INDIA BASED NEUTRINO OBSERVATORY PROJECT

(Dept. of Atomic Energy, Govt. of India)

at Bodi West Hills / Pottipuram Village, Theni District, TAMILNADU. Pin: 625 528.

Detailed Project Report on INO Site

Volume – I

December - 2010

Prepared by

Projects Development wing

Tamil Nadu Generation and Distribution Corporation Ltd.,

(Successor entity of Tamil Nadu Electricity Board)

Chennai – 600 002.

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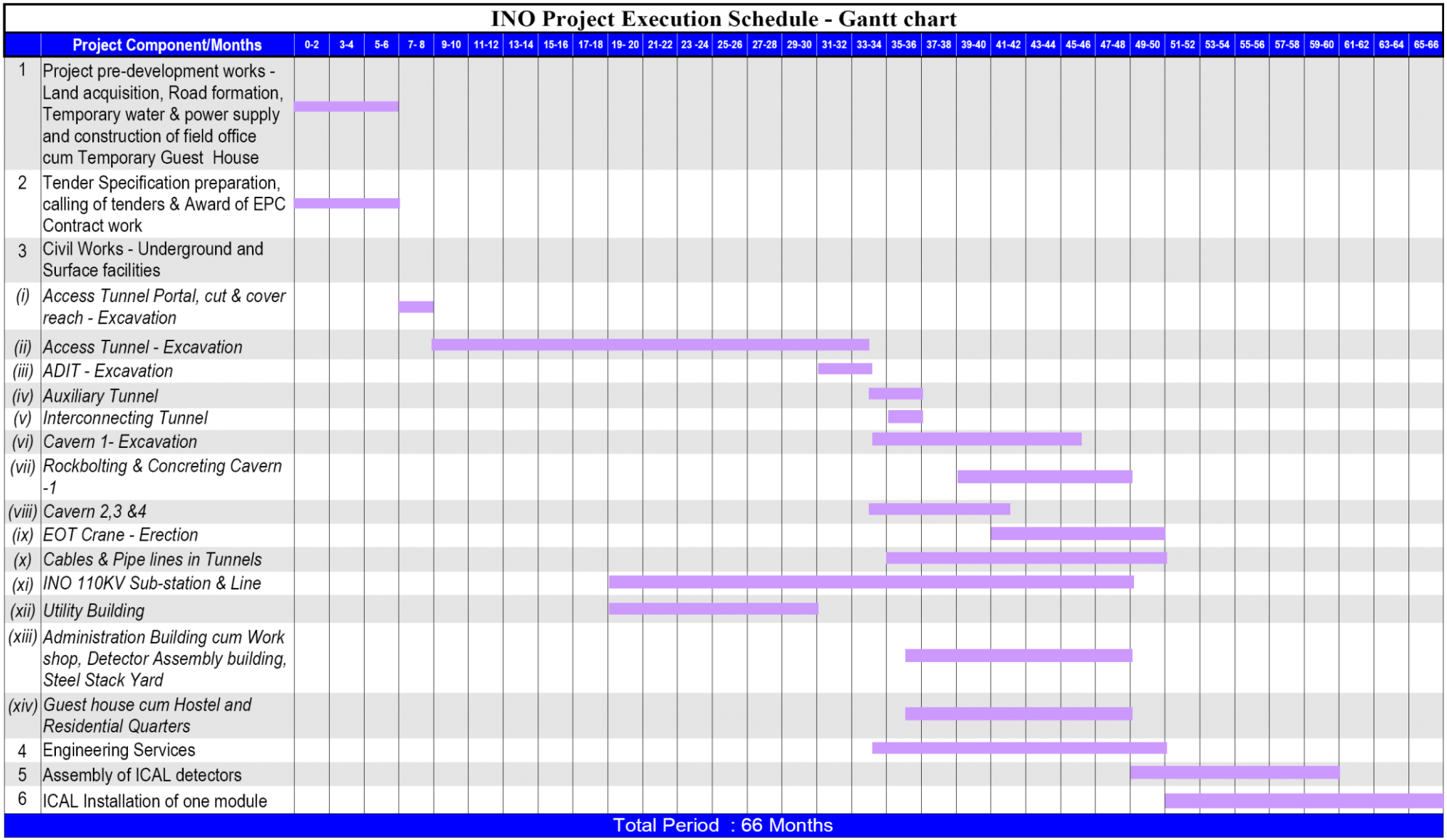

India-based Neutrino Observatory (INO) Project at Bodi west hills/Pottipuram in Theni district

Synopsis

The Detailed Project Report – Volume - I on India-based Neutrino Observatory (INO) Project at Bodi West Hills/ Pottipuram in Theni district mainly deals with the Civil Works and Engineering Services for the establishment of the Laboratories in the caverns.

(i) Civil works – Caverns-1 (Main), 2, 3 & 4 (Intermediate), Tunnels (Access tunnel, Intermediate tunnel, Auxilary tunnel of Additionaly driven intermediate tunnel) to carryout research and surface facilities (Utility building, Guest house, Residential Quarters, Administrative building).

and

(ii) Engineering services needed for the Laboratories (viz.) Power supply and distribution system, Illumination system, Air-conditioning and ventilation system, Communication and Public address system, Firefighting and Alarm system, Lifting and hoisting facilities, Passenger elevator, Cooling water system, Security system, etc. The topics are discussed below:

Part – I General

Chapter-1 Neutrino, detection of Neutrino, its study at India/World level and the existing Neutrino Observatories in the World.

Chapter-2 Selection of site at Bodi west hills/ Pottipuram in Theni district, wherein the INO is proposed to be located and also the various alternative sites studied.

Chapter-3 Base line data of Theni district where the Pottipuram village is located.

Chapter-4 Various infrastructure facilities such as transport (Road, Train & Air facilities) Power, Communication facilities, other living facilities etc., at Pottipuram.

Chapter-5 Requirement and availability of land for locating Tunnel portal, Utility building, Approach roads, various surface facilities such as Administrative building, Residential quarters, Workshop, Hostel, Guest house etc. and also various project enabling works.

Chapter-6 Details on the availability of the various materials required for construction.

Chapter-7 Planning aspects (viz.) Project pre-development works and Project enabling works

Part – II Site survey and Geo-technical investigation

Chapter-8 Detailed Contour & Topographical surveys carried out for locating Caverns-1 (Main), 2, 3 & 4 (Intermediate), Tunnels (Access tunnel, Intermediate tunnel, Auxilary tunnel of Additionally driven intermediate tunnel) and Surface facilities (Utility building, Guest house, Residential quarters & Administrative building).

Chapter-9 Geo-technical investigation to find the hardrock without coreless to finalise the Access tunnel route based on the report of Geologist/GSI and also to finalise the cut & cover reach, weathered rock tunnel reach & Hard rock tunnel reach.

Part – III Technical - Underground Civil works

Chapter-10 The proposed construction methodology and machineries, for the Caverns & Tunnels.

Chapter-11 Design and basic engineering details of Cavern & Tunnels proposed.

Chapter-12 All the surface facilities such as Utility Building, Administrative building, Assembly shop, Guest house, Hostel, Residential quarters etc.

Part – IV Technical - Engineering services

Chapter-13 Power supply & distribution system-various alternative sources, salient features on distribution equipments and illumination system proposed for tunnels & caverns.

Chapter-14 Air-conditioning of Caverns (Fully/Partially), Surface facilities and Ventilation system for Caverns/ Tunnels.

Chapter-15 Communication system proposed covering Telephone & Public addressing systems.

Chapter-16 Lift & hoisting arrangement proposed in the Cavern and in the surface facilities.

Chapter-17 Details on the RPC gas mixture and duct system and details of Nitrogen gas tank.

Chapter-18 Cooling water system proposed for Caverns-1 & 2.

Chapter-19 Security system proposed in the caverns & surface facilities and also miscellaneous services such as audio visual equipment etc.

Chapter-20 Drinking water and Service water supply proposed from Mullai Periyar River and sanitary disposal system proposed for caverns and surface facilities.

Part –V Safety, Health and Risk Assessment

Chapter-21 Safety, Health, and Risk Management proposed for the project.

Chapter-22 Environmental Management Plan

Part – VI Energy Conservation & Social Responsibility

Chapter-23 Energy and Water efficient building, Energy audit, Socio-economic development for neighborhood (proposed by District Collector, Theni).

Part – VII Project cost estimation

Chapter-24 The cost estimation of Civil works – Tunnels, Caverns & Surface facilities has been worked out.

Chapter-25 The cost estimation for various Engineering services required for INO has been worked out.

Chapter-26 The cost estimate of Energy conservation and Socio-economic development for neighborhood as proposed by the District Collector, Theni.

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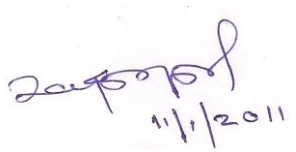

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PART I General

CHAPTER – 1

INDIA-BASED NEUTRINO OBSERVATORY – INTRODUCTION

1.1 Introduction

The India-Based Neutrino Observatory (INO) is a pure science underground laboratory. Its primary goal is to study the properties and interactions of weakly interacting, naturally occurring particle called neutrino. There is world–wide interest in this field, due to its implications for several diverse and allied areas such as particle physics, cosmology and the origin of the Universe, energy production mechanisms in the Sun and other stars, etc.

Several groups belonging to different Universities and Research Institutions in India are part of the collaboration working on the details of INO. The current proposal focuses on neutrino detection with static detectors, to be placed deep underground. It is envisaged that such an under ground facility will develop into a centre for other studies as well in physics, biology, geology etc., all of which will make use of the special conditions that exist deep underground. Apart from the scientific goals, INO will greatly enhance the development of detector technology and its varied applications.

1.2 Neutrinos

Neutrinos are tiny, neutral, elementary particles which interact with matter via weak force. The weakness of this force gives neutrinos the property that matter is almost transparent to them. The Sun and all other stars produce neutrinos copiously due to nuclear fusion and decay processes within their core. Since they rarely interact, these neutrinos pass through the Sun and even the Earth unhindered. There are many other natural sources of neutrinos including exploding stars (supernova), relic neutrinos (from the birth of Universe), natural radioactivity and cosmic ray interactions in the atmosphere of the earth. For example, the Sun produces over two hundred trillion trillion trillion ($2x10^{38}$) neutrinos every second and a supernova can release 1000

times more neutrinos than our Sun will produce in its lifetime of 10 billion years. Billions of neutrinos stream through our body every second, yet, only one or two of the higher energy neutrinos will scatter from us in lifetime. It is no wonder that they are called "Ghostly particles". The neutrino was proposed by Wolfgang Pauli in 1930, but it took another 26 years for it is to be actually detected. In the year 1956, Reines and Cowan found evidence of neutrino interactions by monitoring a volume of cadmium chloride with scintillating liquid near to a nuclear reactor. Reines was jointly awarded the Nobel Prize in physics in 1995 in part for this revolutionary work. There are at least three types of flavours of neutrinos and their antiparticles exist in nature.

They have a tiny mass, whose value is still not known. Moreover, they exhibit a quantum-mechanical phenomenon in which one type of neutrino oscillates into another as it propagates in space. This is called neutrino oscillation and this observation has generated immense excitement in the particle physics community.

1.3 Detection of Neutrinos

From recent experiments, it is known that mass of the neutrino is non-vanishing, but it is unsure how large the masses of the three individual neutrino types are relative to each other, because of the difficulty in detecting neutrinos. This is important because neutrinos are by far the most numerous of all the particles in the universe (other than photons of light) and so even a tiny mass for the neutrinos can enable them to have an input on the evolution of the Universe through their gravitational effects. There are other recent astrophysical measurements that provide information on the evolution of the Universe and it is crucial to seek complementary information by direct determinations of the masses of neutrinos and their other properties. In a sense, neutrinos hold the key to several important and fundamental questions on the origin of the Universe and the energy production in the stars. We have some partial answer but many details are still awaited from the future experiments.

1.4 Underground Laboratory

Neutrinos, as mentioned before, are notoriously difficult to detect in a laboratory because of their extremely weak interaction with matter. The background from cosmic rays (which interact much more readily than neutrinos) and natural radioactivity will make it almost impossible to detect them on the surface of the Earth. This is the reason neutrino observatories are located deep inside the Earth's surface. The overburden provided by the Earth matter is transparent to neutrinos whereas most background noise from cosmic rays is substantially reduced due to their absorption by the Earth, the extent of reduction depends on the depth at which the detector is located.

One of the earliest laboratories created to detect neutrinos underground in the world was located more than 2000 m deep at the Kolar Gold Field (KGF) mines in India. The first atmospheric neutrinos were detected at this laboratory in 1965.

This laboratory has been closed due to the closure of the mines. Most underground laboratories around the world are located at a depth of a km or more. There are two types of underground laboratories: either located in a mine or in a road tunnel.

There are four major laboratories around the world: in Sudbury in Canada, in the Soudan mines in the USA, Kamioka in Japan and under the Gran Sasso mountains in Italy. The first two are located in mines and house relatively much smaller detectors than other labs that are accessed by a road tunnel. Several others are planned including INO which is an attempt to recapture the pioneering studies on neutrinos at KGF. The proposed ICAL detector at INO is however on a much larger scale (3 modules of 16 kton each as opposed to the 0.34 kton detector that was housed at KGF)

1.5 ICAL Detector

The detector initially to be housed in the INO laboratory (Cavern-1) will be a magnetized iron calorimeter detector (ICAL). It is a static device without moving parts. Just as a telescope observes the sky through visible light, the ICAL will observe

the sky through neutrinos. The schematic view of ICAL Detector is shown in *Figure 1.1*.

The detector set up essentially consists of glass Resistive Plate Chamber (RPC) detectors sandwiched between stacks of steel plates. The neutrinos entering the detector, while passing through the steel plates will generate charged particles called muons, whose tracks will be detected by the active detector elements RPCs. The RPC detector is a thin flat glass chamber with metallic coating. The glass chamber is filled with gas mixture of about 95.5% Freon (R134a), 4.2% Isobutane & 0.3% SF6. The total volume of the gas circulating in the detector will be around 200 cubic metres. If required to be replaced, the gas will be suitably diluted with fresh air before being let out to the atmosphere.

The magnets of the detector will be water cooled. The gas and water cooling system will be in a closed cycle.

