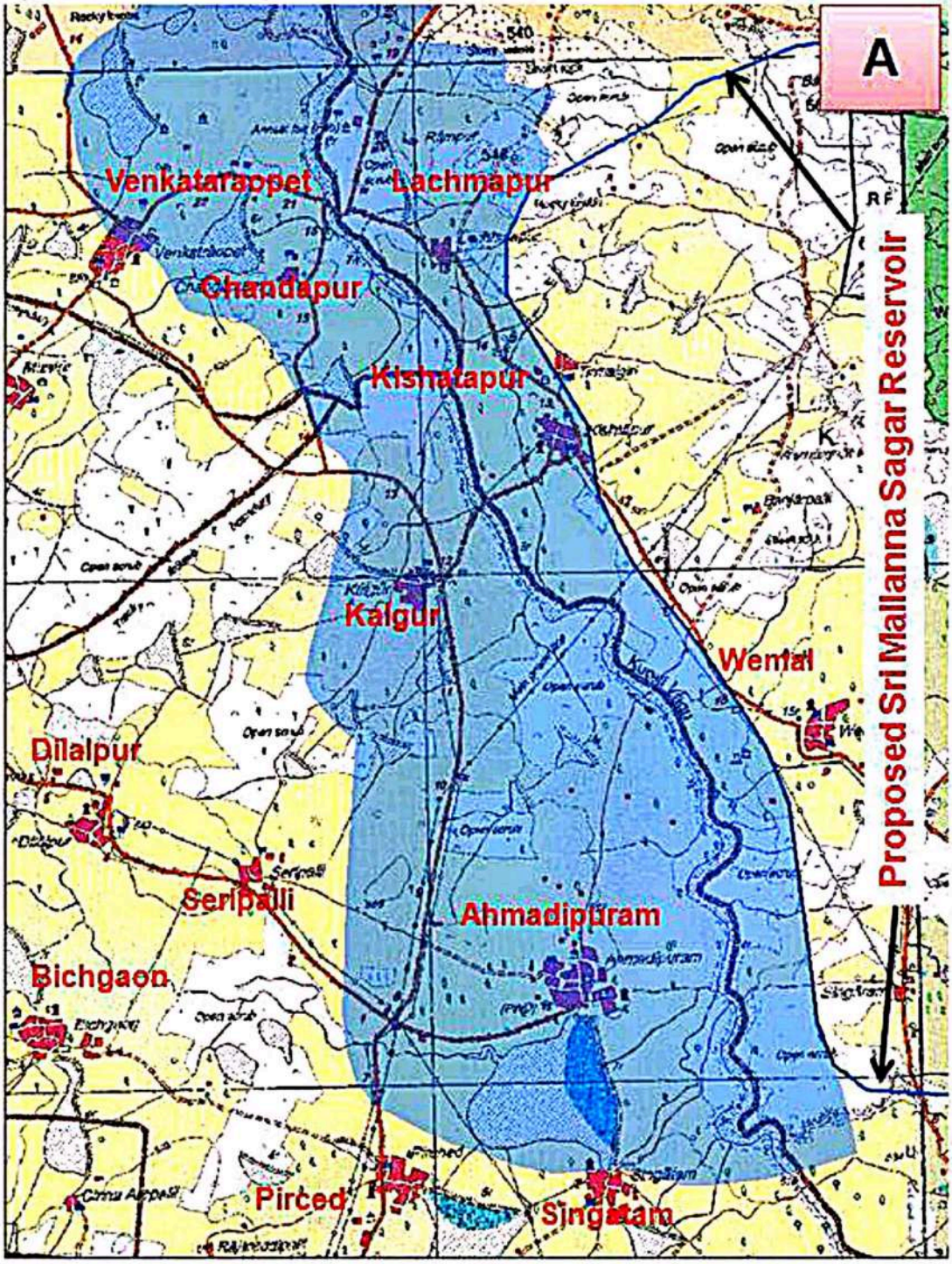

Figure 23: Detail of PART A of inundation map of most likely flooding area

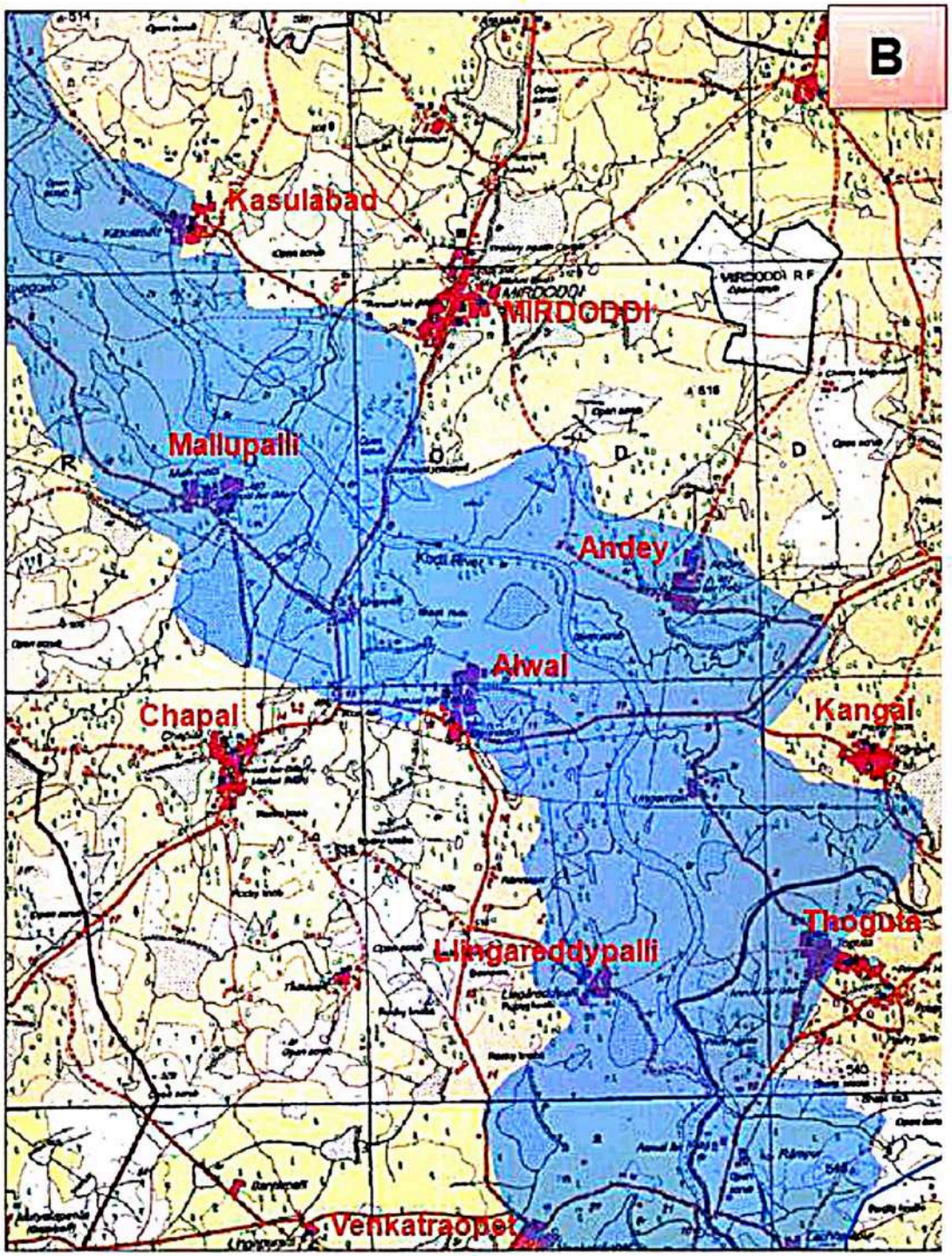

Figure 24: Detail of PART B of inundation map of most likely flooding area

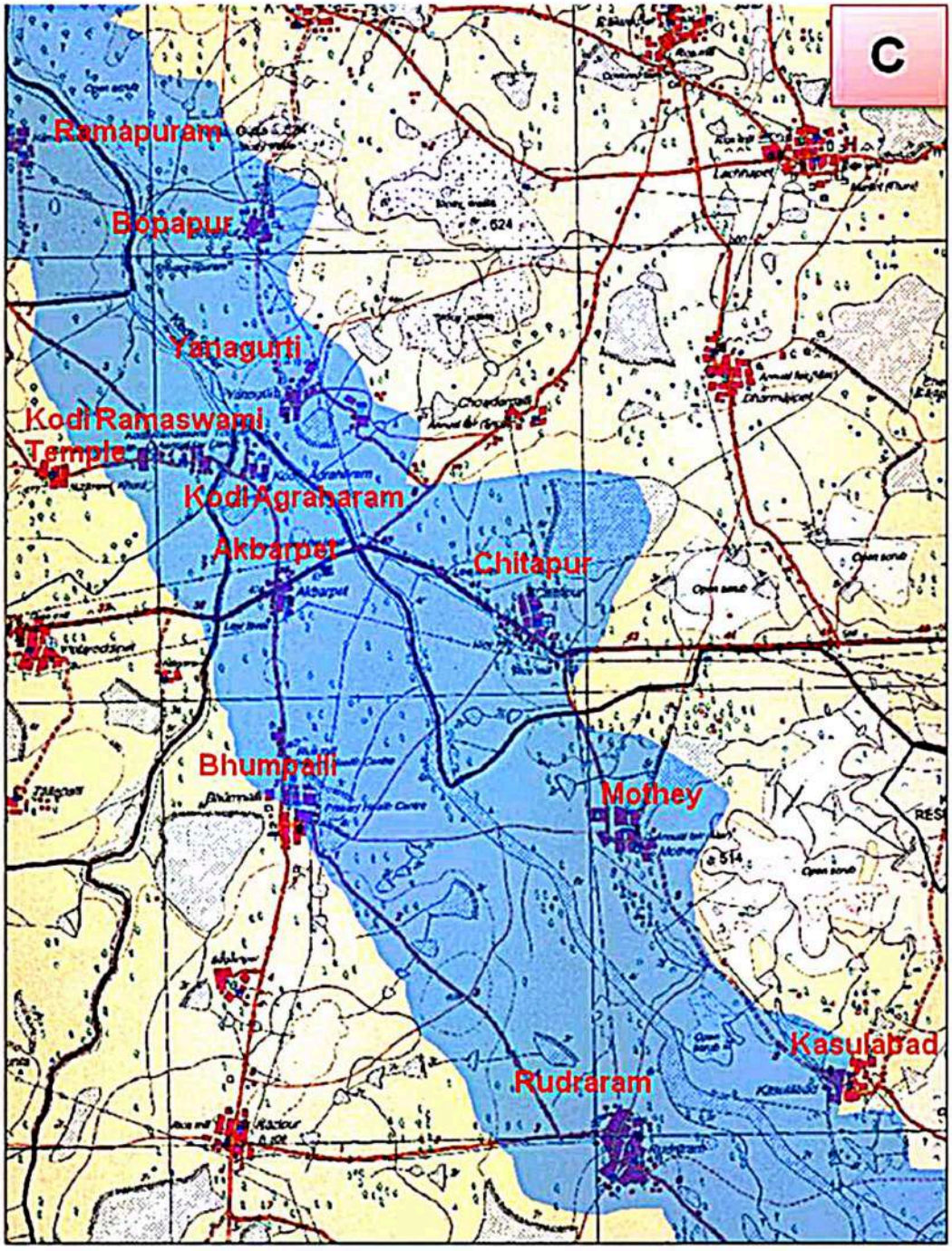

Figure 25: Detail of PART C of inundation map of most likely flooding area

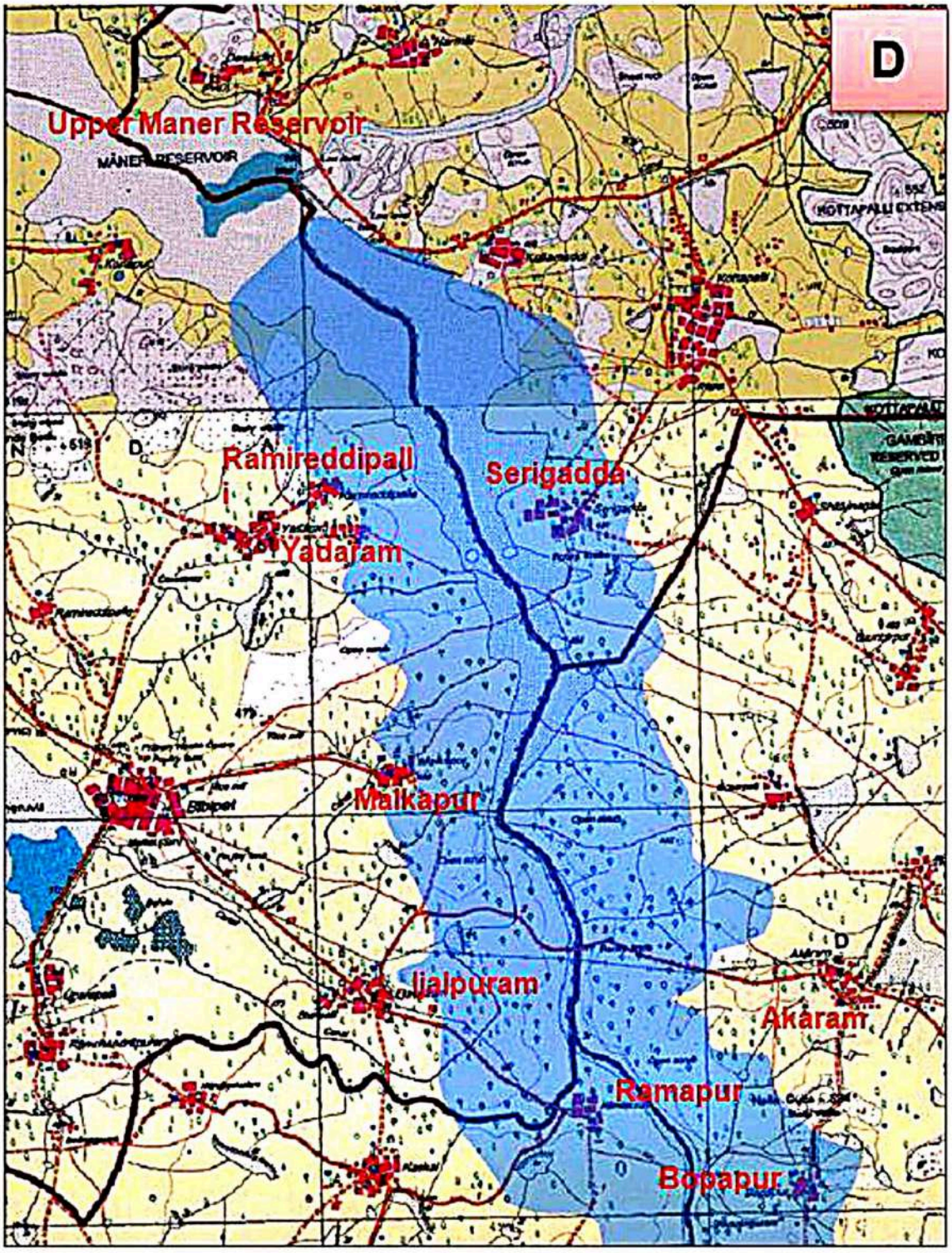

Figure 26: Detail of PART D of inundation map of most likely flooding area

11.0 EMERGENCY ACTION PLAN (EAP)

The general steps in developing an EAP are given below:

1. Identify those situations that would require initiation of an emergency action, specify the actions to be taken and by whom. An emergency may include such items as:
    - *A dam incident* - an abnormal condition or performance of the dam with the potential to endanger the safety of the dam but which is not expected to lead to a breach of the dam.
    - *A dam alert* - an abnormal condition or performance of the dam that, without swift and effective intervention could further degenerate with time and lead to a breach of the dam.
    - *A dam breach* - an actual breach or severe abnormal condition or performance of the dam that has a significant probability of leading to a breach of the dam.

2. Identify all jurisdictions, agencies and individuals including alternate who will be involved in implementing the EAP.
3. Identify primary and auxiliary communication systems, both internal (between persons at the dam) and external (between dam personnel and outside agencies).
4. Identify all persons and agencies involved in the notification process, and draft a notification flowchart which shows whom should be notified, in what order and what other actions are expected of downstream agencies. Each central, state and local government agency involved may have its own general emergency plan. This plan would normally require amendments to include actions required as a result of dam break flooding.

The inundation map prepared with the study results of Dam Break analysis can be utilised as base information for Emergency Action Plan for Disaster Management Planning.

Because of the method, procedures, and assumptions used to determine the flooded areas, the limits of flooding shown and flood-wave travel times are approximate and should be used only as a guideline for establishing evacuation zones. Areas inundated in

an actual event will depend on actual failure conditions and may differ from areas shown on the maps.

The general guidelines for preparation of EAP in case of Dam Break is given as an APPENDIX may be referred.

12.0 CONCLUSIONS

Based on the analysis of result of mathematical model studies using available data following conclusions are made:

1. Dam Break Analysis (DBA) for proposed Sri Komaravelli Mallana Sagar has been carried out using 1-D Dynamic mathematical model HEC–RAS for different breach parameters.
2. For topographical data required for mathematical model, DEM of study area was downloaded from USGS site and processed using ARC-GIS. The cross sections of study reach were extracted from the DEM and used as input for the dam break model. Unsteady flow simulations were carried out for the upstream and downstream boundary conditions for 3 different cases of breaching time viz. 18, 30 and 60 minutes. In all these cases rectangular breach of 300m width up to bottom at the most vulnerable point had been considered for study.
3. Estimated Dam Breach flood hydrographs due to the breach of proposed dam under different scenarios (breach time) have been presented in this report.
4. The Kurelli Vaagu stream reach from Sri Komaravelli Mallanna Sagar upto Upper Maniar reservoir had been simulated considering appropriate roughness factor for Dam Break flood routing.
5. The predicted water surface profiles in figures and tables for all the 3 cases had been given in this report. The corresponding discharges and velocities are also presented in tabular form.
6. After reviewing the results of all three cases, the likely worst scenario was considered as case 1 where the breach time is 18 minutes.
7. For preparation of flood inundation maps for the study reach, required for the emergency action plan, the result of the worst scenario (case 1) has been used. The most probable flood inundation area have been demarcated on topo sheets of Survey of India (SOI) (1:50,000 scale) by the predicted water levels along the stream

and contours generated from DEM. As the inundation map generated has some inherent limitations and thus may be treated as a reference inundation map for EAP.

13.0 GENERAL LIMITATIONS

1) The cross sections and other topographical details of study reach of river were extracted from the SRTM 1 arc DEM downloaded from USGS site having resolution of 30m. It implies there is a limitation in the identification of topography of the area under study due to pixel size of sensor. Thus there can be inherent error in cross sections which may creep in some amount of uncertainty and may affect reliability of the final estimated flood levels to some extent.

2) It was postulated that the dam will breach in Rectangular shape with width and size of breach (300 m wide up to bottom) at the most vulnerable location with reference to some acceptable guidelines in this regard. The time of breach has been taken as 18 minutes for the worst case. The actual breach size and time cannot be identified precisely.

3) The results were superimposed on SoI topo map of scale 1:50,000 having contour interval of 20 m for preparation of inundation map.Toposheets of the scale 1:15000 or 1:25000 having 1m contour interval were not available for identification of villages and other critical locations for flood plain mapping as generally used in detailed Emergency Action Planning.

4) One-dimensional mathematical model has a limitation of providing only depth and discharge as output at every computational cross section along the river. In order to obtain a two dimensional map of the inundated area, one dimensional model results needs to be converted into two dimensional maps by interpolating outputs between 1D model cross sections, based on digital elevation maps. The interpolation process may introduce errors in unsteady simulations, especially over relatively flat terrain. In the case of highly transient flows, the interpolation process does not respect the mass conservation principle. This is an inherent limitation of the model used for this study.

ACKNOWLEDGEMENT

We wish to express our deep sense of gratitude to Dr. (Mrs.) V. V. Bhosekar, Director Incharge CWPRS for her encouragement and valuable suggestions during the course of this study. Our sincere thanks are due to S/Shri Hari Ram, C.E (Kaleshwaram Project), T.Venu, S.E (Project), Chandrasekhar, S.E (Design), K.N. Anand, E.E (Project), Srinivas, E.E (Design) and their staff for their support and co-operation during site visit and discussions. Efforts extended in assisting data processing and preparation of report by staff members of Surface Water Hydraulics Division, CWPRS are appreciated.

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1. Chow, V. T. (1959), "Open Channel hydraulics", Tata McGraw-Hill, Inc. New York
2. U.S. Army Corps of Engineers, USACE (August 2014), "Using HEC-RAS for Dam Break Studies" (TD-39)
3. U.S. Army Corps of Engineers, USACE (2016) version 5.0.3, "HEC-RAS River Analysis System, Hydraulic Reference Manual", Hydraulic Engineering Center Report CPD-69, Davis, CA
4. Central Water Commission, MoWR,RD & GR, Govt. of India (Feb 2016), "Guidelines for Developing Emergency Action Plans for Dams"

APPENDIX

GUIDELINES FOR PREPARATION OF EMERGENCY ACTION PLAN (EAP) FOR DISASTER MANAGEMENT PLANNING

1.0 INTRODUCTION

The increasing use of the risk assessment process as a planning and decision-making tool has highlighted the need for improved embankment breach analysis tools. Risk assessment analyses of Reclamation dams consider all possible loadings and failure scenarios for a dam, the probability of those loadings and sequences of events needed to cause failure and the consequences of failure. The development of effective emergency action plans and design of early warning systems might reduce or eliminate consequences of failure.

An EAP is a formal written plan that identifies the procedures and processes to be followed by the dam authorities in the event of an emergency at a dam. The emergency could be failure of essential components such as spillway and sluice gates, slope failure which may cause failure of dam, or a complete failure of the dam caused due to overtopping, earthquake or piping. By its nature EAP is site specific.

The identification of whether a dam poses a hazard to downstream areas and, hence requirement of a formal EAP is desirable. For example, a large dam retaining a large volume of storage within a confined valley containing significant habitation would clearly need an EAP. Conversely, a small dam in a relatively uninhabited area usually would not. If inhabited areas are potentially affected, a EAP must be prepared.