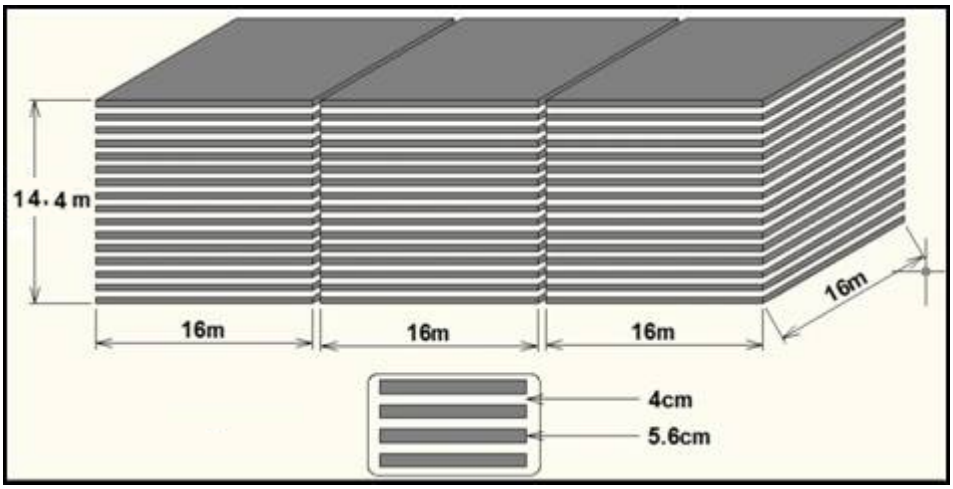


Figure 1.1 Schematic view of ICAL detector

1.6 A vision for INO and the challenge

INO has been conceived on a scale that no other basic sciences project in India has attempted. The MOU signed by seven institutions, that brought the Neutrino Collaboration Group into existence, is already the first of its kind. It is testimony to the enthusiasm and collaborative spirit shown by the scientific community in India.

In the first phase of its operation a magnetised iron calorimeter detector, weighing about 50 Ktons, will be used for studying neutrinos produced from cosmic rays in Earth's atmosphere. The aim is to make precision measurements of the parameters related to neutrino oscillations. An exciting possibility is to determine the ordering of the neutrino masses which is not very well known at present. This is one of the fundamental open questions in neutrino physics and no other detector either existing or planned may be able to provide an answer in the next 10 years. Because of its ability to distinguish the positive and negative muons, this detector can settle this question.

This detector can also be used as the far-detector of a long-base-line (6000 to 11500 km) neutrino experiment using the neutrino beam from a neutrino factory in Japan, Europe or USA. These are neutrinos that will be produced in a future accelerator facility which are beamed towards the detectors situated in a different part of the Earth. This is envisaged as the second phase of the INO activity and is a long-term goal (to be implemented after 10-15 years), since neutrino factories are yet to become a reality. However, there is considerable interest in this possibility not only for the rich physics potential but also because the proposed detector at INO will be capable of charge identification, which is crucial for this mode of operation.

INO will have a great impact on the emerging high energy physics scenario in the country. People trained at INO will not only participate here but also have the expertise to contribute to other high energy and nuclear physics projects around the world. Over the long term, INO is expected to develop into a world class underground science laboratory straddling many 'fields' like Physics, Biology, Geology and allied Engineering fields.

1.7 INO in India

Historically the Indian initiative in cosmic ray and neutrino physics goes back several decades. As a result of extensive studies of the muon flux at several depths in the KGF underground laboratory, it was realized that muon flux was low enough to permit measurements on atmospheric neutrinos. The observation of the Kolar events suggested a decaying heavy particle and this was done using calorimeters weighing up

to 300 tons of iron with usual detection. These Kolar experiments were indeed the harbingers of present day atmospheric neutrino experiments. In view of the importance of this field, it was widely felt that neutrino physics experiments should be revived in India.

The possibility of locating Neutrino Observatory in India was discussed as early as 1989 during several meetings held that year. Since then this question has come up, off and on, in many discussions. The issue was raised again in the first meeting of the Neutrino physics and Cosmology working group during the Workshop on High Energy Physics Phenomenology (WHEPP) held at Chennai in January 2000 and it was decided then to collate concrete ideas for a Neutrino detector.

Further discussions took place in August 2000 during a meeting on Neutrino Physics at the Saha Institute of Nuclear Physics, Kolkata, when a small group of neutrino physics enthusiasts started discussing the possibilities. The Neutrino 2001 meeting was held in the Institute of Mathematical Sciences, Chennai, during February 2001 with the explicit objective of bringing the experimentalists and theorists in this field together. The INO collaboration was formed during this meeting. The first formal meeting of the collaboration was held in the Tata Institute of Fundamental Research, Mumbai, during September 6^{th} and 7^{th} 2001 at which various subgroups were formed for studying the detector options and electronics, physics goals, simulations and site selection.

In 2002, a document was presented to the Department of Atomic energy (DAE), Government of India, which laid out an ambitious goal of establishing an **India-Based Neutrino Observatory (INO)** outlining the physics goal, possible choices for the detector and their physics reach. Since then, many new and fast paced developments have taken place in neutrino physics. The award of the Nobel Prize in Physics (2002) to the pioneers in Neutrino physics is a measure of the importance of this field.

As a result of the support from various research institutes, Universities and scientific community, a **Neutrino Collaboration Group (NCG)** was established to study the

possibility of building an **India-Based Neutrino Observatory (INO)**. The collaboration was assigned the task of doing the feasibility studies for which funds were made available by the DAE.

A memorandum of understanding (MoU) was signed by the directors of the participating Institutes on August 30th 2002 to enable a smooth functioning of the NCG during feasibility period.

The NCG has the goal of creating an underground neutrino laboratory with the long term goal of conducting decisive experiments in neutrino physics as also other experiments which require such a unique underground facility.

The geographical location for such a laboratory is particularly interesting, as all existing neutrino detectors are scattered around the world at latitudes larger than 35^0 North or South. There is none close to the equator yet. In principle, it is possible to push such a detector down to very low latitudes in South India. Such a location will be helpful to the neutrino astronomy researchers to cover the whole celestial sky and to study the solar neutrinos passing through the Earth's core.

1.8 Joint funding

The India-Based Neutrino Observatory (INO) Project is to be funded jointly by Department of Atomic Energy & Department of Science & Technology/ Government of India during 11th & 12th Five Year Plan period.

CHAPTER – 2

PROJECT SITE SELECTION – POTTIPURAM IN THENI DISTRICT

2.1 Site selection criteria

The various parameters considered for site selection are given below:

(i) General

The INO caverns are to be located more than 1000m underground so that there is at least 1000m cover al-round. Hence the choice of site is primarily dictated by the rock quality in order to have a stable and safe environment for long-term scientific activity. Geologically, mountains in Southern parts of India are compact, dense rock mostly gneiss whereas the Himalayan region is predominantly consists of metamorphic sedimentary rock with pockets of gneiss. A considerable area of peninsular India, the Indian shield, consists of Archean gneisses and schists, which are the oldest rocks found in India. While the Karnataka region has more schists type rocks, the Tamil Nadu region has mainly Charnockite, which is the hardest rock known. Hence the mountains of Tamil Nadu are the most attractive one, offering stable dense rocks with maximum safety for locating a cavern.

(ii) Rock mechanics and stability

At depth of over 1000m, rock would be under tremendous stress and the vertical stress is expected to be > 270kg/cm^2. This would create problems like rock bursts, roof collapse etc. The rock must be strong enough to withstand the stress. Charnockite is considered as highly favourable for housing a large cavern at great depths. The location of dykes, shears, faults, weak zones, etc., can be identified so as to prevent/eliminate any problems likely to arise from them. The direction of principal stress and ratio between horizontal and vertical stresses play a major role in orientation of the cavern at great depths and its safety.

(iii) Long term availability of the land

As long term availability of land is very essential for the design and stability of the caverns and surface facilities, availability of Government promboke land will make the project execution easier.

(iv) Rainfall

Low rainfall of about 75-100cm per annum is needed for operating detectors which are sensitive to humidity.

(v) Water required

Adequate water should be available for cooling the magnets that will provide magnetic fields in excess of 1 tesla and for air conditioning underground facilities and surface facilities.

(vi) Environmental impact

Given the nature of the basic requirements, the project location will invariably be located in hilly area close to Reserved Forest land. The environmental impact will be mainly during construction period. It is possible to minimize and manage the impact during construction.

(vii) Construction cost

The construction cost depends on the topography of the project site. If it is in plains, then the material transport as well as disposal of excavated tunnel muck will be easier and economical.

(viii) Operating cost

With increase in ambient temperature, the cost towards air-conditioning & ventilation will also increase.

(ix) Access

It is important to have quick access to the laboratory from major cities with good infrastructure.

(x) Working environment

It should be comfortable from the point of view of easy access to laboratory, living comfort, etc.

2.2 Sites identified for INO Project

The first round of discussion on site selection was held with Geologists and Engineers, who narrowed down the possible sites to two locations, based primarily on the Geology (which is a prime factor for the long-term safety and stability of the site) and physics requirements. These were the sites at Singara, near TNEB's Pykara ultimate hydro-electric station, an underground station in the Nilgiris mountains of Tamil Nadu and Rammam in the Darjeeling district of West Bengal. Out of these two sites, Singara site was selected during the year 2002 for INO Project, considering Geological aspects, Infrastructure facilities etc. The Detailed Project Report for INO Project at Singara was prepared by TNEB during 2007. However the clearance from State Forest Department to the Project site at Singara was not forthcoming, even though all the project surface components were to be located in TNEB land.

The reasons advanced by the State Forest Department were that the project site at Singara falls in the buffer zone of Mudumalai Tiger Sanctuary which include the core/critical tiger habitats of Bandipur & Mudumalai tiger reserves and also it is an elephant corridor facilitating elephant movement from Western Ghats to Eastern Ghats and vice versa.

The Sanctuary notification de-notifying these areas as tiger reserves was issued during 2008, (ie.) six years after the INO Project was proposed at Singara and two years after the application was filed with Tamil Nadu Forest Department for approval.

Hence alternative sites for INO Project in the Theni district in Tamil Nadu were explored and based on geotechnical factors, three locations namely Suruliyar, Pottipuram and Kottagudi sites were identified for detailed study.

The district head quarters Theni town, 72 km from Madurai city, has schools, colleges and a medical college with hospital.

Suruliyar (Periyar) river runs through the middle of the Kambam valley in Theni district and is the main source of water for the region.

2.3 Relative site studies of Singara, Suruliyar, Pottipuram & Kottagudi

The relative merits/demerits of four sites (viz.) Singara in Nilgiris district (which was dropped due to the State Forest Department's objection) and the three sites in Suruliyar (Kambam valley), Pottipuram and Kottagudi have been brought out in *Table 2.1*.

Table 2.1 Comparative study of four sites

Site features	Singara site	Suruliyar site	Pottipuram site	Kottagudi site
Cavern location	Under Reserved Forest (RF)	Under Wild life sanctuary (WLS)/estate	Under Reserved Forest (RF)	Under Reserved Forest (RF)
Rock type	Charnockite	Charnockite	Charnockite	Charnockite
Maximum Vertical cover	1299m	1264m	1279m	1400m
Portal location	TNEB camp	Inside Reserved Forest / Wild life sanctuary	Outside the Reserved Forest boundary	Outside the Reserved Forest boundary
Tunnel route	Partly under RF	Under WLS	Under RF	Partly under RF
Tunnel length	2100m	<3000m	1966m	<3000m
Access	From Masinagudi (crosses elephant corridor)	Road up to Portal	Katcha road (1km) to be strengthened	Katcha road up to Portal to be strengthened
Geo-tech data	Well studied-Good	Appears good	Good	Reasonable
Seismic risk	Zone-2	Zone-2	Zone-2	Zone-2
Environmental risk (lab)	Close to RF/WLS; under RF	Sanctuary edge/ under WLS	Under RF 4.62 ha only	Under RF (RF minimal)

Power	Available	Available	Not available (To be drawn from RasingapuramSS,10km)	
Water	Available	Available	Not available (To be drawn from Mullai Periyar,15km)	
Nearest town	Ooty	Theni	Theni	Theni
Nearest city	Coimbatore	Madurai	Madurai	Madurai

2.4 Pottipuram site selection

Singara site in Nilgiris district had to be shelved as the project site falls within the buffer zone of Mudumalai tiger reserve and the approach road lies within the Elephant corridor.

Suruliyar site in Theni district was not considered as the project site lies within the newly declared Megamalai wild life sanctuary, an ecological sensitive area.

In respect of Kottagudi site there is no forest and environmental issue such as in Singara & Suruliyar sites, but the terrain is hilly involving transport problems.

In case of Pottipuram site, it is a clear site from Forest & Environmental issues. Moreover, the terrain is flat and there will not be any problem in transport of materials and disposal of excavated tunnel muck. The Reserved Forest is of open scrub variety and most of the mountain face is bald with patches of scrub forest.

Good rock quality is available for the cavern formation. The cavern is to be set in massive Charnockite as in Singara site.

One of the main advantages of Pottipuram site is the steepness of the mountain which provides many possibilities for locating the portal depending on the overburden chosen.

Hence, the Pottipuram site in Theni district is selected for INO Project.

2.5 Alternative alignments for Access tunnel considered

The proposed site is located on the eastern fringe of the linear Western Ghat hills and is close to the Kerala-Tamil Nadu State boundary. The escarpment face of the hill ends up against the plain of Kambam Valley of Tamil Nadu, The hill has vertical

scarps at different levels intervened by moderately steep slope of about 35^{o} to 40^{o}. The hill has access only from its eastern peripheral plains of Tamil Nadu, as it has undulating plateau at the peak towards Kerala side.

Three possible alignments of the access tunnel to the lab cavern were identified based on GTS Maps and field visits along the humps avoiding the intervening valleys formed by the streams transecting the hill in E-W and NW/SE directions. They are:

One alignment in the southern side in direction of N 28^{o} W-S 32^{o} E, another at the centre in the direction of N 68º W-S 68º E and third at the northern side in the direction of S 80º - N 80º E.

Emphasis was given to portal locations as the hill slope is rocky and forest boundary begins mostly at the beginning of the hill. All the three alignments have similar surface profile of rocky hill slope against the plain area covered with overburden. The forest boundary in all the three alignments coincided with the surface rock boundary. The project authorities wanted to avoid forest land while establishing the portal. Hence it has become mandatory that the portal is established away from the forest land. This has necessitated the location of portal in the open land with a provision of cut and cover or open cut till sufficient hard rock cover for tunnel is obtained.

Of the three alignments shown in *Figure 2.1*, Alignment-3 located on the northern side (North of village temple) has to be approached through the private land. Moreover the presence of deep and narrow nala valley in N/S direction is also restricting the access to alignment even though no geological problems are noticed. Hence, only Alignment-1 and 2 were studied in detail

2.5.1 Alignment - 1

The portal area and initial reaches of the alignment were studied by taking geological traverses. The site observations show that the proposed portal in the open scrub area in between two small nala courses may have 6m to 7m thick overburden. Weathered rock outcrops are noticed in the stream course, located further down slope, with 7m thick soil cover (depth of the valley is 7m). This soil covered open scrub area with a

very gentle slope is about 260m long from RL 430m to the rim of the rocky hill slope along the proposed alignment Beyond this soil covered area, the profile becomes steeper and rock out crops start appearing from RL 450m. From this chainage, the rock outcrops are continuing all along the alignment with exception of few spots where the hill slope is covered with thin soil cover. Thus, the tentative rock levels as arrived at for the soil covered area of the alignment by connecting the rock outcrops of stream valley and rock out crops at the rim of hill slope. The details are summarized in *Table 2.2.*

Table 2.2 Details of Alignment-1

Sl. No	Description	Ch (m)	Ground level (m)	Assumed rock level (Weathered rock level) (m)	Crown level of tunnel (m)	Total cover (m)	Rock cover available (m)
1	Stream Bed	(-)100	425	425			
2	Stream Bank	(-) 90	430	425.4			
3	Tunnel Entry	0	435	428			
4	Tunnel Portal	185	448	445	430.5	17.5	14.5
5	Sheet Rock Exposure	225	450	450	427	23	23
6	Forest Boundary	250	465	465	426	35	35

It indicates that from Ch 0m to 50m excavation will be in loose soil and beyond that, from Ch. 50m to 185m the excavation will be partly in soil and partly in weathered and hard rock. Thus, an open cut or cut & cover for a length of 185m was envisaged in this alignment. Geologically the alignment is feasible.

2.5.2 Alignment - 2

It is located in central part of eastern hill slope. A prominent rock spur is seen in the hill slope in this area and at the southern side of this spur in the direction of N 68° W-S 68° E the Alignment-2 is proposed.

It has a comparatively gentle gradient in the lower slopes of hill. Similar to Alignment-1, the rock out crop boundary of the hill coincides with forest land and beyond which the open scrub land plain area is with soil cover. A few weathered rock

out crops are seen in the open plain in the area at RL 430 m and 440 m. Surface geological studies indicate that the rock is occurring at shallow depth of 2m to 3m from the surface in the plain area adjacent to forest boundary in the down stream direction. The assumed rock line is formed by joining this rock out crop in the plan area and rock out crops at the hill rim near the forest boundary. A geological section is prepared based on the data available and it shows that the open cut or cut and cover section is of about 160 m and mostly in weathered and fresh rock only which is considered to be favourable that excavation in the loose soil. Geologically the alignment is feasible. The brief summary of the observations made along this alignment are furnished in *Table 2.3.*

Table 2.3 Details of Alignment-2

Sl. No.	Description	Ch in (m)	Ground Level (m)	Assumed rock level (Weathered Rock level) (m)	Crown level of tunnel (m)	Total Cover (m)	Rock cover available (m)
1.	Tunnel entry	0	430	427			
2.	Tunnel portal (EL)	165	442.5	441.5	426	16.5	15.5
3.	Forest boundary (sheet rock exposure)	237	450	450	421	29	29

2.5.3 Selection of Access tunnel alignment

The site specific geological study of the Pottipuram hill to locate the INO cavern was carried out with special emphasis on Access tunnel. The rock mass characteristics of the hill appear to be homogeneous all around the hill and no sharp variation is seen in the geological conditions along the hill slopes of eastern side. No major adverse geological features are seen. Tunneling media (charnockitic gneiss) is hard, fresh and with 3 to 4 sets of joints. Rock mass quality appears to be 'Good' and tunneling is prognosticated to be smooth with some light support like Rock bolt, shotcrete, etc. in the low cover reaches. In the high cover reaches high stress conditions may cause rock bursts.

The bedrock depth is shallow in Alignment-2 (2m from surface) and it is comparatively deeper in Alignment-1 (7m from surface) with probably more depth of weathering at the proposed portal. As the access tunnel portal has to be located away from the forest boundary to avoid forest land, the tunnel entry has to be in the Government promboke land with a cut and cover reach. In the Alignment-2 open cut will be mostly in hard rock as it has thin over burden. The rock profile is also gentler and uniform in the initial and middle reaches. In view of this, geologically, Alignment-2 is preferable. However, Alignment-2 falls in the private land and land acquisition would be a problem, whereas in the case of Alignment-1, portal is located in Government land and so Alignment-1, is finalised. *Refer Figure 2.2.* INO Project underground components are to be located in Bodi West Hills under Reserved Forest and surface components in Pottipuram village (Government Promboke land - Survey No.4/1).

2.6 Subsequent detailed site study

The Access tunnel portal is fixed at EL 432.40m in Survey No.4/1 of Pottipuram Village. The caverns are to be located below the contours of 1579m & 1560m. At this location the vertical rock cover/overburden from the middle level of the stack is above 1279.23m (1560 – 280.77). The cover is comparable to what is available at Gran Sasso in Italy and better than the one at Kamioka mines in Japan. All-round cover exceeds 1000m in all directions. *Refer Figure 2.3* for Comparative study of various atmospheric Muon background as a function of depth.

The topmost level/ peak is EL+1587.325 which is slightly away from top of INO caverns. The site falls under Seismic Zone-II of Seismic Zonation map of India (*Refer Figure 2.4*).