The consequences should be assessed in terms of loss of life, economic value of other losses, damage to property, facilities, and other utilities of the dam, loss of power generation, irrigation, water supply or tailing storage. Other consequences related to environmental, social and cultural aspects which cannot be described in economic terms, may require consideration on a site specific basis subject to any applicable regulatory approval process. Estimation of potential losses both with and without dam failure should be based on inundation and other studies and considers existing and anticipation future downstream development and land

uses. For dams where there is an uncertainty about the consequences of a dam break, a simplified and conservative analysis should be used to make a preliminary assessment. If this analysis demonstrates a potential hazard a more sophisticated analysis should then be undertaken.

2.0 UTILISATION OF DAM BREAK ANALYSIS FOR PREPARATION OF THE EAP

For the preparation of Disaster Management Plan, the results of the Dam Break analysis need to be extracted along the following lines:

- Prepare plan showing inundated area on a contour map drawn to a suitable scale usually ranging from 1:15,000 to 1:25,000 with the contour interval of 1 to 2 m depending upon the area covered.
- Mark cross sections used for study in the plan
- Mark HFL at the cross sections
- Mark important towns, structures etc.
- Mark ground levels at important locations
- Prepare a statement showing the maximum depth of water at important locations
- Prepare a statement showing the time taken by the wave front to travel from the dam site to various locations.
- Prepare a statement showing the time taken to reach the maximum water level at the locations.
- Prepare stage hydrographs and discharge hydrographs
- Prepare a statement showing the total duration of inundation
- Indicate clearly the areas where the flood velocities are likely to be high

3.0 DEVELOPMENT OF EMERGENCY ACTION PLAN (EAP)

The steps in developing an EAP generally are as below:

1. Identify those situations that would require initiation of an emergency action, specify the actions to be taken and by whom. An emergency may include such items as:

- *A dam incident* - an abnormal condition or performance of the dam with the potential to endanger the safety of the dam but which is not expected to lead to a breach of the dam.
- *A dam alert* - an abnormal condition or performance of the dam that, without swift and effective intervention could further degenerate with time and lead to a breach of the dam.
- *A dam breach* - an actual breach or severe abnormal condition or performance of the dam that has a significant probability of leading to a breach of the dam.

2. Identify all jurisdictions, agencies and individuals including alternate who will be involved in implementing the EAP.
3. Identify primary and auxiliary communication systems, both internal (between persons at the dam) and external (between dam personnel and outside agencies).
4. Identify all persons and agencies involved in the notification process, and draft a notification flowchart which shows whom should be notified, in what order and what other actions are expected of downstream agencies. Each central, state and local government agency involved may have its own general emergency plan. This plan would normally require amendments to include actions required as a result of Dam Break flooding.
5. Develop a draft of the EAP

4.0 Central Water Commission (CWC) Guidelines for preparation of EAP

The *Guidelines for Developing Emergency Action Plans for Dams (2016)* prepared by CWC describes all elements of an EAP and comprehensively covers requirements for notification flow charts, emergency conditions, inundation maps, emergency detection, evaluation and classification, emergency preparedness and implementation methodologies. Managing the contingencies caused by a failure of a dam or by uncontrolled release of water due to flooding, requires coordinated efforts of both dam owning/operating agencies and also disaster management authorities, namely District Magistrate/Collector, Armed Forces, Paramilitary Forces, Project Authorities and other Central/State Agencies. An EAP also contains inundation maps to show the disaster management authorities the critical areas for providing necessary relief and taking rescue actions in case of

an emergency. For these reasons, EAPs provide a mechanism for coordination among all the agencies and defines their roles and responsibilities and the actions to be taken to minimize loss of life and damage to environment and property.

The EAP guidelines also provide a template for emergency action plans to facilitate dam authorities in developing their EAPs in a consistent way. All dam authorities in India are advised to use these guidelines for developing EAPs for their dams, or for updating their existing EAPs, and for implementing them. In a nutshell, it outlines "who does what, where, when and how" in an emergency situation or unusual occurrence affecting the dams.

The primary goal of the Central Dam Safety Organisation (CDSO) of the Central Water Commission (CWC) is to encourage and facilitate dam safety practices that will help ensure operation of dams to their full capacities and intended purposes, and also to reduce the risk to lives and property from the consequences of both structural and operational dam incidents and failures. Although most dam authorities have a high level of confidence in the structures they own and are certain their dams will not fail, history has shown that on occasion dams do fail and that often these failures cause extensive damage to property, and sometimes loss of life. Dam authorities are responsible for keeping these threats to acceptable levels. A carefully conceived and implemented Emergency Action Plan (EAP) is one positive step dam authorities can take to accomplish dam safety objectives, protect their investments, and reduce potential liabilities.

An EAP for a dam is a written document prepared by the dam authorities, or the dam operator, describing a detailed plan to prevent or lessen the effects of a failure of the dam or appurtenant structures. An emergency action plan is not a substitute for proper maintenance or remedial construction, but it facilitates recognition of dam safety problems as they develop and establishes nonstructural means to minimize the risk of fatalities and reduce property damage.

The EAP is intended to interface with the emergency operation plans of other Local, District and State agencies to ensure effective and timely implementation of response action. Every EAP has to be thus tailored to site-specific conditions and to the requirements of the dam owning/ operating agency and the local emergency management authorities. These guidelines define the requirements of

an acceptable EAP and facilitate its preparation, distribution, annual update, testing, and periodical revision.

Emergency action plans proposed by the Dam Safety Bill, 2010 (introduced in the Lok Sabha on August 30, 2010) will be put into effect as and when conditions arise that are likely to be hazardous to a dam or potentially hazardous to public safety, infrastructure, other property, or the environment.

4.1General Procedure for Developing an EAP:

Development of an EAP generally follows the steps listed below.

Step 1. Determine the potentially inundated area by defining flood profiles downstream from the dam for conditions that may include the following:

- Dam failure with the reservoir level at normal storage elevation (a so-called "fair weather" failure).
- Inflow design flood both with and without dam failure.
- Extremely large spillway flows resulting from severe weather and emergency conditions.

Step 2. Prepare inundation maps that clearly depict the flooded areas from a dam failure. The time of arrival of wave front, maximum depth of inundation, and maximum velocity of flow may also be estimated for areas of high impact. For dams with limited downstream development, a generalized inundation map and narrative description may suffice.

Step 3. Identify situations or events that could trigger an emergency condition and require action.

Step 4. Evaluate the warning time available for the various triggering events.

Step 5. Identify all jurisdictions, agencies, and people who will be involved in the EAP. Contact the local District Disaster Management Authority (DDMA) / District Collector for assistance. Coordinate the development of the EAP with all involved parties.

Step 6. Identify primary and auxiliary communications systems, both internal (between persons at the dam) and external (between dam personnel and outside entities).

Step 7. List all the persons and entities that need notification in case of dam distress, prioritize the order of notification, and draft the notification flowcharts.

Step 8. Develop a draft of the EAP.

Step 9. Hold one or more coordination meetings with all local agencies and other parties on the notification list to receive their review and comments on the draft EAP.

Step 10. Submit a draft to the State Dam Safety Organization (SDSO) for review. For dams of national importance, the CDSO may be approached for review.

Step 11. Make any necessary revisions, obtain the necessary signatures for plan approval, and distribute the EAP to those who have responsibilities under the plan (EAP to include the Distribution List). Information about the EAP may also be made available on the websites of dam authorities / operator and the SDSO.

Step 12. Update the EAP annually for correcting the contact addresses, and share the updates with all concerned as per EAP Distribution List. Carry out a tabletop drill to test the efficacy of EAP at least once every five years. Revise the EAP, as and when required, in line with the outcomes of tabletop drill or the implementation hurdles observed during actual extreme events or other emergencies.

4.1 Outline of the EAP Five-Step Response Process:

Five steps should generally be followed when an unusual or emergency incident is detected at a dam. These steps constitute the EAP response process as outlined below:

Step 1. Event Detection

Step 2. Emergency Level Determination

Step 3. Notification and Communication

Step 4. Actions to be Taken

Step 5. Termination and Follow-up

The five steps to take during an unusual event or emergency are illustrated in the flowchart shown in Figure 1. Responses for each alert type (Internal Alert for **BLUE** level emergency, or External Alert for **ORANGE** or **RED** level emergencies) contain all five steps. Depending on the type of alert to be issued, these steps will contain different notification lists and procedures. Careful preparation and review of all five steps will provide guidance during an unusual event or emergency.

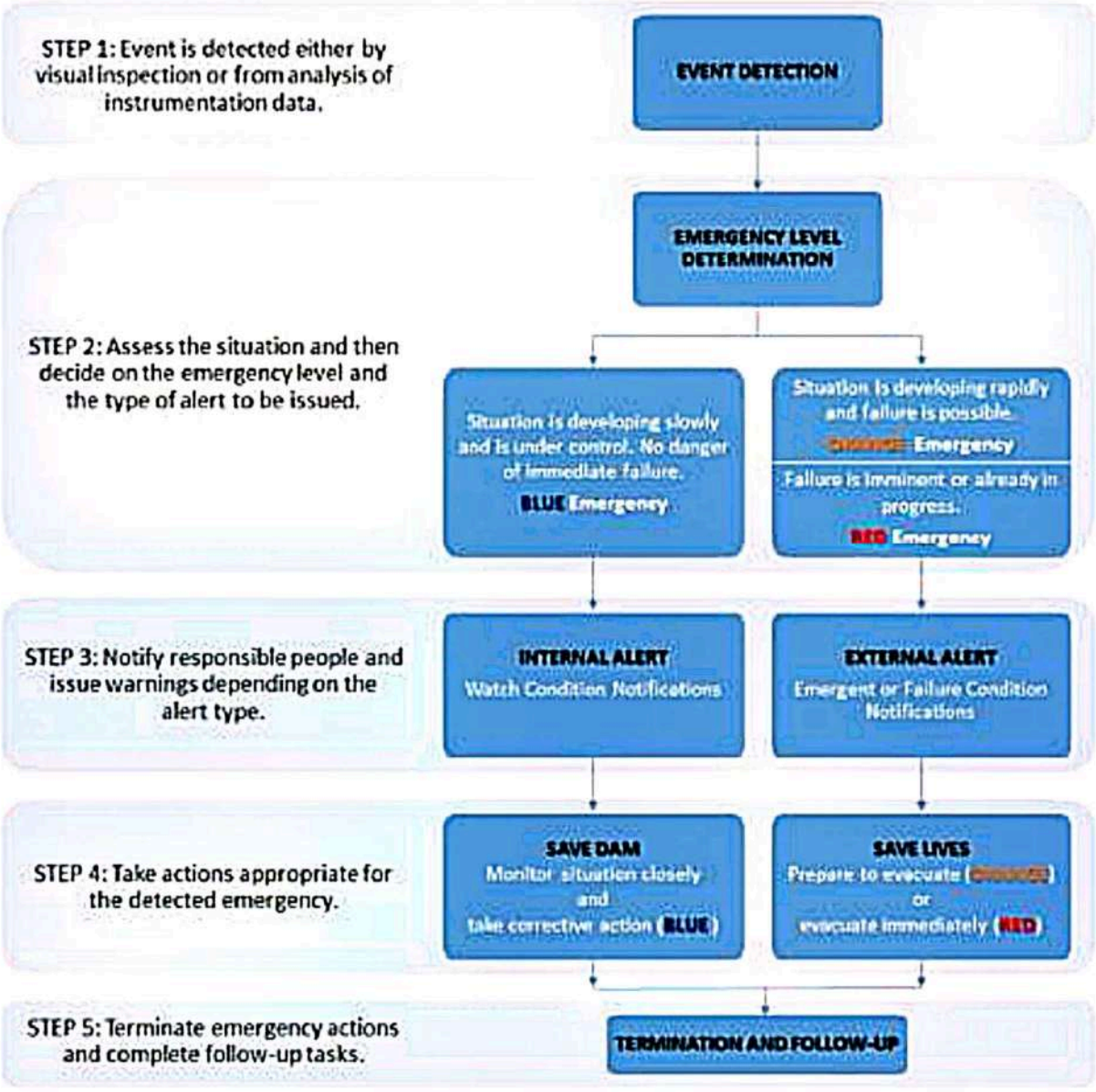

Figure 1: Flowchart showing the five-step response process of an EAP for a dam.