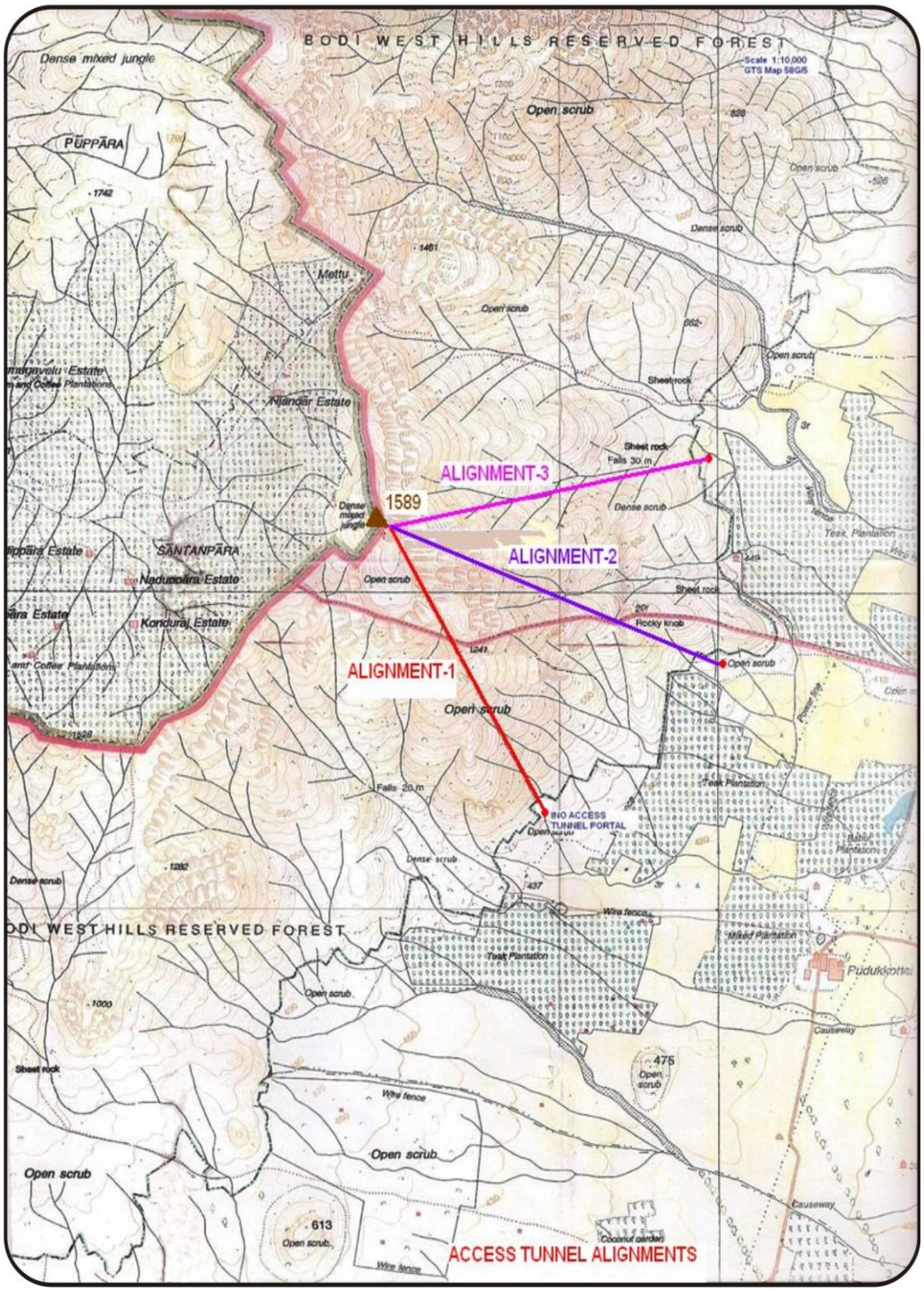


Figure 2.1 INO Project – Three alternative alignments of Access tunnel

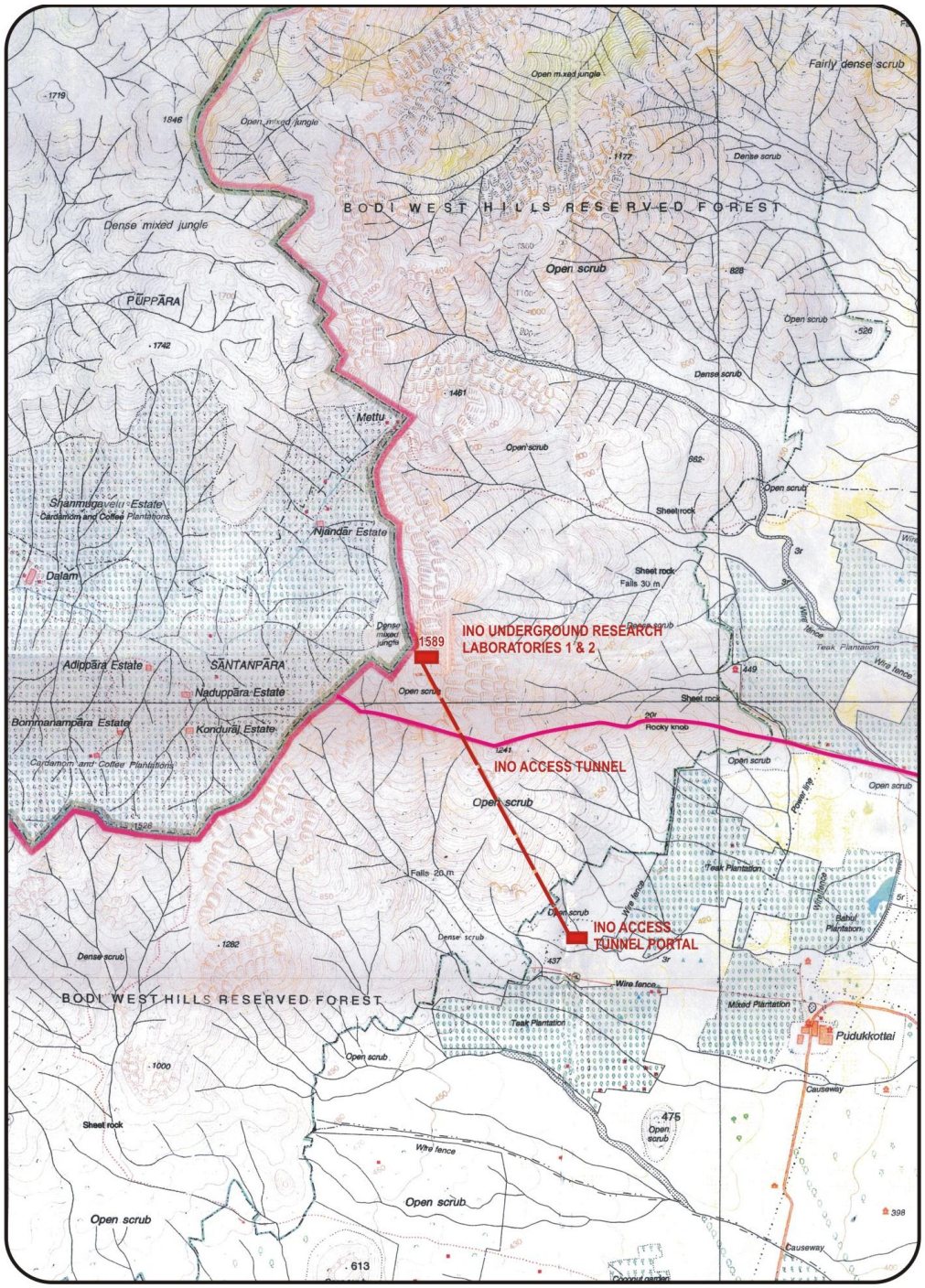


Figure 2.2 Site location in GTS Map

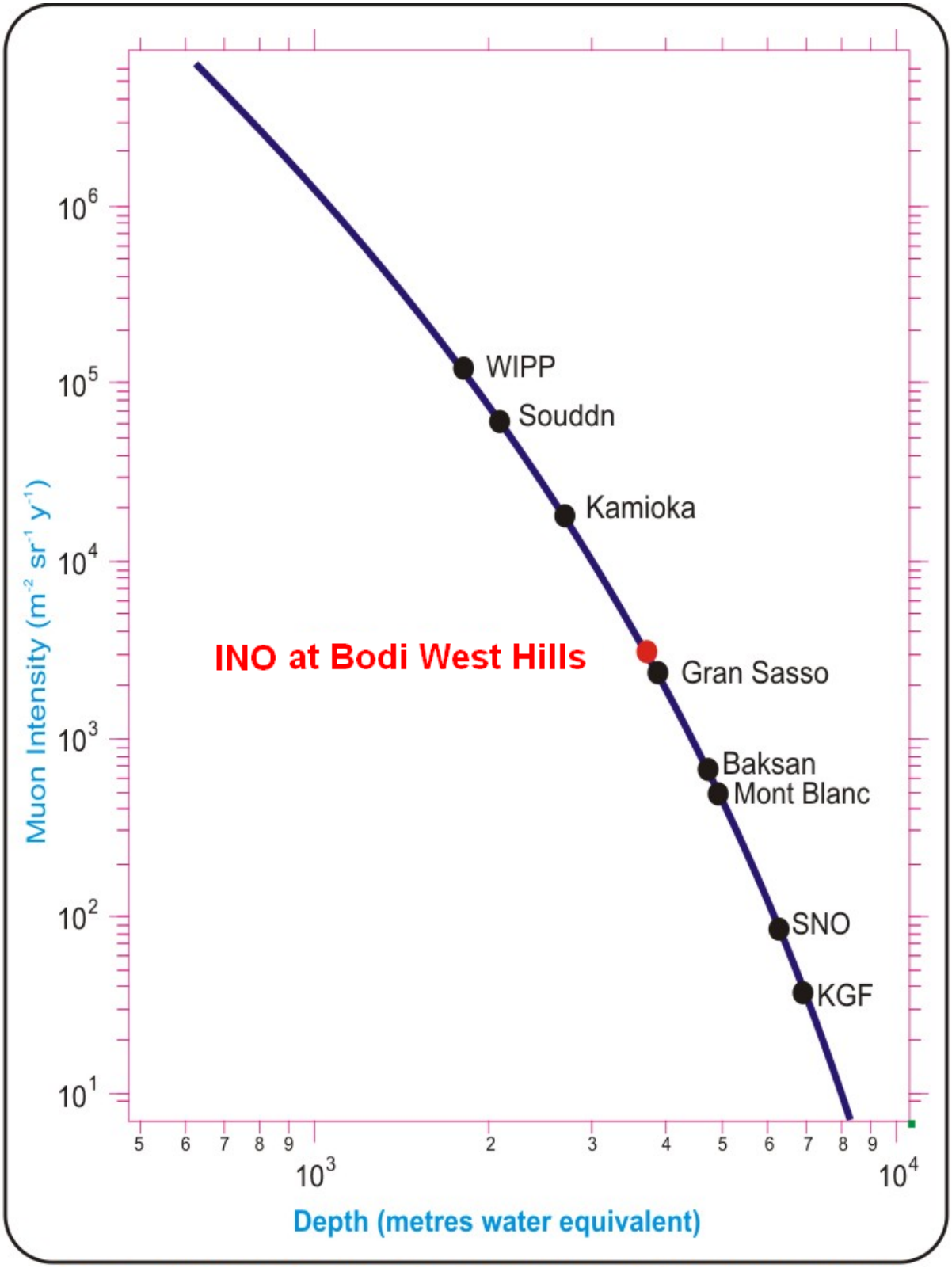


Figure 2.3 Atmospheric muon background as a function of depth

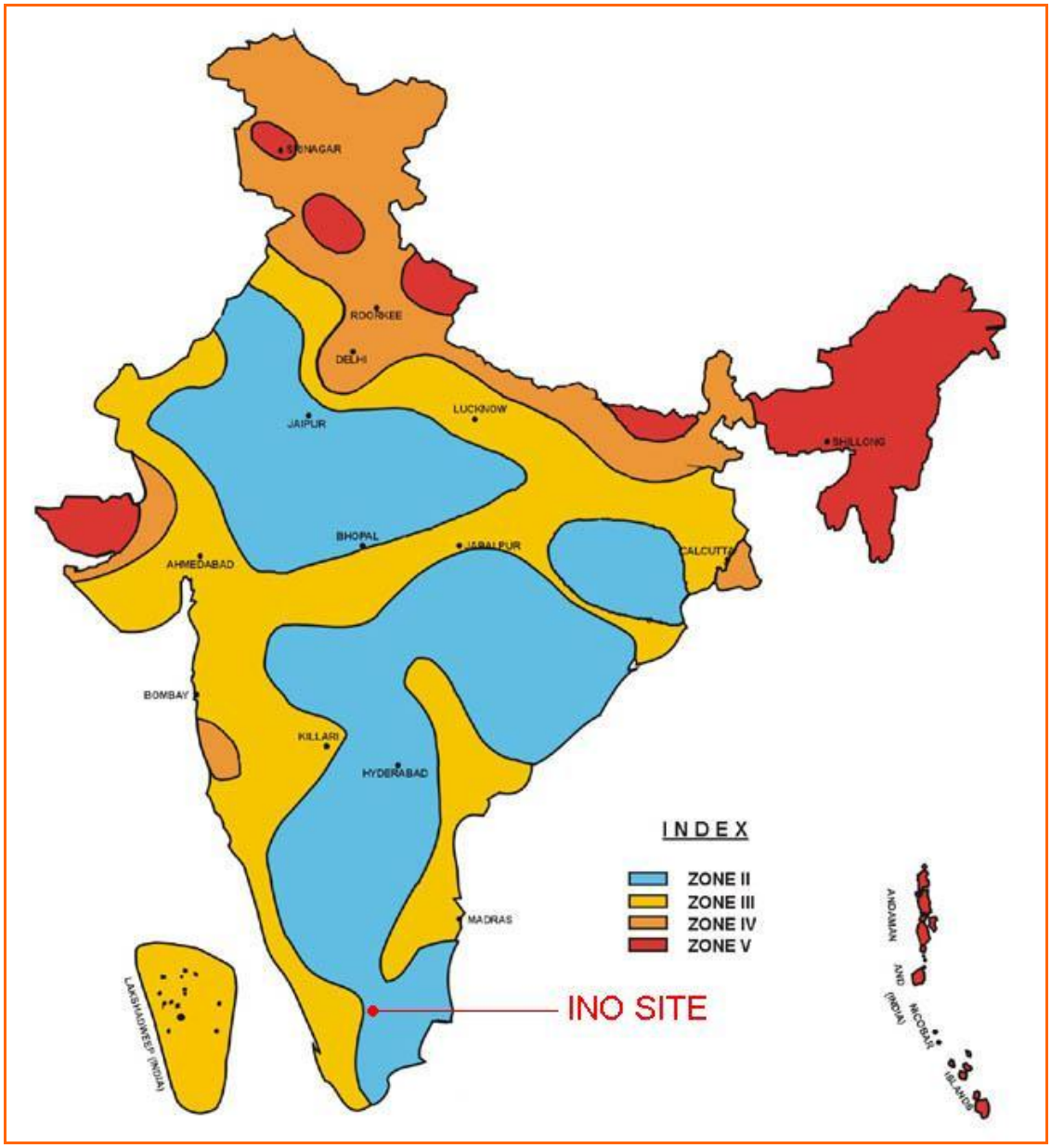


Figure 2.4 Seismic zonation map of India

CHAPTER – 3

THENI DISTRICT - DETAILS

3.1 Introduction

Theni district is in the Southern part of Tamil Nadu. This district is surrounded by the Western ghats, with its ubiquitous green cultivated lands and tea gardens. The main route (viz.) Theni-Uthamapalayam-Kambam-Gudalur to access Munnar and Thekkady wild life sanctuary in Kerala State, lie in Theni district.

The district is divided into two natural divisions, the hilly areas constituted by parts of three taluks Periyakulam, Uthamapalayam & Andipatti with thick vegetation and perennial streams from the hills on the western side and Kambam valley in Uthamapalayam taluk.

Theni district was formed by the bifurcation of erstwhile Madurai district during 1996.

The region covered by present day Theni district was scarcely populated before 1900s. In 1886, Mullaiperiyar dam project brought water from Periyar river down hill to Kumbam valley. Theni was itself a small and less known town in 1900. After the Mullai-Periyar project, people from nearby dry arid regions (Sivakasi, Kovilpatti, Virudhunagar, Sattur and several nearby towns) settled in Kambam Valley (present day Theni district). So there was influx of people during the period from 1890 to 1920 and since then Theni developed in rapid pace and became a business center. Refer Figure 3.1 for location of Theni District.

3.2 Social aspects

3.2.1 District Details

District	:	Theni
Sub district	:	Periyakulam, Theni, Andipatti, Uthamapalayam, Bodinayakanur
Legislature seats	:	5
Population	:	10,93,950 (2001)
Urban	:	5,91,841 (2001)
Density	:	379/km^2 (892/sq.mile)
Sex ratio	:	Male – 50.5%, Female – 49.5%
Literacy	:	71.58%
Male	:	81.88%

Female	:	61.19%
Official languages	:	Tamil and English
Time zone	:	IST (UTC + 5:30)
Area	:	2,889km^2 (1,115sq.mile)
Coastline	:	Nil
Rainfall	:	833.5mm (32.8")
Temperature		
Summer	:	40° C (105° F)
Winter	:	15° C (59° F)
Geographical Co-ordinates		
Latitude	:	9° 39' N & 10° 30' N
Longitude	:	77° 00' E & 78° 30' E

3.2.2 Geography

A range of hills which runs parallel to Western ghats from North to South separate it from the neighbouring state of Kerala.

3.2.3 Rivers and Dams

The Periyar river, Mullai river, Vaigai river, Kottagudi river, Suruliyar river, Varahanathi, Manjalar and varattaru flow through the district. The important dams in the district are Vaigai dam, Manjalar dam, Sothuparai dam, Shanmuganathi dam, Manalaru dam and Melmanalaru dam.

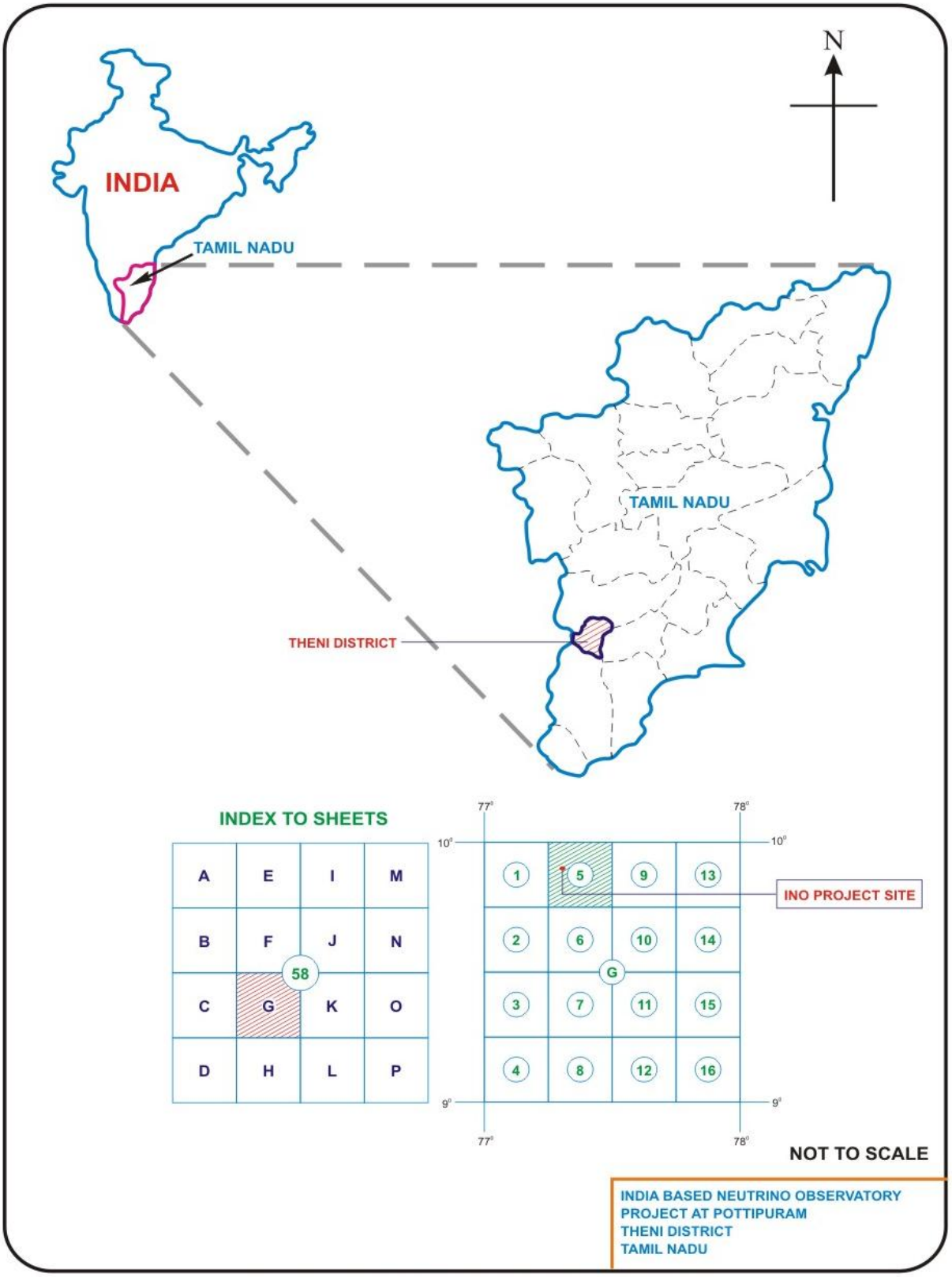


Figure 3.1 Location of Theni District

3.3 Economy

Its economy is mostly agricultural. Utilisation of land area for cultivation in Theni district is 40.33%. The principal crops & produces of this district are Sugarcane, Cotton, Silk, Rice, Millets and Cereals, Pulses, Groundnut, Ginger, Silk, Banana, Coconut, Tea, Coffee, Cardamom, Grapes and Mangoes.

Kambam Valley is a major centre for grape production with 4000 small farmers cultivating Muscat grapes, known locally as "Panneer dhrakshai" and "Thomson seedless grapes". The unique feature here is that the grapes are harvested through out the year, while in most grapes growing centre elsewhere, the season ends with summer.

Cotton Spinning Mills and Sugar Mills are the major industries in this district. In Andipatti Taluk Handloom weaving and power looms are flourishing. In Uthamapalayam Taluk, the Highways Estate produces a good amount of Tea. Bodinayakanur (Bodi) is a major market place for Cardamom, Coffee, Tea and Black Pepper. This town is also called Cardamom town because of the large quantity of Cardamom trade in this area. It has an auction centre for Cardamom.

The Periyar and Suruliyar hydro-electric stations and the Vaigai micro hydro power station have 181 MW installed capacity.

Theni is one of the active business hubs in the Western side of Tamil Nadu, inviting more industries to its locality.

3.4 Madurai–Nearest city – Cultural Capital of Tamil Nadu

The proposed Project site at Pottipuram is 115 km from Madurai city. Madurai, located on the banks of Vaigai river, is the second largest city in Tamil Nadu and is more than 2500 years old. The city was an important cultural and commercial centre even as early as 550 A.D., when the Pandyas made it their capital.

The city of Madurai is synonymous with the Meenakshi Sundereswarar temple, is one of the best examples of Dravidian architecture and sculpture. The hall of thousand pillars is a museum of icons, photographs and illustrations. Apart from being a very

sacred spot to the religious Hindus, the Meenakshi temple is one of the country's most important tourist landmarks.

Madurai Meenakshi Sundereswarar Temple

CHAPTER – 4

POTTIPURAM SITE – INFRASTRUCTURE DETAILS

4.1 Location

The India-based Neutrino Observatory (INO) project to be located in Bodi West hills, Pottipuram village in Uthamapalayam taluk, Theni district.

Access is very good up to T.Pudukottai village which comes under Pottipuram revenue village and a Katcha road exists up to the proposed portal location. The site is about 115 km from Madurai City and about 36 km from Theni town.

This project is located between the following Geographical Co-ordinates:

Latitude : Between 77° 1’ 00” E &77° 30’ 0” E

Longitude : Between 9° 57’ 30” N & 10° 0’ 0” N

4.2 Approach to site

Refer *Figure 4.1* for approach to the site from major cities in South India and *Figure 4.2* for approach from the towns in Southern Tamil Nadu.