Table 1: Description of Emergency Alert Levels and Notification Types

Type of alert	Emergency level	Situation	Actions to be taken
INTERNAL ALERT (Watch Condition Notifications)	**BLUE**	Existence of anomalies or events that are either harmless or might compromise to some degree the structural or operational safety of the dam or the dam observation system. The situation is stable or is developing extremely slowly. Existing problems must lead to the belief that no serious consequences are expected downstream of the dam, and impacts (if any) will be small and confining to immediate downstream areas of the dam. Events leading to such a slowly developing situation include the following: 1. Existence of adverse meteorological conditions; 2. Existence of minor foundation problems	1. Issue Watch Condition notifications with a **BLUE** emergency level alert. 2. Monitor situation closely. 3. Take corrective measures to solve the problem
EXTERNAL ALERT (Failure Condition Notifications)	**ORANGE**	Situations with a high probability of dam failure, with the belief that it might not be possible to control the situation and might cause serious consequences downstream of the dam. Events leading to such a rapidly developing situation include the following: 1. Detection of severe anomalies in- dam structural elements, or- in dam operational elements 2. Existence of severe foundation problems 3. Occurrence of extremely large floods Under these conditions the dam authorities or operator might call for assistance from outside agencies. "Some amount of time" will be available for analysis, decisions, and mitigation before off-site impact will probably occur.	1. Issue Failure Condition notifications with an **ORANGE** emergency level alert. 2. Take corrective emergency measures to solve the problem. 3. Warning – Population downstream of the dam to prepare for evacuation.
	RED	Situation of inevitable catastrophe described asfollows: 1. Imminent dam failure because of flood waters overtopping the dam crest, or appearance of large flows through channels (piping) eroded through the embankment. 2. Dam failure in progress. No time will be available for analysis, decisions, and mitigation to be made before downstream impacts occur	1. Issue Failure Condition notifications with a **RED** emergency level alert. 2. Issue the most severe evacuation warning. Focus on evacuating first those most at risk. 3. Warning – Immediate evacuation.

Table 2: Description of Authorities and Actions to be taken at different Alert levels

Sl. No.	Alert Level	Official / authority responsible	Response / Actions to be taken
1.	**BLUE**	Dam Operation Office, Manager (Civil), PCD	1. Measures to solve problem. 2. Give internal alert signal of blue level. 3. Inform to: a. Dam Supervisor, AGM (PC) b. Dam authorities, CMD, M/s KIOCL
		Dam Supervisory Office, AGM (PC) /Dam authorities	Get full report and satisfy himself / herself regarding appropriateness of the measures being taken to solve the problem.
2.	**YELLOW**	Dam Operation Office, Manager (Civil), PCD	1. Measures to solve problem. 2. Give internal alert signal of blue level. 3. Inform to: a. Dam Supervisor, AGM (PC) b. Dam authorities, CMD, M/s KIOCL
		Dam Supervisory Office, AGM (PC) /Dam authorities	1. Get full report and satisfy himself / herself regarding appropriateness of the measures being taken to solve the problem. 2. Seek expert advice, if considered necessary. 3. Inform civic administration / local disaster management authority for their preparedness.
3.	**ORANGE**	Dam Operation Office, Manager (Civil) / Dam Supervisory Office, AGM (PC) /Dam authorities	1. Measure to solve problem. 2. Give external alert signal of orange level 3. Review preparedness as per para 2.5. 4. Inform to (a) District Collector & S.P. (b) State Flood Control Cell Warning – Population downstream the dam to be ready for evacuation
		Local Disaster Management Authority	1. Review preparedness as per para 2.5 2. Inform all officers responsible for District Disaster Management for preparedness 3. Inform all residents of affected regions through their leaders / representatives / local radio / wireless etc.
4.	**RED**	Dam Operation Office, Manager (Civil) / Dam Supervisory Office, AGM (PC) /Dam authorities	1. Give external alert signal of red level. 2. Inform to: (a) Local Disaster Management Authority (b) State Flood Control Cell Warning - Population downstream of the dam to evacuate quickly.
		Local Disaster Management Authority	1. Take actions as per para 2.5. 2. Get all officers responsible for District Disaster Management in action. 3. Inform all residents through their leaders / representatives / local radio / wireless etc. 4. Initiate search, rescue and relief operations

4.2 Elements of an EAP:

At a minimum, an EAP needs to contain the following items:

- title page
- purpose
- general description of dam
- responsibilities
- notification flowcharts
- inundation maps
- possible emergency conditions
- preventive actions to be taken
- supplies and resources
- implementation procedures

4.3 Dam Safety and Maintenance Manual:

Based on standard recommended guidelines for the safety inspection of dams a manual should be prepared by the project proponents in respect of dam safety surveillance and monitoring aspects. This should be updated with the availability of instrumentation data and observation data with periodical review. The need for greater vigil has to be emphasized during first reservoir impoundment and first few years of operation. The manual should also cover on the routine maintenance schedule of all hydro-mechanical and electrical instruments. It should cover quantum of specific construction material needed for emergency repair along with delineation of the suitable locations for its stocking and also identify the much needed machinery and equipment for executing emergency repair work and for accomplishing the evacuation plan.

4.4 Administration and Procedural Aspects:

The administrative and procedural aspects of the Emergency Action Plan consist of flow chart depicting the names and addresses of the responsible personnel of project proponent and the District Administration. In order of hierarchy, the following system will usually be appropriate. In the event that the failure is imminent or the failure has occurred or a potential emergency condition is developing, the observer at the site is required to report it to the Junior Engineer who will report to the Superintending Engineer/ Divisional Engineer for their

reporting to the Chief Engineer through fastest available fastest communication system. The Engineer-in- Charge will keep the district administration informed regarding the developing situation. Each personnel are to acknowledge his/her responsibilities under the EAP in an appropriate format at a priority. The technical aspects of the EAP consist of preventive action to be taken with regards to the structural safety of the dam. The EAP is drawn at a priority for the regular inspection of the dam. For this purpose, providing an adequate and easy access to the dam site is a necessity. The dam, its sluices, overflows and non-overflow sections should be properly illuminated for effective operations during night time. Whenever sinkholes, boils, increased leakages, movement of masonry rock, gate failure, rapid rise or fall of the level in the reservoir, rise in the level of reservoir beyond the maximum working level, or wave overrun of the dam crest are observed, the personnel on patrol is required to inform immediately to the Assistant Engineer (AE)/Sub-Assistant Engineer (SAE) for initiation of the execution of EAP. They are required to inform the Engineer-in-Charge and the local administrative authorities. It is desirable that the downstream inhabitants are warned using siren, if available, so as to make them aware of the likely imminent danger.

4.5 Preventive Action:

Once the likelihood of an emergency situation is suspected, action has to be initiated to prevent a failure. The point at which each situation reaches an emergency status shall be specified and at that stage the vigilance and surveillance shall be upgraded both in respect of time and level. At this stage a thorough inspection of the dam should be carried out to locate any visible sign(s) of distress. Engineers responsible for preventive action should identify sources of equipment needed for repair, materials, labour and expertise for use during an emergency. The amount and type of material required for emergency repairs should be determined for dam, depending upon its characteristics, design, construction history and past behavior. It is desirable to stockpile suitable construction materials at appropriate sites. The anticipated need of equipment should be evaluated and if these are not available at the dam site, the exact location and availability of these equipments should be determined and specified. The sources/agencies must have necessary instructions for assistance during emergency. Due to the inherent uncertainties about their effectiveness,

preventive actions should usually be carried out simultaneously with the appropriate notification on alert situation or a warning situation.

The other preventive measures may include availability of sufficient number of sandbags at several selected downstream locations and logs (for holding sandbags) and at the dam site, one tractor, two motor boats, gas lanterns, Manila ropes and life jackets. Areas from where the labour can be mobilized should be chalked out at a priority. In addition to these, public participation in the process of execution of the EAP may further help in amelioration of the adverse impacts of the likely disaster. For this, it is necessary that the public should be made aware of its responsibilities.

4.6 Communication System:

An effective communication system and a downstream warning system are absolutely essential for the success of an emergency preparedness plan. The difference between a high flood and dam-break situation must be made clear to the downstream population.

4.7 Evacuations Plans:

Emergency Action Plan includes evacuation plans and procedures for implementation based on local needs. These could be: - Demarcation / prioritization of areas to be evacuated. - Notification procedures and evacuation instructions. - Safe routes, transport and traffic control. - Safe areas/shelters. - Functions and responsibilities of members of evacuation team.

Any precarious situation during floods will be communicated either by an alert situation or by an alert situation followed by a warning situation. An alert situation would indicate that although failure of flooding is not imminent, a more serious situation could occur unless conditions improve. A warning situation would indicate that flooding is imminent as a result of an impending failure of the dam. It would normally include an order for evacuation of delineated inundation areas.

4.8 Evacuation Team:

The Engineer-in-Charge will be responsible for the entire operation including prompt determination of the flood situation time to time. Once the red alert is declared the whole state machinery will come into swing and will start evacuating people in the inundation areas delineated in the inundation maps. For successful execution, annually demo exercise will be done. The District Magistrare is to monitor the entire operation.

Public Awareness for Disaster Mitigation: In addition, give guidelines that have to be followed by the inhabitants of flood prone areas, in the event of flood resulting from dam failure, which form part of public awareness for disaster management.

4.9 Notifications:

Notification procedures are an integral part of any emergency action plan. Separate procedures should be established for slowly and rapidly developing situations and failure. Notifications would include communication of either an alert situation or an alert situation followed by a warning situation. An alert situation would indicate that although failure or flooding is not imminent, a more serious situation could occur unless conditions improve. A warning situation would indicate that flooding is imminent as a result of an impending failure of the dam. It would normally include an order for evacuation of delineated inundation area.