(i) Approach to project site from Madurai city

By Road from Madurai to Theni Town (NH 44)		: 80 km
By Road from Theni Town to Bodinaickanur (NH44)		: 15 km
By Road from Bodinaiyakanur to Rasingapuram (SH100)		: 10 km
By Road from Rasingapuram to T.Pudukottai (ODR)		: 8 km
By cart track	From T.Pudukottai to INO site	: 2 km
		----------
		115 km

- *NH* ---- *National Highways*
- *SH* ---- *State Highways*
- *ODR* ---- *Other District Roads*

(ii) Nearest Rail head:

Madurai	: 115 km
Bodinaickanur (Bodi)	: 20 km (Metre gauge is only available. Broad gauge conversion has been takenup. It is proposed to be completed within three years.)

(iii) Nearest Airport

Madurai	: 115 km

4.3 Infrastructure facilities

The Infrastructure facilities at the Project site are as follows:

(i) Availability of Land

The main advantage of the site is the availability of Govt. revenue Promboke land (dry) to an extent of 26.82.5 ha for the Project in Survey No. 4/1 of Pottipuram village. This land will be sufficient to locate the tunnel portal and to house the Utility building, Surface laboratory & Assembly, Administrative building, Residential quarters, Guest house, Tunnel muck transit yard for disposal and Temporary labour quarters etc. The availability of Government land will be a main advantage to locate the tunnel entry to avoid the over ground forest land. However as the site is barren land at the foot of the hill, all the infrastructure facilitation have to be created from the scratch.

(ii) Availability of water

As the project area is of grey area, availability of ground water is low. Moreover, to ally the apprehension of the local people living in the T.Pudukottai village and nearby villages, the groundwater will not be tapped for the project and the following two ways will be adopted.

<u>During construction stage</u>

About 5 lorry loads of each 8000 litres per day (8 KLD) will be arranged for the Project construction works (viz.) for the Field office, Quarters, Labour quarters, Wet drilling, Sprinkling the tunnel muck and also dust suppression.

<u>During operation period</u>

Assured surface water supply by Tamil Nadu water supply and Drainage Board (TWAD) from Mullai Periyar river at 15 km from the Project site will be undertaken under Deposit Contribution Work. TWAD Board will develop

the infiltration wells in the riverbed and 400KLD of water will be carried through the dedicated water pipe line to the project site to meet the water needs of INO underground and surface facilities.

(iii) Power supply

Dedicated 110/11 KV substation in the project site will be established to ensure uninterrupted and reliable power supply.

(iv) Mobility aspect

The Project site and Residential site are reachable throughout the year. Bodinaickanur or Bodi is the nearest town from where transport buses of Tamil Nadu are plying to various places in Tamil Nadu. Hence the project site will not be an isolated place. As the landscape upto the project site is almost plains, the movement of material and tunnel muck disposal will be easier

(v) Road facilities

The Project site is approachable from Madurai-Theni-Bodi-Uthamapalayam road by taking a turn near Rasingapuram village. As the Pottipuram village road is very narrow, it will not facilitate the movement of construction materials & ICAL steel plates to the Project site and also considering the inconvenience to the village people, a dedicated bye-pass road for 1km length partly on private land will be laid for a width of 7.5m (Two way traffic) connecting to the existing village road of 7km length to T.Pudukottai village which is to be widened and to be strengthened for 7.5m width. Beyond Pudukottai village, in the existing cart track and path, a dedicated road for 7.5m width for a length of 2km to the Project site is to be formed. Refer *Drg No. INO/DPR 1*. In this 2km stretch, a box culvert has to be constructed to cross over a stream at the foot of the hill downstream. Bridge is not considered necessary as the seasonal flow in the stream is very low. Refer *Figure 4.3* for the location of link road to be formed from the existing road and refer *Figure 4.4* for the Stream at the INO site wherein the Box culvert is to be constructed.

(vi) Rail connectivity

As Theni-Bodi Stretch is meter gauge section which is yet to be upgraded as broad gauge, Madurai city which is located at 115 km from the Project site and which is connected to all the major cities of our country, is the best rail

connection. The gauge conversion of Madurai-Theni-Bodinaickanur sector has been taken up and expected to be completed with in three years. On completion Bodi will become the rail connection and it will lead to cost cutting in the transport of steel plates.

(vii) Air connectivity

Madurai airport, is a domestic airport having connectivity to Chennai, Mumbai and Delhi and it is poised to become an International airport shortly.

(viii) Weather condition

In the plains, the temperature ranges from a minimum of 15° C to maximum of 40^0 C. In the hills, the temperature can range from as low as 5° C to 25° C. However, the average mean temperature ranges between 24.2° C to 27° C.

The project site is located in a high wind area and so suitable trees/ vegetation have to be grown for comfortable stay in the residential areas.

4.4 Other site advantages

(i)	Seismic Risk	:	Zone-2. No discernible faults
(ii)	Environmental Impact	:	Minimum. Since tunnel Portal is to be located in Government Promboke land.
(iii)	Law & Order	:	Good
(iv)	Site advantages		Easy land acquisition as it is a Govt.Poromboke land and also as land is in the plains, site accessibility will be easier.
(v)	Nearby Cities/ Towns	:	Madurai, Trichy, Tirunelveli & Nagercoil Tamilnadu is the most urbanized and industrialized state in the country.
(vi)	Site connectivity	:	Good network of roads

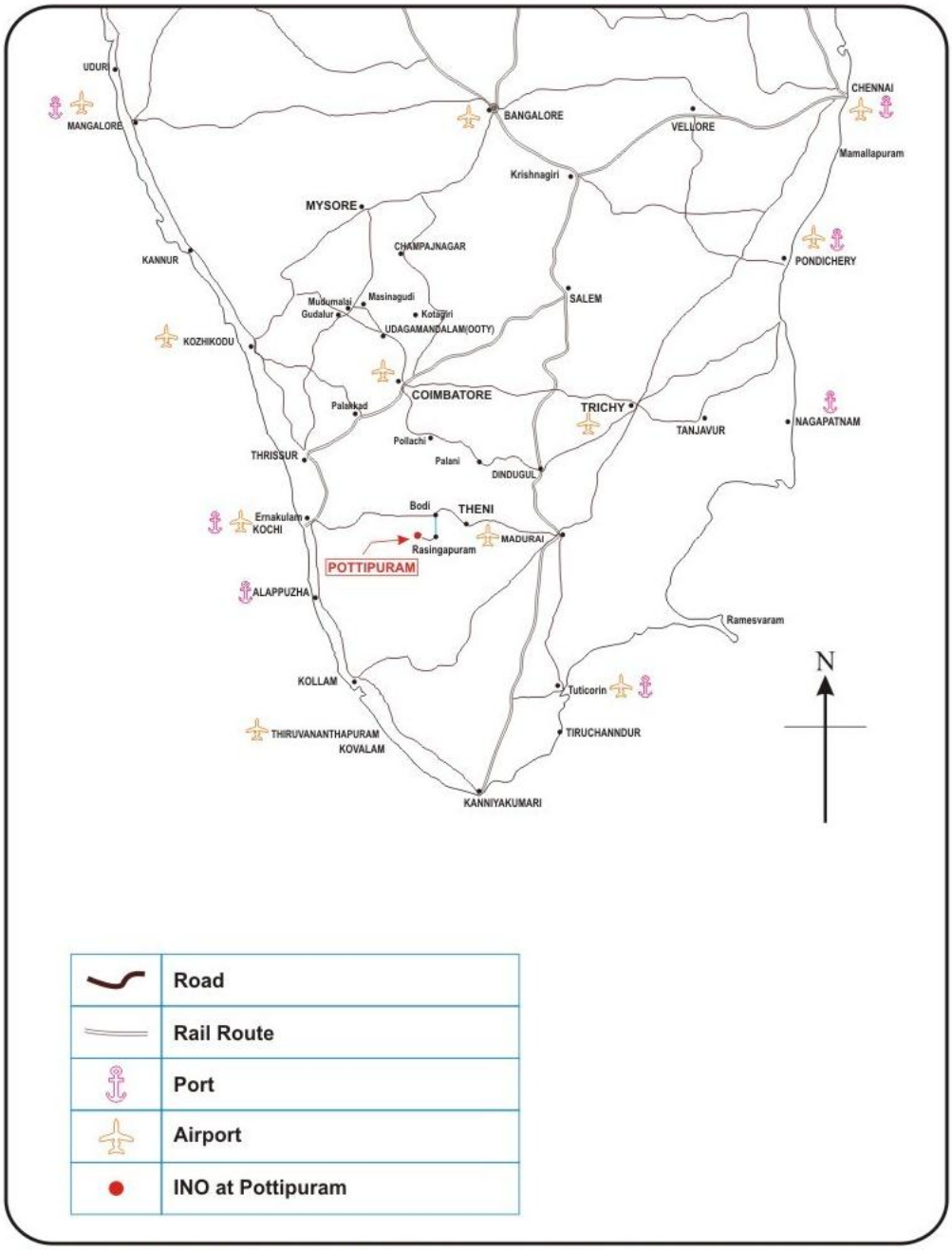


Figure 4.1 Approach to INO site from major cities in South India

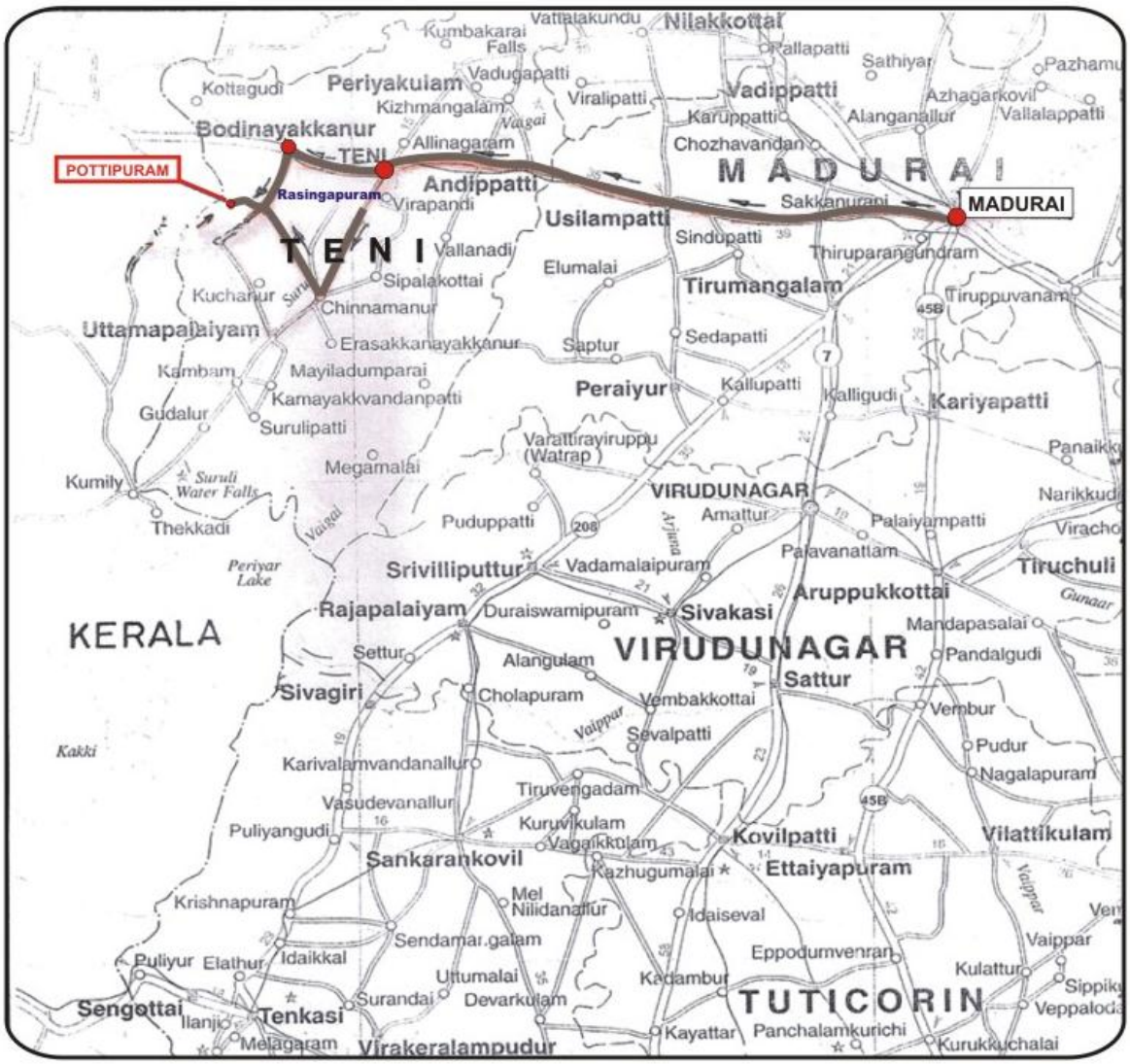
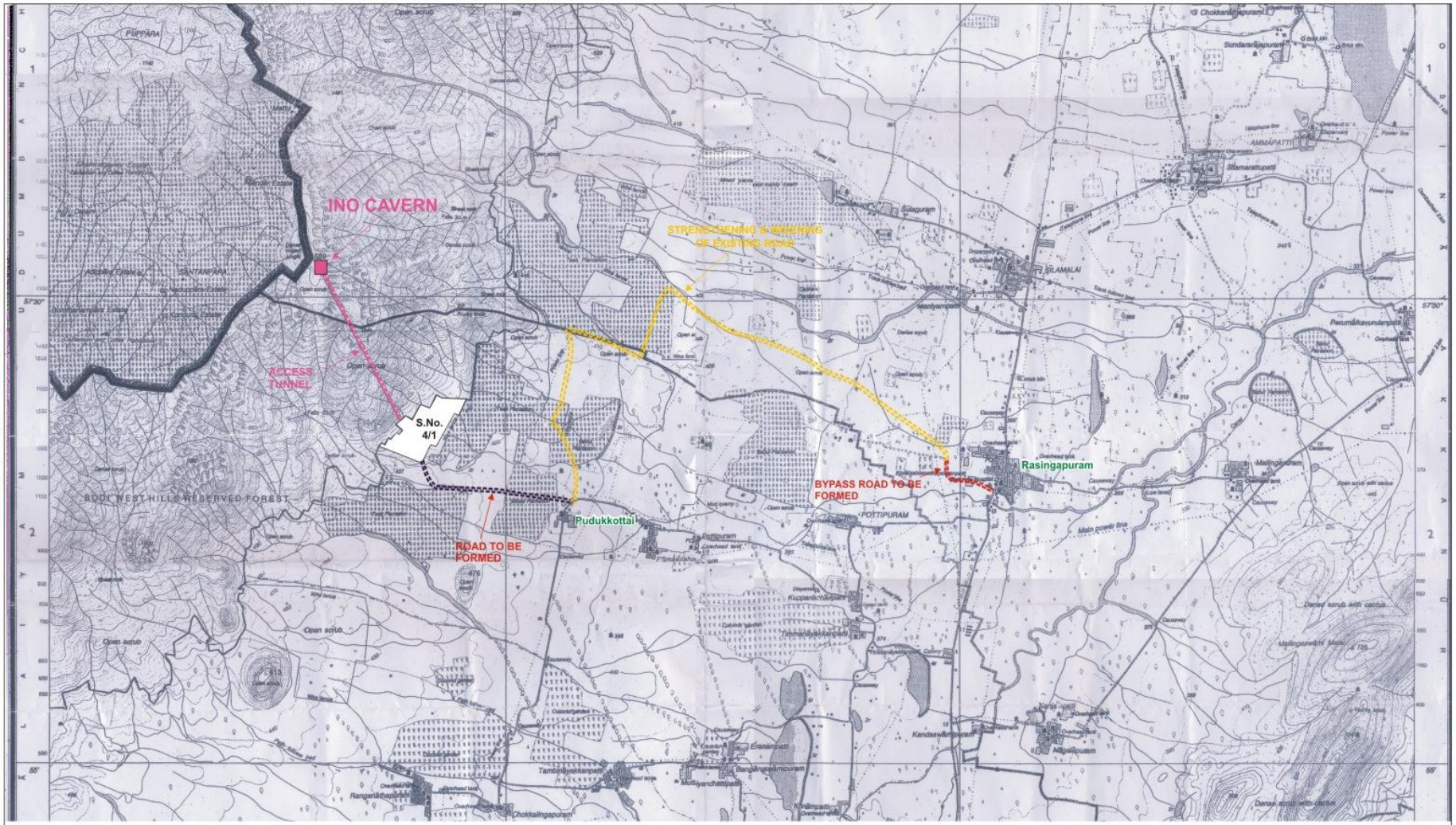