4.10 Notification Procedures:

Copies of the EAP that also include the inundation map are displayed at prominent locations, in the rooms and locations of the personnel named in the notification chart. For a regular watch on the flood level situation, it is necessary that the flood cells be manned by two or more people so that an alternative person is always available for notification round the clock. For speedy and unhindered communication, a wireless system is a preferable mode of communication. Telephones/cell phones may be kept for back up, wherever available. It is also preferred that the entire flood cells, if more than one, are tuned in the same wireless channel. It will ensure communication from the dam site to the control rooms. The communication can be established by messenger service in the absence of such modes of communication.

4.11 Management after receding of Flood Water:

It is to be accepted that in the event of dam break, even with maximum efforts, the loss of human lives, livestock and property would be inevitable. Under such a scenario, a massive effort would be taken by various government agencies to provide various relief measures to the evacuees.

4.12 Training:

Training of the people involved in the EAP should ensure that they are thoroughly familiar with all elements of the plan, the availability of equipment, and their responsibilities and duties. Again, the level of detail involved in training depends

on the size and complexity of a dam. For small dams with simple EAPs, training may simply involve having responsible persons read the EAP and submit written confirmations annually.

In the case of larger, more complex dams, training will be much more involved. Schedule training for employees associated with the dam to familiarize them with the EAP by addressing the following elements of the plan:

- How to use the EAP;
- How to identify the severity of a problem;
- How to use the notification procedures and the communication equipment;
- What resources are available;
- The importance of employees' roles during emergencies; and
- The importance of updating downstream information.

Train enough people to guarantee adequate coverage at all times. Mock Drills simulating dam failures are excellent training mechanisms for ensuring readiness. It is advisable to cross-train people for more than one responsible position. Keep a record of training completed by key personnel.

Officeof the Superintending Engineer,
IrrigationCircle,
. Gajwel, Siddipet Dist.

Present :**Sri.T.Venu, M.Tech**
Superintending Engineer

*****

Proc.No.SE/IC/GAJ/DSE/DEE/AEE-2/SKMS R-4/2024/724 Dt: 07-08-2024

Sub: Kaleshwaram Project- Formation of Sri Komaravelli mallanna sagar Reservoir with a capacity of 50TMC - formation of Earth Bund with all associated components for Reach-4 from Km 16.700 to km 22.900 along with its structures and adjoining with Reach-3 at Km 16.700 and saddle bund of 1.60 Km length - **Sanction for an Amount of Rs.12,63,520/-Towards preparation of Emergency Action Plan for Sri Komaravelli Mallanna Sagar Reservoir** - Reg.

Ref: 1.ENC(I)/GJL/DCE/DEE-4/AEE-1/SKMS-R4/Vol-IV/2024/973 Dt:08.05.2024
2. EE/Irrg/D6/Gajwel/DB/2024-25/198 Dt:05.08.2024

*****

Anent to the above subject and vide reference 1st cited, the Engineer-in-Chief(I), Gajwel has accorded permission for depositing an amount of **Rs. 12,63,520/-** for preparation of Emergency Action Plan for Sri Komaravelli Mallanna Sagar Reservoir in favour of CWPRS, Pune. It is also mentioned that the expenditure incurred shall be obtained from Kaleshwaram Irrigation Project Corporation Limited (KIPCL) funds.

Therefore, the sanction is hereby accorded for **Rs. 12,63,520/-(Rupees Twelve Lakhs Sixty Three Thousand Five Hundred and Twenty only)** towards preparation of Emergency Action Plan for Sri Komaravelli Mallanna Sagar Reservoir in favour of CWPRS, Pune.

The Executive Engineer, Irrigation Division No.6, Gajwel is requested to take further necessary action in the matter.

Superintending Engineer
Irrigation Circle,Gajwel.
05/08/24

To:
The Executive Engineer,Irrigation Division No.6, Gajwel.

Government of Telangana
Irrigation & CAD Department

From
Sri S. Venkateshwar Rao, B.E.,
Executive Engineer, I&CADD,
Irrigation Division No. 6,
Gajwel.

To
The Superintending Engineer,
Irrigation Circle,
Gajwel.

Lr.No.EE/Irrg/D6/Gajwel/DB/2024-25/198 **Date: 5/8/2024.**

Sir,

Sub: Kaleshwaram Project- Formation of Sri. Komaravelli Mallanna Sagar Reservoir with a capacity of 50 TMC - Formation of Earth Bund with all its associated components for Reach-4 from Km 16.700 to Km.22.900 along with its structures and adjoining with the Reach-3 at Km 16.700 - Depositing Rs.12,63,520/- towards the preparation of Emergency Action Plan for Sri Komaravelli Mallanna Sagar Reservoir – Permission to deposit the funds in to DDO account for remittance to CWPRS, Pune - Reg.

Ref: ENC(I), Gajwel Proc. No. ENC(I)/GJL/DCE/DEE-4/AEE-1/SKMS-R4/Vol-IV/ 2024/973, Dt: 08-05-2024.

***

It is to submit that, the Engineer-in-Chief (Irrigation), Gajwel has accorded permission to deposit an amount of Rs. 12,63,520/- towards the preparation of Emergency Action Plan for Sri Komaravelli Mallanna Sagar Reservoir vide reference cited above. The above expenditure incurred shall be obtained from Kaleshwaram Irrigation Project Corporation Limit ed (KIPCL) funds from the L.S provision under the work of Formation of Sri. Komaravelli Mallanna Sagar Reservoir with a capacity of 50 TMC - Formation of Earth Bund with all its associated components for Reach-4 from Km.16.700 to Km.22.900 along with its structures and adjoining with the Reach-3 at Km.16.700.

In this regard, to facilitate the depositing of funds to CWPRS, Pune it is requested to permit to deposit the funds into the DDO account of this Division.

Yours faithfully,

Executive Engineer, I&CADD.,
Irrigation Division No. 6,
Gajwel

Proceedings of the Engineer-in-Chief (Irrigation), Gajwel, Siddipet District.

Present: SriB.Hari Ram, *B.Tech., F.I.E,*
Engineer-in-Chief (I),
Gajwel, Siddipet.

ProcNo.ENC(I)/GJL/DCE/DEE-4/AEE-1/SKMS-R4/Vol-IV/2024/973,Dt:08-05-2024.

Sub: **Kaleshwaram Project** - "Formation of Sri Komaravelli Mallanna Sagar Reservoir with a Capacity of 50 TMC - Formation of Earth Bund with all associated components for Reach-4 from Km 16.700 to Km 22.900 along with its structures and adjoining with Reach-3 at Km 16.700 and saddle bund of 1.600 KM length" - **Permission for depositing Rs.12,63,520/- towards preparation of Emergency Action Plan for Sri Komaravelli Mallanna Sagar Reservoir - Accorded**- Reg.

Ref: 1. CWPRS final report on Dam Break Analysis and Emergency Action Plan Dt:31.10.2017
2. T.O.Lr.No.ENC(I)/GJL/DCE/DEE4/AEE1/SKMS/Vol.II/2024/365, Dt:20.02.2024
3. CWPRS,Pune Lr.No.TC/DMP/2024/251/169 Dt:07.03.2024
4. T.O.Memo No.ENC(I)/GJL/DCE/DEE4/AEE1/SKMS/Vol-IV/2024/530, Dt:12.03.2024
5. SE,IC,Gajwel Lr.No.SE/IC/GJL/DSE/DEE/AEE-2/2024/237, Dt:07.05.2024

* * * * *

Under the circumstances reported by the Superintending Engineer, Irrigation circle, Gajwel vide reference 5th cited, permission hereby accorded for depositing an amount of Rs.12,63,520/-(Rupees Twelve Lakhs Sixty Three Thousand Five Twenty only) for preparation of Emergency Action Plan of Sri Komaravelli Mallanna Sagar Reservoir in favor of CWPRS, Pune with the following scope of work:

i. Site Inspection for reconnaissance survey and to decide entities for notification under difference alerts and warnings in the event of dam distress/failure.
ii. Preparation of detailed inundation maps presenting flood levels, velocity, water depth and arrival time of flood at critical locations. Providing vicinity map, top sheets involves identifying inundation area downstream of the dam.
iii. Preparation of notification flow chart for different types of alerts.
iv. Preparation of Evacuation maps.
v. Demarcating the area of inundation at important locations and installations.
vi. Compiling the evidence of distress if any for identify emergency condition level along with suitable recommendations.
vii. Preparation of Emergency Action Plan.

The above expenditure incurred shall be obtained from Kaleshwaram Irrigation Project Corporation Limited (KIPCL) funds.

The SE,IC,Gajwel is requested to take necessary action accordingly.

Sd/-(B.Hari Ram), Dt:08-05-2024
Engineer-in-Chief (Irrigation)
Gajwel, Siddipet District.

To,
The Superintending Engineer,
Irrigation Circle,
Gajwel.

1. Copy submitted to the Managing Director, KIPCL, Jalasoudha Building, Hyderabad with a request to arrange an amount of Rs.12,63,520/- (Rupees Twelve Lakhs Sixty Three Thousand Five Twenty only) towards preparation of Emergency Action Plan of Sri Komaravelli Mallanna Sagar Reservoir in favor of CWPRS, Pune from Kaleshwaram Irrigation Project Corporation Limited (KIPCL) funds.
2. Copy submitted to the Director of Work Accounts, Hyderabad for favour of kind information.
3. Copy submitted to the Engineer-in-Chief(General), I&CAD, Jalasoudha, Hyderabad for favour of kind information.
4. Copy to the Director, CWPRS, Pune for favour of information.

Sd/-(B.Hari Ram), Dt:08-05-2024
Engineer-in-Chief (Irrigation)
Gajwel, Siddipet District.

//Attested//

08/05/2024

Dy. Chief Engineer
O/o Engineer-in-Chief (Irrigation),
Gajwel, Siddipet District

8/5/24

173 Inward No: 662

11/03/2024 SPEED POST

भारत सरकार / Government of India
जल शक्ति मंत्रालय/ Ministry of Jal Shakti
जल संसाधन, नदी विकास और गंगा संरक्षण विभाग
Department of Water Resources, River Development and Ganga Rejuvenation

केन्द्रीय जल और विद्युत अनुसंधान शाला
खडकवासला, पुणे - ४११०२४
CENTRAL WATER & POWER RESEARCH STATION
Khadakwasla, Pune – 411 024

टेलीफोन : 020-24103378
फैक्स :020-24381004
वेबसाइट :www.cwprs.gov.in
ईमेल- :cro_tc@cwprs.gov.in

No.TC/DMP/2024/ 251/169

Date: 06 MAR 2024
07 MAR 2024

To,
Shri B. Hari Ram,
Engineer-in-Chief (Irrigation),
Irrigation & CAD Department,
2nd floor, Integrated Office Complex,
Sangapoor Road, Gajwel,
Siddipet District, Telangana – 502278

DCE 11/03/24 DEE-4/AEE1 11/3/24 AEE 1 DyEE

Sub: Preparation of Emergency Action Planning for Sri Komaravelli Mallanna Sagar reservoir, Telangana.

Ref: Your Letter No. ENC(I/GJL/DCE/DEE-4/AEE-1/SKMS/ Vol.II/2024/365 dated 20.02.2024.