Figure 4.2 Approach to INO site from major towns in Southern Tamil Nadu



Drg. No. INO/DPR/ 1 Existing and proposed roads

Figure 4.3 Link road to be formed from the existing road

Figure 4.4 Stream at the INO site - Box culvert to be constructed

CHAPTER – 5

LAND AVAILABILITY AND REQUIREMENTS

5.1 Project components

5.1.1 Underground facilities

(i) Access tunnel portal

(ii) Access tunnel

(iii) Auxiliary tunnel

(iv) Interconnecting tunnel

(v) Additionally Driven Intermediate Tunnel (ADIT)

(vi) Cavern-1

(vii) Cavern-2

(viii) Cavern-3

(ix) Cavern-4 (Intermediate)

5.1.2 Surface facilities

(i) Utility service building

(ii) Detector assembly building and surface Lab

(ii) Residential quarters

(iii) Visitors hostel cum Guest house

(iv) Administrative building cum workshop

(v) Approach roads from the State Highways (Forming & Strengthening the existing one)

(vi) Box culvert/ Bridge across the stream

(vii) Future research centre

(viii) Main underground sump

(ix) Over head tank

(x) Security building

(xi) Dedicated 110/11 KV Sub-station

(xii) Compound wall construction

(xiii) Horticulture & Landscaping

(xiv) Storm water drain

(xv) Internal roads in project complex

5.1.3 Temporary facilities

i) Tunnel muck transit yard
ii) Magazine to stack explosives
iii) Diesel bunk
iv) Steel plates stack area
v) Labour quarters
vi) Crushing unit for BG metal
vii) Field office cum Guest house
viii) Detector assembly shop
ix) Weigh bridge

5.2 Land availability/ requirement

5.2.1 Forest land

The Project components mentioned under item 5.1.1 are to be located under ground in the forest land. Nominal diversion of forest land in Bodi West hills for an extent of 4.62 ha is needed for the under ground components. Forest land will not be occupied over ground

5.2.2 Government Promboke land

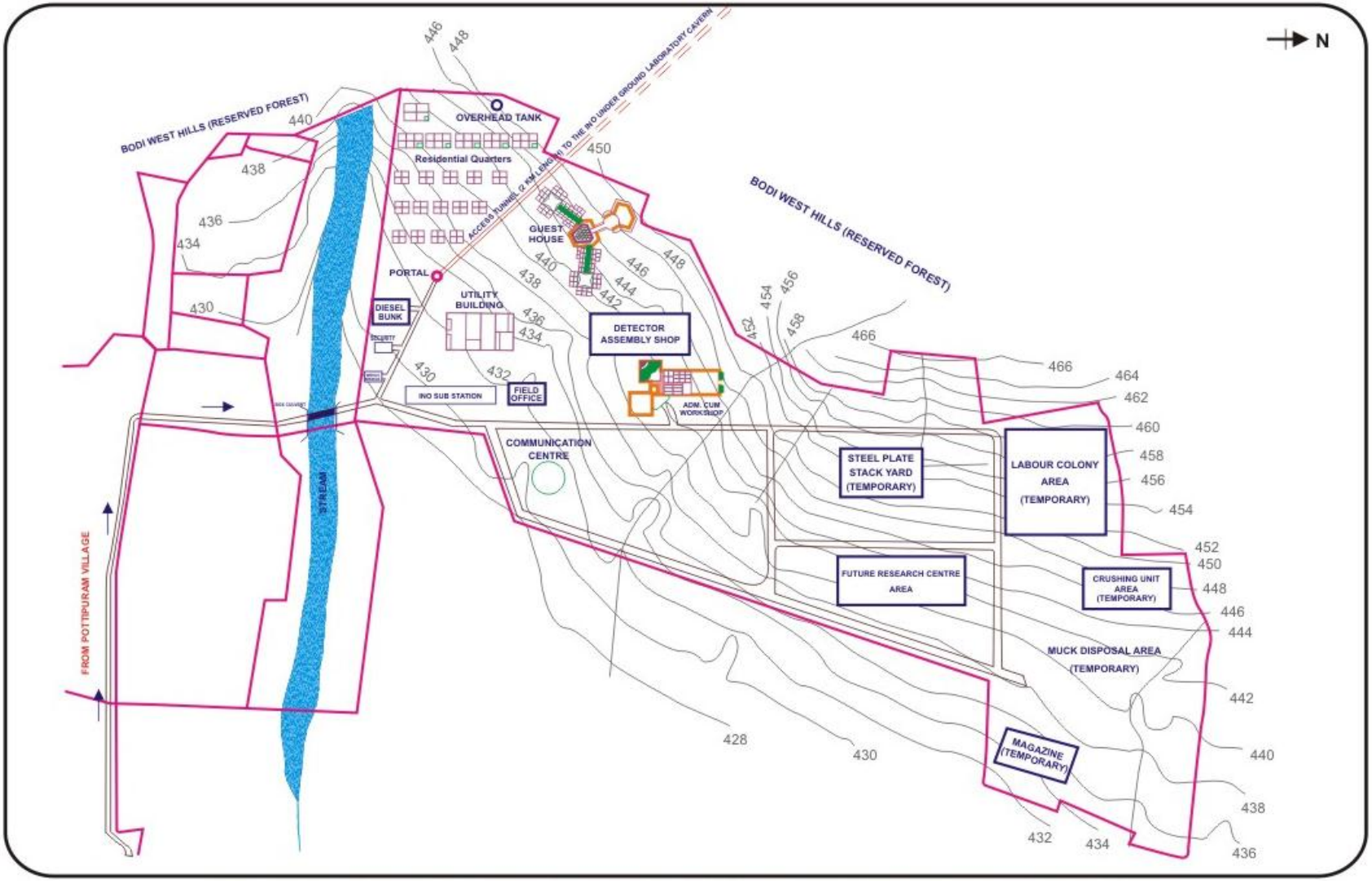
About 26.82.5 ha of Government promboke land in Pottipuram village (Survey.No.4/1) will be made available to this project by the Government. Out of this 26.82.5 ha the usable land extent is only 23 ha, the balance is a narrow strip. The access tunnel portal will be located in the Government Promboke land to avoid the Forest surface land.

The various surface facilities will be located in Government Poramboke land. For the sake of transport convenience and as vast area is needed, the steel stack area and the Detector assembly shop will be located near the entry itself. The utility building is proposed close to the portal. The Administrative building, visitors hostel and Guest house are centrally located. The residential quarters are located nearer to the Guest house. The Labour colony and Tunnel/ Cavern muck transit area will be located away from permanent buildings. The Magazine building will be located with sufficient clearance from residential area as per BIS provision.

Refer *Drg. No. INO/DPR/ 2* for the disposition of these project components.

5.2.3 Private land

Access road to Tunnel portal from the village road	0.1 ha
Link road from State Highways at Rasingapuram	0.4 ha



Drg. No. INO/DPR/ 2 Disposition of surface facilities

CHAPTER - 6

CONSTRUCTION MATERIAL SURVEY

6.1 Lead – main aspect

The lead distance plays an important role in the cost of construction material as all the materials have to be transported from Madurai (115 km) or Theni Town (35 km).

6.2 Cement and Steel

Cement and Steel are to be arranged by the contractors by tying up with the cement manufacturing companies and steel dealers in Madurai city or Theni Town. To avoid sub-standard re-rolled steel rods for the construction, the steel reinforcement rods from M/s Steel Authority of India Limited or such reputed manufacturing companies are to be insisted.

6.3 Blue granite metal

BG metal of size 12mm to 20mm and crusher sand will be generated from the excavated rock muck by installing a crushing unit at the site.

6.4 River sand

Transport of river sand for construction work involves a lead distance of 80 km from Vaigai River. Hence, river sand may be replaced by crusher sand/'M' sand in concrete mix to reduce its consumption by suitable mix design.

6.5 Bricks and concrete blocks

Chamber burnt bricks (Class I/II) or Concrete blocks (by beneficially utilizing the rubble generated from rock excavation) will be used for surface level structures (Office and Residential quarters).

6.6 Aluminium glazed windows/Particle Board shutters

For Environmental conservation, Aluminium glazed windows instead of wooden framed windows will be adopted. For doors, Particle Board shutters in Teak wood door frames will be provided. In the case of wash rooms, PVC doors are proposed. All these items can be procured from authorized dealers of BARC.

6.7 Explosives

The EPC contractor has to procure the explosives required for excavation of Tunnels and Caverns from Tamil Nadu Explosives Limited, Katpadi, Vellore district in Tamil Nadu. All the guidelines as per BIS and the formalities in stacking the explosives as per the Government rules in vogue have to be kept by the EPC Contractor.

6.8 Tunnel muck

About 2.3 lakh m^3 of Tunnel/Cavern muck generated will have to be utilized in a beneficial way. After meeting the project construction (viz) Tunnel/Cavern lining and building construction needs, the tunnel muck has to be disposed expeditiously, for which a mechanism may be evolved with the co-operation of District Revenue Authorities.

6.9 Diesel/Lubricant Oil

A private Diesel/Petrol bunk is available at Bodinaickanur (Bodi). However, a diesel pumping station may be considered to be installed at the project site by the EPC contractor to meet the demands of Diesel and Lubricants during the construction phase for the construction machineries (viz.) Dumpers, Tippers etc.

6.10 Other construction materials

Hand tools, portable tools and accessories like Drilling rods, Rubber hose, GI sheet, MS plates, GI & PVC pipes, Oxygen & Acetylene Gas, welding electrodes, tiles, lime and hardware materials can be procured from Madurai city/ Theni town.

CHAPTER - 7

PROJECT PRE-DEVELOPMENT AND ENABLING WORKS

7.1 Project pre-development works

The following works should be undertaken, to enable the launching of the project on ground and these works will be considered as project pre-development works.

(i) Land acquisition/Enter upon permit

The Govt. Promboke land to an extent of 26.82.5 ha in Survey No.4/1 of Pottipuram Village has to be alienated for this project purpose or at least "Enter upon permit" from Revenue Authorities has to be obtained to start the project works.

Also the land owners/custodians of the approach road have to be identified prior to taking up road formation/strengthening work.

(ii) Field office Cum Guest house

This building will house the Field offices and the Discussion Room in the Ground Floor and 4 suits & kitchen in the First Floor. The overhead tank of 10,000 liters capacity is proposed at the terrace of the building. The total built up area of the structure will be 15mx15m=225m^2+225m^2 = 450m^2 (4842 SFT). During the operation phase, this building will be converted as INO maintenance office for all the underground installations & surface facilities.

(iii) Widening and strengthening the existing approach road

The width of the approach road will be 7.5m so as to have hassle free two way traffic. The approach to site from SH 100 comprises of:

- *Length of by-pass road skirting Pottipuram village from the State Highway SH 100 at Rasingapuram – Formation* — *1 km*
- *Length of Other District Road (ODR) to Ondiveerapasamy Kovil for - Widening and strengthening* — *7 km*
- *Length of Link Road from T. Pudukottai village to the project site - Formation* — *2 km*

(iv) Construction of Box-culvert across stream

The construction of Box-culvert for a width of 7.5 m across the stream will enable the project work to start quickly. Box-culvert is proposed instead of road bridge, as the flow during rainy season is very limited. Box-culvert construction will be a cost cutting exercise. Moreover Box-culvert construction is justified, as there is one Box-culvert on the downstream of the site.

(v) Temporary water supply

A service provider is to be identified prior to starting of the project work for the daily supply of water 5 lorry loads of 8000 liters capacity each for 4 years (Underground Civil works- 3years + Engineering services- 1 year).

(vi) Temporary power supply

Temporary power supply arrangements from TNEB for construction purpose for 4 years are to be firmed up.

(vii) Fencing the area

26.82.5 ha Government promboke land on alienation has to be fenced, prior to construction of the pucca compound wall with random rubble masonry, that will be generated from the Tunnels/ Caverns excavation.

7.2 Project enabling works for surface facilities

Apart from the above project pre-development works, the following works will have to be undertaken as part of project works when the main project construction work is underway.

(i) Security Guard building

At the entrance of the project site for security guards.

(ii) Diesel bunk

To be erected by the contractor for fueling of construction machineries during the project construction phase.

(iii) Tunnel muck transit area

Tunnel muck transit area is to be formed by the contractor with masonry work upto 4m height to retain the muck and with GCI sheets thereon to prevent the dust flow to the nearby village T.Pudukkottai which is about 1.2km away.

(iv) Magazine

Magazine is to be constructed by the contractor as per IS provisions, at minimum 500m from the nearest habitations, to store Explosives, Detonators & Fuse coils in separate compartments/rooms. The storage may be for 10 days rock blasting/excavation work. The requirement of explosives for the project work has to be tied up with Tamil Nadu Explosives Ltd., Katpadi, Vellore District, Tamil Nadu by the EPC Contractor on award of work.

(v) 110 KV Sub-station

Dedicated 110 KV Sub-station is to be erected by TNEB under deposit contribution work for the uninterrupted and quality power supply. This sub-station will be located in one portion of the same Government promboke land S.No.4/1, Pottipuram village.

(vi) Steel plates stack yard

The area earmarked for stacking steel plates will be done with special type heavy duty flooring. Steel plates stack yard with walling & roofing of GCI sheets with required height to accommodate EOT crane is to be constructed to protect the steel plates from rain & sunshine.

(vii) Labour quarters

Temporary labour quarters with brick walls with roofing of appropriate non-asbestos roofing material will have to be constructed by the contractor. Once the contract is over, these quarters have to be dismantled and the land is to be handed over to the INO project proponents in clean condition.