Sir,

This has reference to the above letter regarding subject proposal. CWPRS would be glad to take up the study in accordance with the identified scope. An estimate for the following study as detailed below is enclosed in duplicate for your acceptance and approval.

Sr No.	Name of the Work	Cost of study (Rs.)*
1.	Preparation of Emergency Action Planning for Sri Komaravelli Mallanna Sagar reservoir, Telangana.	12,63,520/-
	GST	Nil
	Total	12,63,520/-

(Rupees Twelve lakh sixty three thousand five hundred and twenty only)
[*Including contingency charges @ 5%]

It is requested that one copy of the estimate duly countersigned in token of your approval and acceptance may be returned to this office. **E-PAYMENT IS TO BE MADE STRICLY UPON REGISTERING AT https://bharatkosh.gov.in/UserRegistration.aspx** and following necessary steps thereon as a onetime process for all future payments. **E-PAYMENTS BY ANY OTHER MEANS SHALL NOT BE ENTERTAINED.** The remitter must read the guidelines and follow the same while making payment **(https://bharatkosh.gov.in/UserRegistration.aspx).**

The details of the E-payment MUST be informed to this office in the proforma given in "FORM E" (copy enclosed) through email at **cpc.cwprs-pune@gov.in** with a copy to **cro_tc@cwprs.gov.in** and **paocwprs@gmail.com** or by Fax on 020-24381004.

The work will be taken up only on receipt sanction to the estimate and deposit of the full estimated amount. For any clarification you may contact Dr.(Mrs) Neena Issac, Additional Director (Tel. 020-24103331, email: neena.isaac@gov.in).

Goods and Services Tax @ 18% is applicable to the services provided by CWPRS, Pune as per rules. These services fall under the reverse charge mechanism as per section 9(3) of CGST Act 2017. Therefore the recipients of the services shall pay GST @ 18% (if applicable). **CWPRS GSTN registration No. is 27AAATC7523J1ZO & Service area code (SAC) is 998349. The PAN No. of CWPRS is AAATC7523J.** A certificate along with the approval and GSTN Number is to be submitted to CWPRS along with details of payment of the full estimated amount.

CWPRS being a Government of India Organization under the Ministry of Jal Shakti, Department of Water Resources, River Development & Ganga Rejuvenation, no tax is deductible at source as per Section 196 of Income Tax Act 1961. Also no deduction is made from the payment towards GST / commission for Demand Draft etc.

Thanking you and assuring of the best of our services.

Yours sincerely,

Encl: As above

05/3/19

(एस.जी.मंजुनाथ / S. G. Manjunatha)
वैज्ञानिक 'ई' (तकनीकी समन्वय)
Scientist 'E' (Technical Co-ordination)
For Director, CWPRS

Annexure -IX

Phones: 020 – 24103378
Website: www.cwprs.gov.in

Fax : 020 - 24381004
E-mail : cro_tc@cwprs.gov.in

भारत सरकार

Government of India

जल शक्ति मंत्रालय,

Ministry of Jal Shakti,

जल संसाधन, नदी विकास और गंगा संरक्षण विभाग

Department of Water Resources,River Development and Ganga Rejuvenation

केंद्रीय जल और विद्युत अनुसंधान शाला

Central Water and Power Research Station

खडकवासला पुणे-४११०२४

Khadakwasla, Pune - 411 024

100 years and beyond ...

प्रारंभिक प्राक्कलन / PRELIMINARY ESTIMATE

NAME OF WORK	:	PREPARATION OF EMERGENCY ACTION PLANNING FOR SRI KOMARAVELLI MALLANNA SAGAR RESERVOIR, TELANGANA.
DATE	:	MARCH 2024
NAME OF LABORATORY	:	RIVER AND RESERVOIR SYSTEMS MODELING

Government of India
Central Water and Power Research Station, Pune

STATE	DIVISION	BRANCH
MAHARASHTRA	CW&PRS	DMP

Name of Work:-Preparation of Emergency Action Planning for Sri Komaravelli Mallanna Sagar reservoir, Telangana.

Major Head	*Minor Head*	*Detailed Head*
	Deposit	

Estimate framed by the Scientist 'C', Disaster Management Planning Division of the probable cost of **Rs.12,63,520/- (Rupees Twelve lakh sixty three thousand five hundred and twenty only)** including contingency charges @ 5% towards the subject studies.

REPORT

History	:	Sri Komaravelli Mallana Sagar is a huge reservoir with a capacity of 50 TMC, designed to establish a comprehensive water storage system within the Kaleshwaram Project. It aims to provide operational flexibility and meet irrigation requirements during the Kharif season, along with addressing other anticipated demands such as supplying drinking water to the twin cities of Hyderabad and Secunderabad, as well as fulfilling industrial water needs throughout the year. Considering the significance of the reservoir and in accordance with the Dam Safety Act-2021, it is imperative to develop an Emergency Action Plan for Sri Komaravelli Mallana Sagar promptly. In response to this requirement, Engineer-in-Chief, Irrigation & CAD Department, Gajwel, Siddipet District, Telangana has requested CWPRS to carry out study for Preparation of Emergency action planning for Sri Komaravelli Mallana Sagar Reservoir, Telangana vide their letter dated 20.02.2024. Accordingly, a cost estimate has been framed amounting to Rs. 12,63,520/- (Rupees twelve lakh sixty three thousand five hundred and twenty only) to cover the expenditure likely to be incurred for carrying out mathematical model study.	
Scope of studies	:	The study includes following work components:	
		(i)	Site Inspection for reconnaissance survey and to decide entities for notifications under different alerts and warnings in the event of dam distress/failure.
		(ii)	Preparation of detailed inundation maps presenting flood levels, velocity, water depth and arrival time of flood at critical locations. Providing vicinity map, toposheets involves identifying inundation area downstream of the dam.
		(iii)	Preparation of notification flow chart for different types of alerts.
		(iv)	Preparation of Evacuation maps (based on data provided by Project Authority).
		(v)	Demarcating the area of inundation at important locations and installations.
		(vi)	Compiling Evidence of Distress if any for identify Emergency condition level along with suitable recommendations.
		(vii)	Preparation of Emergency Action Plan.
Methodology	:	Following methodology will be adopted for the study:	
		(ii)	Review of salient features of the dam and downstream area.
		(iv)	Preparation of inundation maps that clearly depict the flooded areas from a dam failure. The time of arrival of wave front, maximum depth of

			inundation, and maximum velocity of flow will also be estimated for areas of high impact.
		(v)	Preparation of notification flow chart for different types of alerts.
		(vi)	Preparation of evidence of distress for different emergency condition level.
		(vii)	A report based on the study will be prepared and submitted using CWC guidelines.
Duration of Studies	:	6 months after receipt of all requisite data, receipt of sanction to the cost estimate and deposit of full estimated amount.	
Validity of estimate	:	This estimate is valid for six (6) months from the date of issue. Further, the estimate can be revised based on the requirement from Project Authority	
Other information	:	(i)	This preliminary estimate amounting to Rs. 12,63,520/- (Rupees Twelve lakh sixty three thousand five hundred and twenty only) has been framed and abstract of cost is enclosed.
		(ii)	Prevailing market rates / schedule rates have been adopted while framing the estimate, which is applicable for all Government agencies.
		(iii)	Goods and Service Tax @ 18% is applicable to the services provided by CWPRS Pune as per rules. These services fall under the reverse charge mechanism as per section 9(3) of CGST Act 2017. Therefore the recipients of the services shall pay GST @ 18% (if applicable). CWPRS GSTN registration number is 27AAATC7523J1ZO & Service area code (SAC) is 998349. The Pan No. of CWPRS is AAATC7523J. A certificate along with the approval and GSTN No. is to be submitted to CWPRS along with the details of payment of the full estimated amount.
		(iv)	The provision for TA covers the expenses for the travel from CWPRS, Pune to nearby railway station / airport to the project site and back only. The project authorities will have to make the arrangements for further travel.
		(v)	All the data required for the studies will be collected and provided to CWPRS by project authorities. A tentative list of data requirement will be sent. Further requirement, if any would be intimated in due course.
		(vi)	CWPRS would use the data and research findings for academic purposes and research publications.
		(VII)	CWPRS reserves the right to publish the findings of the studies in Conferences/Journals.

Signature : 05/03/2024
Name : S. D. Marulkar
Designation : Scientist 'C'
Division : DMP

Date: 05/03/2024

Government of India
Central Water and Power Research Station, Pune 411024

STATE	DIVISION	BRANCH
Maharashtra	CWPRS, Pune	DMP

Abstract of Cost

Name of Work: Preparation of Emergency Action Planning for Sri Komaravelli Mallanna Sagar reservoir, Telangana.

Sr. No.	*Subhead of charges*	*Amount (Rs.)*
I	Model construction / Fabrication	Nil
II	Procurement of Equipment Material	84,000
III	Service / Operational / Software charges	1,02,480
IV	Other charges	21,980
V	TA / DA / Transport Charges	2,00,480
VI	Establishment Charges	7,94,409
	Sub Total	**Rs. 12,03,349/-**
	Contingency charges @ 5% on Sub Total	**Rs. 60,167.45/-**
	GST	**NIL**
	Grand Total	**Rs. 12,63,516.45/-**
	Say	**Rs. 12,63,520/-**

(Rupees Twelve lakh sixty three thousand five hundred and twenty only)

Signature: 05/03/2024
Name: S. D. Marulkar
Designation: Scientist 'C'
Division: DMP

Date: 05/03/2024

CERTIFICATE

This is to certify that the GST applicable to the above estimated cost will be paid by this office and a copy of challan shall be submitted to you at the earliest.

Accepted

Signature:
Name of signatory:
Designation:
Address:

Seal

FORM – E

DETAILS OF PAYMENT TO BE FORWARDED TO THE CENTRAL WATER AND POWER RESEARCH STATION, PUNE

Sr. No.	PARTICULARS
1	Name and Address of the Project Authority
2	Name and address of the bank through which the payment has been made
3	Branch name of the bank through which the payment has been made
4	Amount
5	Date of Payment
6	IFS Code of the bank
7	C I Number (Unique Transaction Number)
8	Letter No. & Date of CWPRS Cost Estimate
9	Note: The above details can be sent to fax this office fax no. 020-24381004 or send e-mail to **cpc.cwprs-pune@gov.in/ cro_tc@cwprs.gov.in.**Then only as intimated by the project authority this office will settle the said transaction with the Reserve Bank of India, Mumbai
10	GST number of project authority

Proceedings of the Engineer-in-Chief (Irrigation), Integrated Office Complex, Gajwel, Siddipet Dist.

Present: Sri. B. Hariram, *B.Tech., F.I.E,*
Engineer-in-Chief (I)

Proc.No. ENC(I)/Gajwel/DCE/DEE-4/AEE-7/SKMS R-4/2022/1027 Dt:16-05-2022

Sub: **Kaleshwaram Project** – "Formation of Sri komaravelli Mallanna Sagar Reservoir with a Capacity of 50 TMC - Formation of earth bund with all its associated components for reach-4 from km 16.700 to km 22.900 along with its structures and adjoining with the reach-3 at km 16.700 and Saddle Bund of 1.60 km length"– **Variation -IV - Approved** – Regarding.