(viii) Compound wall

As the INO project is proposed to be located near a village and as the area earmarked for INO is to be protected, a compound wall for a length of 2.71km covering the 26.82.5 ha area in Survey No.4/1 has been proposed. The compound wall will be built of RR Masonry to a height of 1.8 m and fencing for about 0.3m over it.

(ix) Weigh bridge

Erection of Weigh Bridge is optional to the project proponent, to weigh the detector materials and the excavated tunnel mucks that to be disposed off.

(x) Crushing unit for BG metal

The contractor has to erect his crushing unit for the manufacture of Blue granite metal and crusher sand for the reinforced cement concrete works in RCC lining. Suitable dust suckers have to be erected to suck the dust emanating from the crushing unit.

(xi) Internal road formation

During the project construction, the internal roads need to be formed with rain water drains to facilitate vehicles movement.

(xii) Benching, Landscaping and Green-mapping of the project site

As the detailed topographic survey of the land in S.No 4/1 shows sudden dips and rise, all surface facilities of INO project will have to be accommodated in between contours 430m and 470m. Hence in order to avoid heavy account of cutting & filling, suitable landscaping is proposed. Landscaping will also give aesthetic appearance to the project site.

As Pottipuram is a wind prone area, growing suitable plants and trees has to be taken up in consultation with Forest Department/ Horticulture Department to reduce the impact of sand laden wind during the initial stage of Project itself, and also to give good green cover when the project is completed.

PART II Site Survey and Geo-Technical Investigation

CHAPTER - 8

DETAILED SITE SURVEY & INVESTIGATION

8.1 Detailed site survey

To finalise the location of various project components, topographic survey and precision contour survey of the area identified for the project have been carried out.

The salient features of the detailed site survey are:

(i) Establishing permanent benchmark for the project

(ii) Fixing global positioning station

(iii) Providing permanent triangulation points

(iv) Precision contour survey

(v) Topographic survey

(vi) Longitudinal section survey

Figure 8.1 to *Figure 8.5* shows the locations of survey conducted at Portal location, Access tunnel top surface EL 1500m, EL1530m, top surface of INO Cavern EL 1560m and Peak EL 1589m away from INO Cavern top surface.

8.1.1 Establishing Permanent benchmark for the project

Nearest benchmark is available at Bodinaickanur railway station (EL +347 m). Distance from this station to INO site is 19.6 km.

The permanent bench mark (i.e.) +427.317m has been established at INO project site (near Tunnel portal) based on the bench mark at Bodinaickanur.

8.1.2 Fixing Global Positioning Station

Global positioning station has been established near Tunnel portal in INO Project. The co-ordinates are:

N: 1101644.010

E: 92137.201

Z: 427.317

8.1.3 Providing Permanent Triangulation points

Permanent Triangulation points are provided at four locations as reference points by erecting masonry pillars as per BIS, for carrying out further survey works. These locations should not be disturbed in any way during the project executions as these points will be referral point till the project completion.

8.1.4 Precision contour survey

Detailed precision site survey is carried out using Total Station equipment along the Access tunnel alignment from Chainage 0.00 of tunnel portal up to the INO Cavern-1 for a total length of 1966m with 100m width on either side of the proposed alignment of the Access tunnel and covering all the caverns & network of tunnels with 100 m coverage all-round the area.

Refer *Drg. No. INO/DPR/ 3.*

8.1.5 Topographic survey

The detailed topographic survey for the surface components for an extent of 23 ha in Survey No. 4/1 of the Pottipuram village and approach road (2 ha) from T.Pudukottai village to INO site have also been carried out.

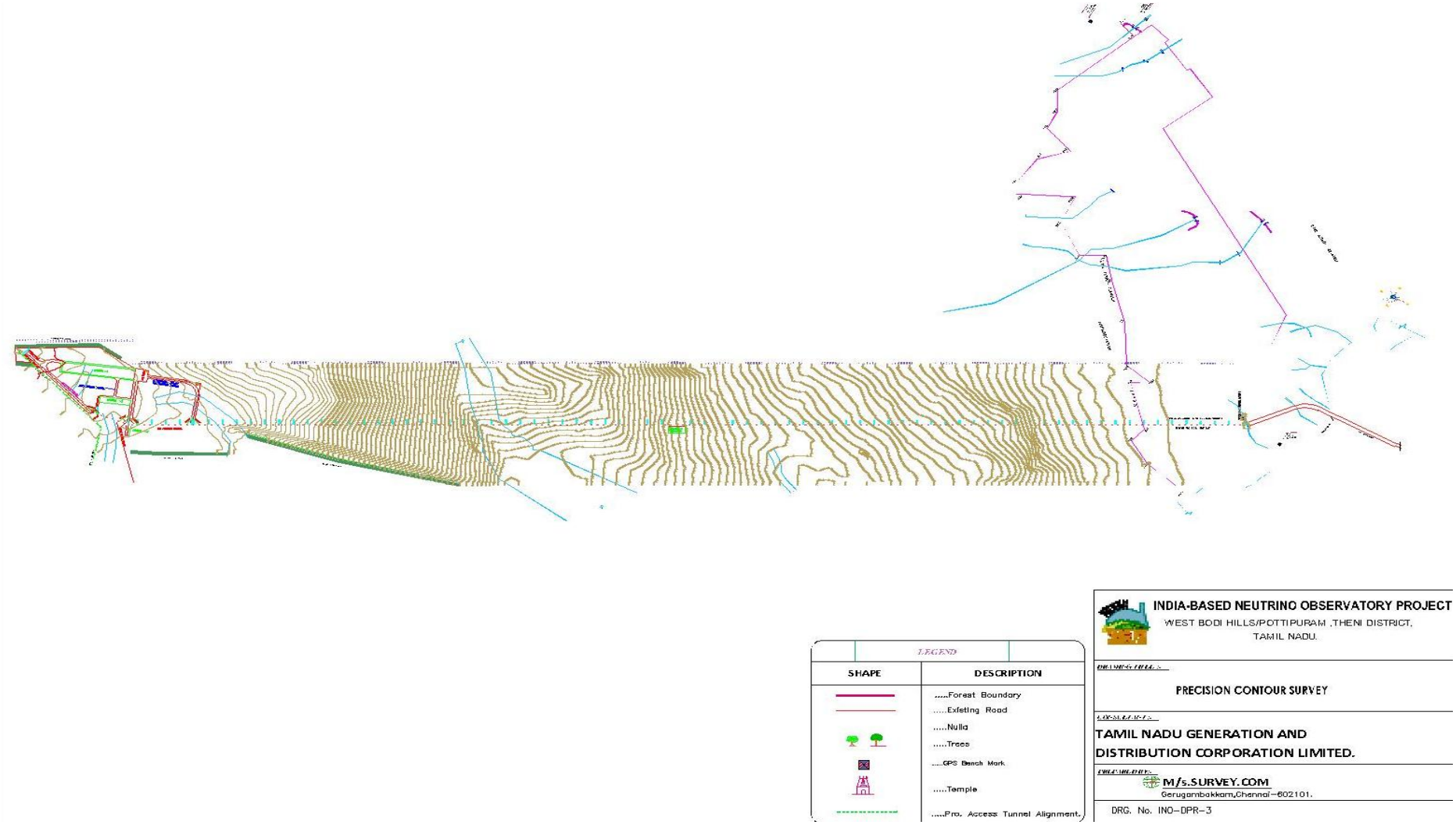
The levels are taken at 5m intervals, incorporating all existing features and structures. Topo drawings with contours at 5m intervals in a scale 1:1000 have been prepared.

Refer *Drg. No. INO/DPR/ 5*

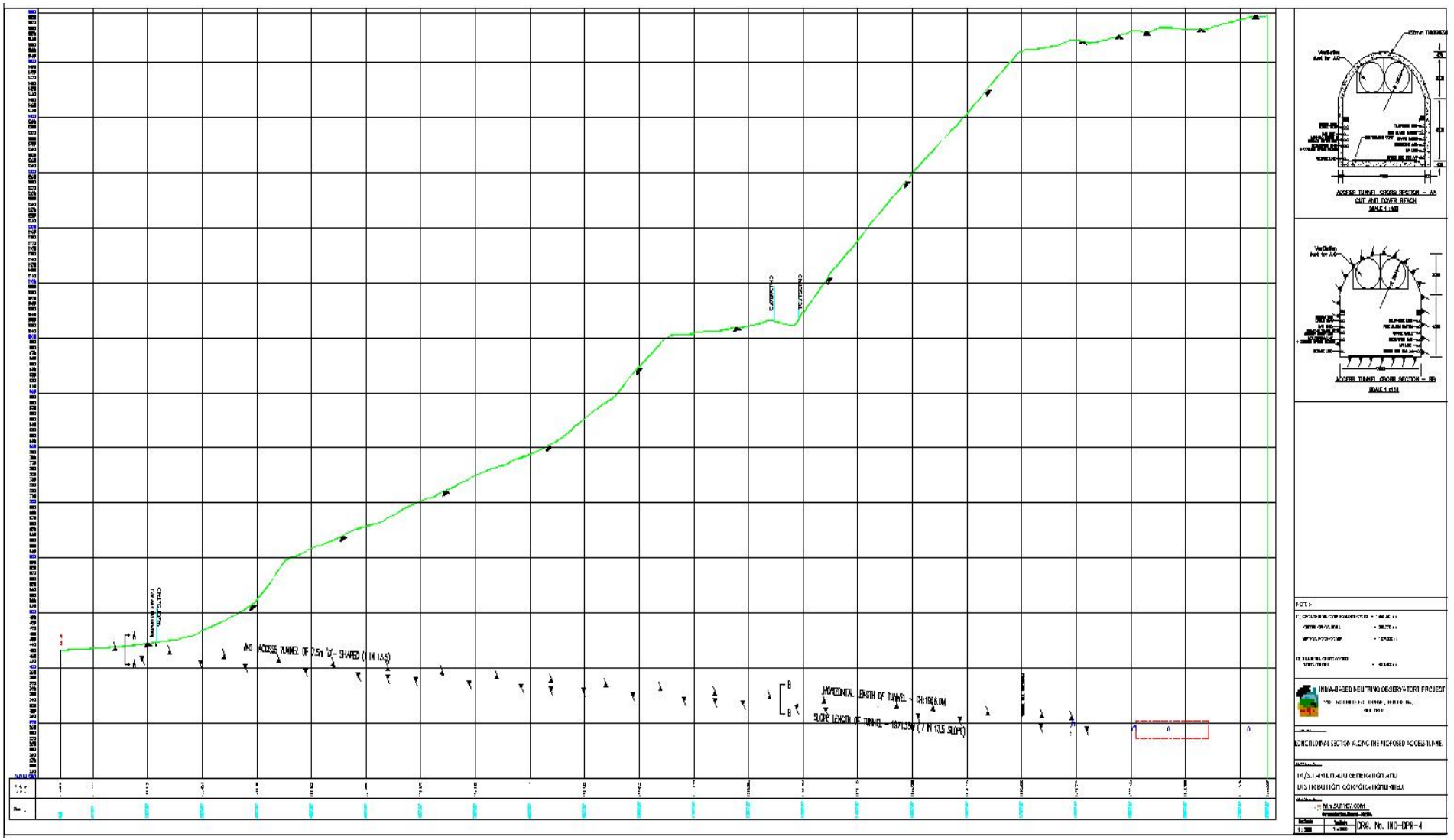
8.1.6 Longitudinal Section Survey

The Cavern – 1 lies between contour levels of 1579 m & 1560 m. The middle level of ICAL detector is 280.77 m. Hence a vertical rock cover of 1279.23 m is available. Also rock cover of more than 1000m is available in all directions.

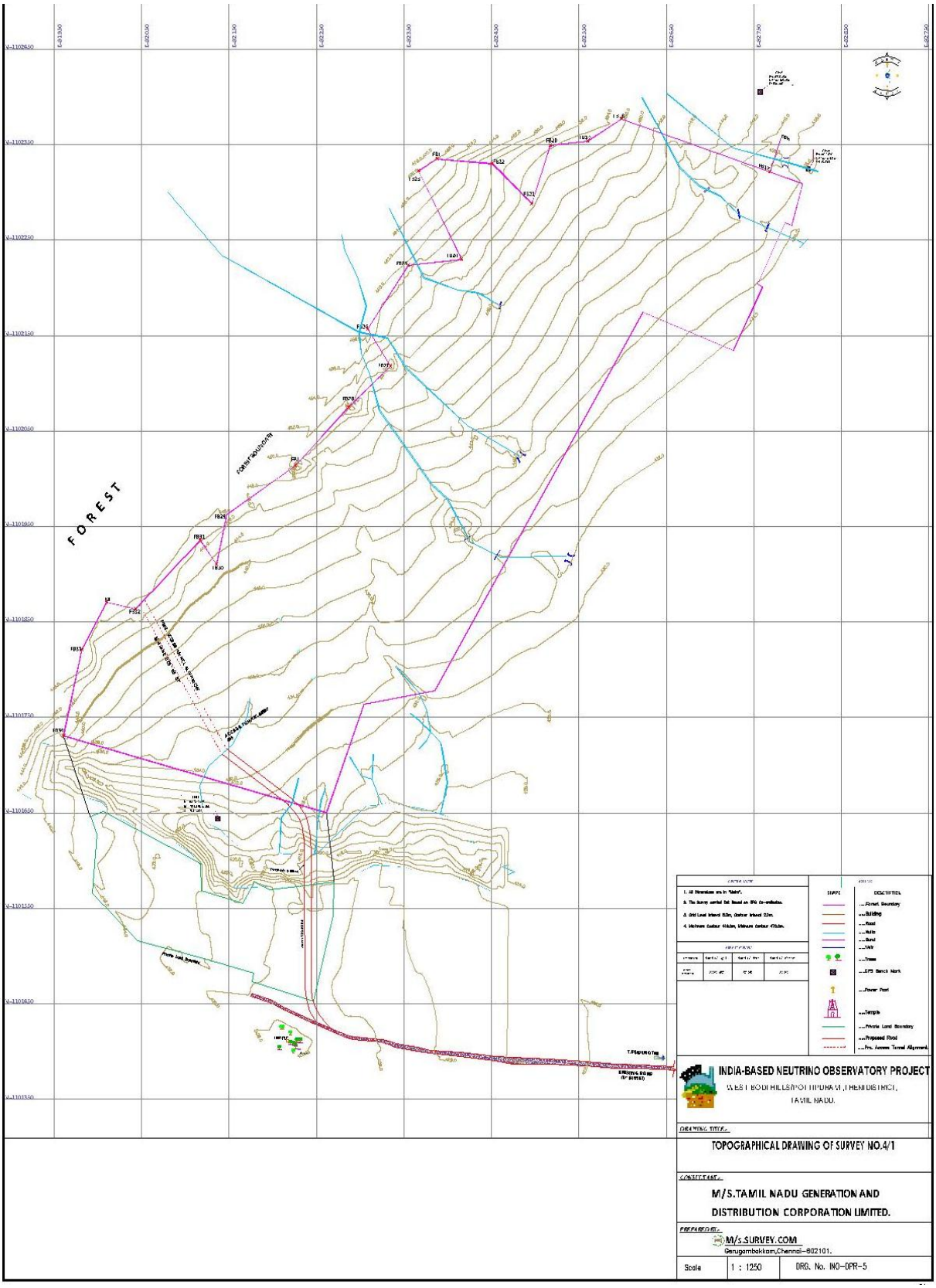
Refer *Drg. No. INO/DPR/ 4.*



Drg. No. INO/DPR/ 3 Precision contour survey



Drg. No. INO/DPR/ 4 Longitudinal section along Access tunnel



Drg. No. INO/DPR/ 5 Topographic drawing of survey No. 4/1

Figure 8.1 Portal location

Figure 8.2 Access tunnel top surface at EL 1500m

Figure 8.3 Survey instrument level EL 1530m

Figure 8.4 Top surface of INO Cavern EL 1560m

Figure 8.5 Raising peak EL 1589m – Away from INO Cavern – 1 top surface

CHAPTER – 9

GEO-TECHNICAL INVESTIGATION

9.1 Access tunnel in Bodi west hills-Geo-technical investigation

To know the exact rock depth and to fix the portal of Access tunnel with cut and cover reach, it was recommended by GSI to drill bore holes at 7m, 57m, 132 m, & 172 m from the reserved forest boundary , upto 7m depth into the fresh rock with more than 5m of core recovery. Accordingly four bore holes marked in the Access tunnel route by Engineering Geology Division of GSI/ Chennai and two more bore holes apart from four bore holes were drilled. As good rock was not available as per the expectation, one more borehole within the reserved forest territory at 45m from the forest boundary was drilled to ascertain the rock level.