Ref:
1. G.O. Rt. No. 185, Irrigation & CAD (Projects-IV) Dept., Dated 08-03-2017
2. Engineer-in-Chief(I)Lr.No.(ENC(I)/DCE1/OT2/AEE20/CE/KPH/SKMS/2017 Dt:29-06-2017
3. T.O. Proc. No. CE/KPH/DCE/DEE-1/AEE-1/SKMS-R4, Dt. 01-07-2017.
4. Agreement No.11/2017-18, Dt.16.11.2017
5. T.O Proc. CE/KPH/DCE/DEE-1/AEE-1/SKMS-Reach-4/2020/529, Dt: 13-03-2020.
6. T.O Proc. ENC(I)/GJL/DCE/DEE-4/AEE-7/SKMS R-4/2021/1068/A, Dt:16.07.2021
7. T.O Proc. ENC(I)/Gajwel/DCE/DEE-4/AEE-7/SKMS R-4/2021/65, Dt: 07-01-2022
8. SE, IC, GAJ, Lr.No.SE/IC/GAJ/DSE/DEE/AEE-2/2021-22/590, Dt: 30-04-2022

****

Under the circumstances explained by the Superintending Engineer, Irrigation Circle, Gajwel vide reference 8th cited, the Variation –IV due to Price Adjustment of Steel Plates, HYSD Steel, Cement, POL, Labour and Other Material for the work done up to 10th RA Bill are hereby approved for an amount of **Rs. 1766,12,00,000**/- **(Rupees One Thousand Seven Hundred and Sixty Six Crores and Twelve Lakhs only)** including tender Premium amount of Rs.47,09,02,361/-. The amount of variation-IV excluding above tender premium works out to **Rs.1719,02,97,639/-** against the technical sanction amount of Rs. 1552,49,00,000/- with **(+)10.727 %** excess and an amount of **Rs.1633,37,59,083/-** against Agreement value of Rs.1482,74,76,747/- with **(+) 10.159%** excess is herewith communicated for taking further necessary action subject to the following conditions:

1. The Superintending Engineer is instructed to restrict the payment in the R.A. bills to 80% of the sanctioned amount of Price Adjustment (except cement & steel).
2. The Superintending Engineer is responsible for the correctness of the Soil Classification quantities.
3. The Superintending Engineer shall ensure that the work is carried out as per the approved drawings.
4. The Superintending Engineer is responsible for the correctness of the quantities and rates.
5. Any excess payment noticed at a later date, shall be recovered from the subsequent bill of the agency promptly.

The Superintending Engineer, Irrigation Circle, Gajwel is requested to incorporate the above variation while submitting the Final Estimate.

Encl: Variation-IV.

Sd/- B.Hariram Dt:16-05-2022
Engineer-in-Chief (Irrigation),
Gajwel, Siddipet-District.

To
The Superintending Engineer
Irrigation Circle, Gajwel.

// Attested //

Dy. Chief Engineer,
O/o the Engineer-in-Chief (I)
Gajwel, Siddipet District
16/5/22

VARIATION STATEMENT - 4

Name of Work : Kaleshwaram Project- Formation of Sri Komaravelli Mallanna Sagar Reservoir with a capacity of 50 TMC – Formation of Earth Bund with all its associated components for Reach-4 from Km 16.700 to Km.22.900 along with its structures and adjoining with the Reach-3 at Km 16.700 and saddle bund of 1.60 km length.

Sl.No.	Description of Item	Amount in Rs. As per Technical Sanction (Provisional Estimate)	Amount in Rs. As per Variation -1	Amount in Rs. As per Variation -2	Amount in Rs. As per Variation -3	Amount in Rs. As per Variation -4
A	**Part - I (Contract Items)**					
a	Contract Items	14,36,77,16,000.00	14,36,77,10,026.00	**14,41,10,81,695.00**	**14,77,20,80,148.00**	**14,77,20,80,148.00**
b	Deduct Embedded Tax Amount	-	-	-5,58,95,706.00	-5,63,81,369.00	-5,63,81,369.00
	Sub Total	**14,36,77,16,000.00**	**14,36,77,10,026.00**	**14,35,51,85,989.00**	**14,71,56,98,779.00**	**14,71,56,98,779.00**
	Add (+3.20%) Excess Tender Premium		45,97,66,721.00	45,93,65,952.00	47,09,02,361.00	47,09,02,361.00
c	Price Adjustment for Cement, Fuel, Labour and Other Materials from RAB 1 to 10th & Part Bill	-	-	-	-	1,14,71,57,943.00
	Total of Part - I	***14,36,77,16,000.00***	***14,82,74,76,747.00***	***14,81,45,51,941.00***	***15,18,66,01,140.00***	***16,33,37,59,083.00***
B	**Part - II**					
a	Price Adjustment for Cement, Fuel, Labour and Other Materials from RAB 1 to 9th & Part Bill	-	-	55,23,08,959.00	94,83,16,980.00	-
b	Provision towards Labour welfare cess @ 1.0%	14,36,77,000.00	14,36,77,100.00	15,36,68,609.00	16,13,49,181.00	16,33,37,591.00
c	Provision towards NAC @ 0.1%	1,43,67,000.00	1,43,67,710.00	1,53,66,861.00	1,61,34,918.00	1,63,33,759.00
d	Provision towards SMET @ 2% on Seinorage Charges	-	-	2,07,81,386.00	2,12,96,417.00	2,12,96,417.00
	Sub Total	**15,80,44,000.00**	**15,80,44,810.00**	**74,21,25,815.00**	**1,14,70,97,496.00**	**20,09,67,767.00**
e	Provision towards VAT/GST @ 5.00%	71,83,86,000.00	71,83,85,501.00	77,78,33,888.00	81,66,84,932.00	82,67,36,343.00
	Total of Part - II	***87,64,30,000.00***	***87,64,30,311.00***	***1,51,99,59,703.00***	***1,96,37,82,428.00***	***1,02,77,04,110.00***
C	**PART - III (Non Contract Items)**					
a	Provision towards Detailed investigation, design, preparation of drawings and estimates, subsoil exploration etc.,	6,80,54,000.00	6,80,54,000.00	6,80,54,000.00	6,80,54,000.00	6,80,54,000.00
b	Provision towards Shifting of HT Towers Lines, Electric lines, Telephone lines and water pipeline etc.,	20,56,00,000.00	22,30,63,894.00	22,30,63,894.00	22,30,63,894.00	22,30,63,894.00
c	Provision towards Fixing of boundary stones, chainage stones, DCBM stones, HP sign boards and gateways.	40,00,000.00	40,00,000.00	40,00,000.00	40,00,000.00	40,00,000.00
d	Provision towards for Instrumentation in Earth Bund and General Instrumentation	31,00,000.00	31,00,000.00	31,00,000.00	31,00,000.00	31,00,000.00
e	Ls Items such as doors, Ventilator & windows and Electrical items etc., for conctruction of control room purpose	-	-	15,00,000.00	15,00,000.00	15,00,000.00
	Rounding Off	-	-	70,462.00	899.00	18,913.00
	Total of Part - III	***28,07,54,000.00***	***29,82,17,894.00***	***29,97,88,356.00***	***29,97,18,793.00***	***29,97,36,807.00***
	GRAND TOTAL (Part - I, Part - II & Part -III)	***15,52,49,00,000.00***	***16,00,21,24,952.00***	***16,63,43,00,000.00***	***17,45,01,02,361.00***	***17,66,12,00,000.00***

1	Amount as per Technical Sanction	15,52,49,00,000.00				
	Amount of deviation as per Variation -4 Without T.P	17,19,02,97,639.00				
	Excess Over Tech. sanction : (17190297639 - 15524900000)	1,66,53,97,639.00				
	Percentage Excess over Tech. Sanction: (1665397639 / 15524900000) *100	**10.727**	**%**			

2	Amount as per Agreement	14,82,74,76,747.00				
	Amount of deviation as per Variation -4	16,33,37,59,083.00				
	Less Over Tech. sanction : (16333759083 - 14827476747)	1,50,62,82,336.00				
	Percentage Excess over Tech. Sanction : (1506282336 / 14827476747) *100	**10.159**	**%**			

DEE

Executive Engineer, I&CADD.,
Irrigation Div. No.6
Gajwel

Superintending Engineer
Irrigation Circle
Gajwel

Self- B. Hari Ram, dt: 16-05-2022
Engineer-in-Chief (Irrigation)
I & CAD, Department, Gajwel
Siddipet District.

//ATTESTED//
16/5/2022
Deputy Chief Engineer
O/o. The Engineer-In-Chief (I)
I & CAD Department
16/5/22 **Gajwel, Siddipet District**

Annexure -X

No. J-12011/1/2017-IA-I(R)
Government of India
Ministry of Environment, Forest & Climate Change
[IA.I - Division]

Indira Paryavaran Bhavan
3rd Floor, Vayu Wing
Jor Bagh Road
New Delhi —110 003

Dated: 22nd December, 2017

To,

Shri B. Hariram
The Chief Engineer
Kaleshwaram Project
1st Floor, Jalasoudha Building
Errumanzil
Hyderabad - 500082.

Subject: Kaleshwaram Project in Karimnagar District of Telangana by I & CAD Department, Government of Telangana - Environmental Clearance (EC) - regarding.

Sir,

This has reference to your letter No.CE/KPH/DCE-3/DEE-3/AEE-9/EIA&EMP/Vol.II/2017 dated 16.11.2017 and 26.11.2017 on the above mentioned subject.

2. The above referred proposal was considered by the Expert Appraisal Committee (EAC) for River Valley & Hydroelectric Projects in its meeting held on 5.12.2017. The comments and observations of EAC on the project may be seen in the Minutes of the meeting which are available on the web-site of this Ministry.

3. The Public Hearings were conducted in 15 Districts (i.e. Karimnagar on 22.8.2017, Nizamabad on 22.8.2017, Medchal-Malkajgiri on 22.8.2017, Yadagdri-Bhunanagiri on 22.8.2017; Peddapally on 23.8.2017, Nalgonda on 23.8.2017, Sangareddy on 23.8.2017, Kamareddy on 23.8.2017; Nirmal on 24.8.2017, Jagityal on 24.8.2017, Medak on 26.8.2017, Jayashankar-Bhupalapally on 26.8.2017, Manchiryal on 26.8.2017, Rajanna Sircilla on 26.8.2017 & Siddipet on 26.8.2017) of Telangana and 1 District (Gadchiroli on 27.9.2017) of Maharashtra as per the provisions of EIA Notification, 2006.

4. The project envisages construction of a barrage across River Godavari in near Medigadda village in Karimnagar District of Telangana for diversion of 180 TMC of water for providing irrigation facility in 7,38,851 ha covering 7 Districts namely Adilabad, Karimnagar, Nizamabad, Warangal, Medak, Nalgonda and Rangareddy Districts. It is also proposed to stabilize the existing command area of 7,62,028 ha of area. The project is also proposes to provide drinking water facility for Hyderabad and Secunderabad cities. Total land requirement is about 37,852 ha. Out of which

3168.1315 ha is forest land and 34,684 ha is private land. The total submergence area is about 18,302 ha. In addition to Medigadda barrage, 2 more barrages between Medigadda and Sripada Yellampally Project are likely to be constructed, one at Annaram and the other at Sundilla. The total length of water canal system is about 1,832 km. This project lies in the interstate boundary with submergence of 174.37 ha of area in Maharashtra State. Total estimated cost of the project is about Rs. 80,499.71 Crores and proposed to be completed in 3 years.

5. It was noted that the project involves (i) diversion of 180 TMC water from Godavari river, (ii) additional 20 TMC water will be drawn from Yellampally barrage, (iii) 10 TMC of water from self-yield tanks and (iv) 25 TMC of water from utilizable groundwater; put together 225 TMC of net water availability. Out of this, 30 TMC of water will be used for providing drinking water facility for twin cities of Hyderabad and Secunderabad, 10 TMC of water to en-route villages, 16 TMC of water for industrial purpose, 134.5 TMC for irrigation facility in 7,38,851 ha of new command area and 34.5 TMC of water for stabilization of 7,62,028 ha of area. The CWC has cleared water availability vide letter No. 6-231/2017-PA(S)/1327-28 dated 30.10.2017 for the project.

6. The Expert Appraisal Committee, after due consideration of the relevant documents submitted by the project proponent and clarification furnished in response to its observations, have recommended for grant of Environmental Clearance for the project mentioned above. Accordingly, the Ministry of Environment, Forest & Climate Change hereby accords necessary environmental clearance for the above project as per the provisions of Environment Impact Assessment Notification, 2006 and its subsequent amendment in 2009, subject to compliance of following conditions:

Part – A - Specific Conditions:

i. The Catchment Area Treatment (CAT) Plan as has been proposed in the Chapter-9 of EMP (9.1 - CAT Plan; November, 2017) shall be implemented in consultation with the Telangana State Forest Department. The allocated grant of Rs. 362.04 Crores for this purpose should be fully utilized and not be diverted for any other purpose. As per plan, the area of CAT is 32.83 Sq.km.

ii. The project involves acquisition of 34,684 ha of land. The R&R benefits for the land losing will have to comply with the Right to Fair Compensation and Transparency in land acquisition, Rehabilitation & Resettlement Act, 2013 or any other act which would be beneficial to the project oustees. Adequate publicity of the compensation package should be circulated in the affected villages. All R&R issues shall be completed before commissioning of the project.

iii. Construction work to be carried-out after following due procedure of the Right to Fair Compensation and Transparency in Land Acquisition, Rehabilitation and Resettlement Act, 2013 as applicable to the State of Telangana (21/2017) as amended by Act.

iv. A Monitoring Committee for R&R shall be constituted which shall include representatives of project affected persons including representative from SC/ST category and a woman beneficiary.

v. All commitment made during the public hearing should be fulfilled completely by the project proponent and record maintained, if any.

vi. The Command Area Development (CAD) Plan as proposed in the EIA/EMP report (November, 2017) report shall be strictly implemented.

vii. Consolidation and compaction of the generated muck should be carried-out in the muck dumping sites. As proposed in the muck disposal plan, out of 1480 lakh m^3 muck generated, the entire to be utilized for service road & inspection paths, embankments, land leveling, filling trenches, and construction material for CD works, road etc. and restoration works for canal banks should be strictly adhered. The muck disposal sites shall be reclaimed/ restored with vegetation once capacity is utilized. Allocated amount of Rs.32.79 crores for this purpose should be fully utilized and not be diverted for any other purpose.

viii. The proposed compensatory afforestation programme in 5333.817 ha of degraded forest area with twenty two (22) local plant species identified for the programme shall be undertaken strictly in consultation with State Forest Department. The allocated amount of Rs. 722.30 Crores for this purpose should be fully utilized and not to be diverted for any other purpose.

ix. To enhance the environment of project site, greenbelt, as proposed in the EIA/EMP report (November, 2017) shall be developed. The proposed greenbelt shall be developed in the barrages of the project and reservoirs periphery of 110.20 km and canal bank of 116.334 km of the project proposed with local plant species in consultation with State Forest Department should be taken-up strictly. The allocated grant of Rs. 19.21 Crores should be fully utilized this purpose and not be diverted for any other purpose.

x. The Fisheries Development Plan as proposed in the EIA/EMP (November, 2017) for the conservation of fish in river & reservoir shall be implemented completely in consultation State Fisheries Department. A budget of Rs. 485 Crores provided for fisheries development plan should be utilized fully for this purpose and not to be diverted for any other purpose.

xi. The proposed Biodiversity Conservation and Management Plan as proposed in the EIA/EMP report (November, 2017) should be implemented in consultation with State Forest Department. The allocated grant of Rs. 3.36 Crores should be fully utilized this purpose and not be diverted for any other purpose.

xii. Water User Association's (WUAs) / Co-operative shall be formed and involvement of the whole community for disciplined use of available waters shall be ensured.

xiii. Conjunctive use of surface water shall be planned to check water logging as well as to increase productivity.

xiv. The equipment likely to generate high noise levels during the construction period or otherwise shall meet the ambient noise level standards as notified under the Noise Pollution (Regulation and Control) Rules, 2000, as amended in 2010 under the Environment Protection Act (EPA), 1986. Ambient Noise level monitoring shall be conducted on a monthly basis during the period of construction at suitable locations and copy of the test reports to be submitted to Regional Office, MoEF & CC, Chennai on six monthly basis.

xv. The On Farm Development (OFD) works shall be completed and WUAs (Water User Associations) shall be made functional before commencement of irrigation.

xvi. Occurrence of stagnant pools/slow moving water channels during construction and operation of the project providing breeding source for vector mosquitoes and other parasites. The river should be properly channelized so that no small pools and puddles are allowed to be formed. Even after taking precautions, due to un-foreseen situations, breeding of mosquito and resultant malaria or mosquito borne diseases can increase. If such a situation arises, it will be the responsibility of project authorities to take all steps i.e. residual insecticidal spray in all the project area and surrounding 3 km area keeping the flight range of mosquitoes in consideration.

xvii. Any other clearance from any other organization/department if required should be obtained.

xviii. The submergence area is very large, micro-climatic change conditions in the project area during construction/post-construction period to be brought-out/reported at regular intervals.

xix. Plans for greenbelt development and reservoir rim treatment have to be made in consultation with State Forest Department. Preference shall also be given to plant local indigenous species.

xx. Solid waste generated, especially plastic waste should not be disposed of as landfill material. It should be treated with scientific approach and recycled.

xxi. Six monthly compliance reports shall be submitted to Regional Office, MoEF & CC, Chennai until completion of the modernization works.

Part - B. General Conditions:

i. Adequate arrangements for providing free fuel like LPG shall be made at the project cost for the labour engaged in the construction work so that indiscriminate felling of trees is prevented.

ii. Medical facilities as well as recreational facilities shall also be provided to the labourers.

iii. The labourers to be engaged for construction works shall be thoroughly examined by health personnel and adequately treated before issuing them work permit.

iv. Water sprinkling arrangements shall be made to suppress the fugitive emissions and on monthly basis, ambient air quality to be monitored during the period of construction.

v. Potable drinking water and proper sanitary facilities shall be provided for the labour force.

vi. Restoration of construction area including dumping sites of excavated materials shall be ensured by leveling, filing up of borrow pits, landscaping etc. The area should be properly treated with suitable plantation.

vii. Environmental parameters shall be monitored and six monthly monitoring reports shall be submitted to the concerned Regional Office of the Ministry, Chennai.

7. The Project Proponent shall provide full cooperation and all required documents / data to the Officials from concerned Regional Office of the Ministry, Chennai who would be monitoring the implementation of environmental safeguards.

8. The responsibility of implementation of environmental safeguards and carrying out environmental monitoring rests fully with Irrigation & CAD Department, Government of Telangana.

9. Besides the above stated conditions, the Project Proponent shall also implement all environmental safeguards, as proposed in the EIA/EMP report and other reports from time to time. The Regional Office of the Ministry, Chennai shall monitor implementation of EMP at regular intervals.

10. The Environmental Management Plan (EMP) shall be strictly adhered to and a sum of Rs. 16230.43 crores, the budgetary provisions for the implementation of EMP, shall be fully utilized and not to be diverted to any other purpose. In case of revision of the project cost or due to price level change, the cost of EMP shall also be updated proportionately

11. In case of change in the scope of the project, the same shall be intimated to the Ministry and fresh approval, if required, shall be taken from the Ministry.

12. The Ministry reserves the right to add additional safeguard measures subsequently, if found necessary and to take action including revoking of the clearance under the provisions of the Environment (Protection) Act, 1986, to ensure effective implementation of the suggested safeguard measures in a time-bound and satisfactory manner.

13. This clearance letter is valid for a period of 10 years from the date of issue of this letter for commencement of construction work of the project.

14. A copy of the clearance letter shall be marked to concerned Panchayat/Zilla Parishad/ Municipal Corporation, Urban local body and local NGO, if any, from whom any suggestion/representations were received while processing the proposal. The clearance letter shall also be put on website by the project proponent.

15. State Pollution Control Board / Committee shall display a copy of the clearance letter at the Regional Office, District Industries Centre and Collector's / Tehsildar's Office for 30 days.

16. The project proponent should advertise at least in two local newspapers widely circulated in the region around the project, one of which shall be in vernacular language of the locality concerned informing that the project has been accorded environmental clearance and copies of clearance letters are available with the State Pollution Control Board / Committee and may also be seen at Website of the Ministry of Environment, Forest & Climate Change at http://www.moef.nic.in .

17. After 5 years of the commissioning of the Project, a study shall be undertaken regarding impact of the project on the environment and downstream ecology. The study shall be undertaken by an independent agency, decided in consultation with the Ministry.

18. The project proponent shall also submit six monthly reports on the status of compliance of stipulated EC conditions including the results of monthly monitored data (both in hard copies as well as by email) to the respective Regional Office of MoEF&CC, Chennai.

19. Any appeal against this environmental clearance shall lie with the National Green Tribunal, if preferred, within a period of 30 days from the date of issue, as prescribed under Section-16 of the National Green Tribunal Act, 2010.

Yours faithfully,

(Dr.S. Kerketta)
Director

Copy to:

1. The Secretary, Ministry of Water Resources, RD & GR, Shram Shakti, Bhawan, Rafi Marg, New Delhi 1.
2. The Special Chief Secretary, Irrigation & CAD Department, Government of Telangana, 5th Floor, B- Block, Secretariat, Hyderabad – 500 001.
3. The Principal Secretary, Environment, Forests, Science and Technology Department, Government of Telangana, 3rd Floor, D- Block, Secretariat, Hyderabad-500 001.
4. The Chief Engineer, Project Appraisal Directorate, Central Water Commission, Sewa Bhawan, R.K. Puram, New Delhi-110066.
5. The Addl. PCCF (Central), Regional Office (SR), Ministry of Environment, Forest & Climate Change, Regional Office (SEZ), 1st and 2nd Floor, Handloom Export Promotion Council, 34, Cathedral Garden Road, Nungambakkam, Chennai - 600034.
6. The Member Secretary, Telangana State Pollution Control Board, Payavaran Bhawan, Industrial Estate, Sanath Nagar, Hyderabad.
7. Guard file/Notice Board.

(Dr.S. Kerketta)
Director