Hence 7 bore holes were drilled from Chainage 0 to 222 (Forest boundary at chainage 177) to ascertain the level of hard rock with out a core loss of 5 m.

Refer *Figure 9.1* for drilling of Borehole No .4.

Refer *Figure 9.2* for Borehole Chart.

Refer *Figure 9.3* for Rock Profile.

9.2 Bore holes

The Senior Geologist has furnished the detailed report on the borehole results *(Appendix - 1)* the extract of which is furnished below in *Table 9.1*.

Table 9.1 Abstract log of Bore holes cores

BH No.	Location chainage (m)	Total depth drilled (m)	Ground elevation (m)	Weathered (moderately weathe-red) rock level (m)	Fresh rock level (m)	Lithology and other details
1	Ch 0	33.79	432.40	416.80	413.62	0 to 5.80m Soil. 5.80m to 15.60m completely weathered rock with small rock fragments. 15.60m to 18.78m – moderately weathered mafic rich hornblende biotite gneiss. From 18.78m onwards fresh charnockite with high core recovery and RQD is massive and joints are less.

2	Ch 41.5	35.05	435.40	-	-	The bore hole was drilled all through its depth in soil and completely weathered rock only. Fresh rock was not met. (No core or soil sample was preserved beyond 9m depth)
2A	Ch 44.5	28.00	435.55	412.05	408.15	0 to 23.50m soil and completely weathered rock (sample preserved only up to 9.00m depth). 23.50 to 23.70m pink pegmatite moderately weathered. 23.70 to 27.40m gneissic rock moderately weathered with core loss in between. From 27.40m onwards fresh rock with long core indicating high core recovery and RQD
2B	Ch 82	25.36	437.90	423.90	416.37	0 to 14 soil and completely weathered rock (sample preserved only up to 3m), 14.00 to 17.86m – Hornblende biotite gneiss, moderately weathered 17.86m to 19.41m – pink granite moderately weathered. 19.41m-21.53m core loss. 21.53m onwards fresh charnockite with high core recovery and RQD.
3	Ch 122	29.25	441.20	423.42	419.27	0 to 17.27m – Soil and completely weathered rock (sample preserved up to 9.30m) 17.27 to 17.78m boulder. 17.78 to 19.53m – charnockite slightly weathered, 19.53 to 20.43m – core loss 20.43 to 21.13m charnockite moderately weathered 21.13 to 21.93m pegmatite moderately weathered. From 21.93m fresh and massive charnockite with high core recovery and RQD.
4	Ch 170	25.00	446.07	427.07	424.92	0 to 19 – Soil and completely weathered rock (sample preserved up to 17m) 19m to 20.21m-charnockite moderate to highly weathered. 20.21m to 20.90m – charnockite slightly weathered. 20.90m to 21.15m – charnockite moderate to highly

						weathered. From 21.15m onwards charnockite fresh rock with high core recovery and RQD.
4A	Ch 215	11.58	452.79	452.39	452.33	0 to 0.10m soil, 0.10 to 0.40m completely weathered rock. 0.40 to 0.46m moderately weathered. Charnockite 0.46 to 7.74m. Fresh and massive charnockite 7.74 to 11.56m. Fresh and massive grantic rock with high core recovery and RQD.

9.2 Rock profile

From the rock profile, hard rock of more than the twice the dia of Access tunnel (ie) 15 m hard rock cover over the crown of the tunnel is available from Ch 197m onwards. Hence the rock tunnel starts from chainage 197 m onwards. Prior to that reach (viz.) Ch 0 to 157m the section will be of cut and cover reach and weathered rock tunnel.

Figure 9.1 Bore hole No.4 inside reserved forest

(White marking indicates the reserved forest boundary)

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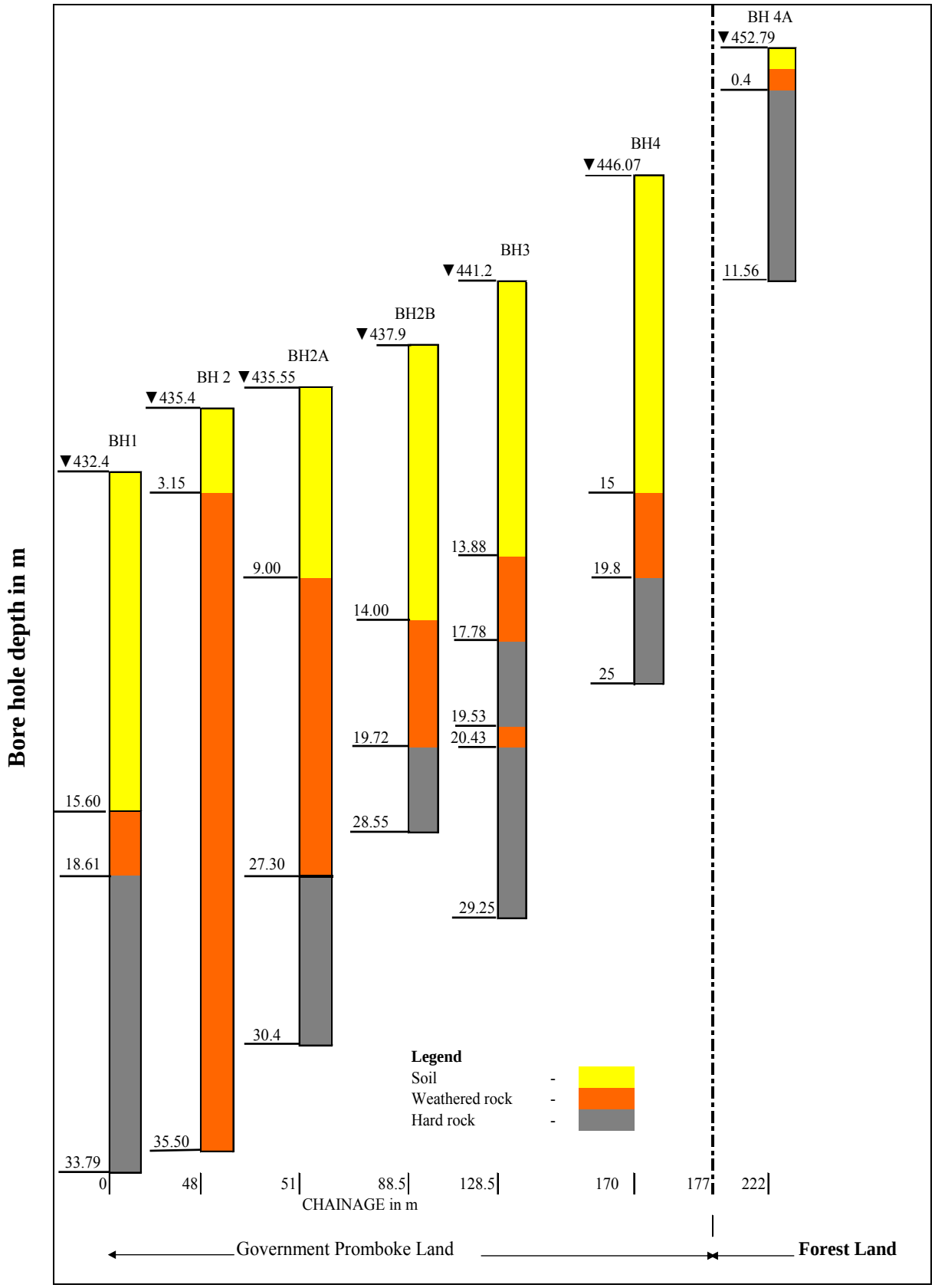


Figure 9.2 Bore hole chart

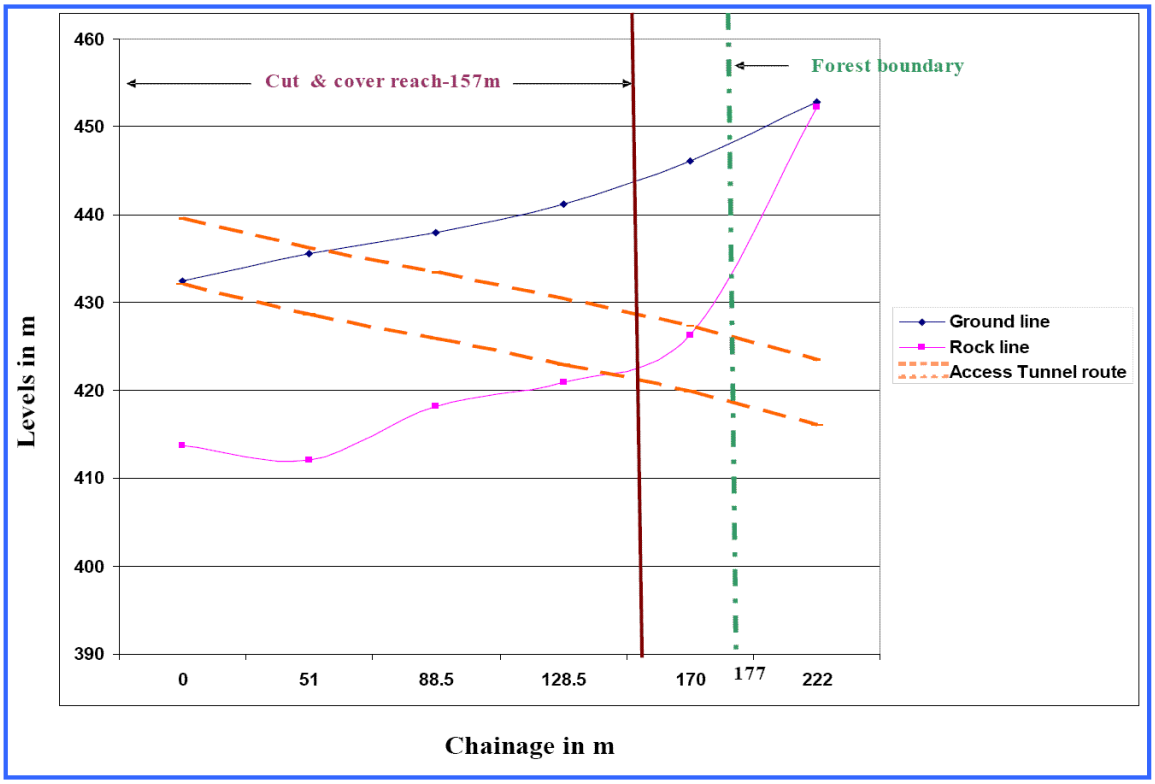


Figure 9.3 Rock profile

PART III Technical – Civil Works

CHAPTER - 10

UNDERGROUND CONSTRUCTION METHODOLOGY

10.1 Tunnels

10.1.1 Alignment

The following aspects are taken into account in the finalization of alignment:

- Access tunnel length should be the shortest possible
- It should be straight as far as possible
- It should be easily accessible

10.1.2 Size & Shape

The following shapes are generally used for tunnels:

- Circular section
- D-shaped section
- Horse-shoe section
- Modified horse-shoe section.

D-shaped section is found to be suitable in tunnels located in good quality, intact sedimentary rocks and massive external igneous, hard, compacted, metamorphic rocks where the external pressures due to rock and water are not very large and where the lining is not designed to carry any external or internal pressures.

For a D-shaped section given in *Figure 10.1*, the dimensions are as below:

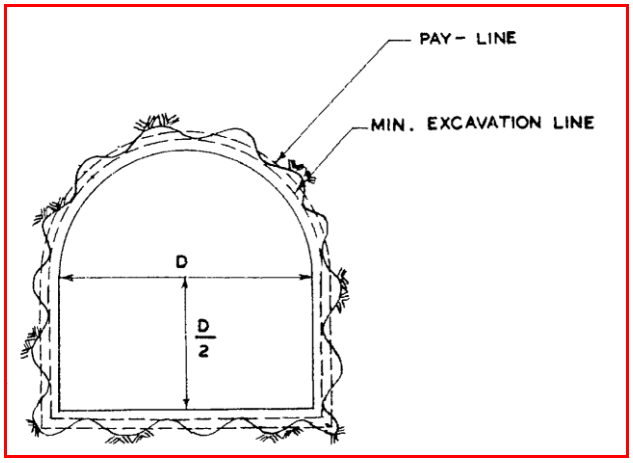
A (Area) $= 0.905D^2$

P(Perimeter) =3.58 D

r (Radius) =A/P =0.2528 D

After the final alignment of the tunnel has been decided by carrying out detailed planning and investigation, appropriate size and geometric section of the Access tunnel indicated in *Figure 10.1* (7.5m - D shaped) has been chosen based on

- Geological conditions prevailing along the alignment.
- Structural considerations.
- Functional requirements.



A =0.905D2

P =3.58D

Figure 10.1 'D' Shaped section

10.2 Sequence of operations for construction of tunnel

The actual tunneling starts after fixing the alignment of Access tunnel and formation of portal at the entry of tunnel. The following are the general sequence of operations involved for construction of tunnel adopting conventional drilling and blasting method.

- Marking and drilling of holes with suitable drilling pattern.
- Loading of drilled holes with explosives.
- Blasting of holes.
- Defuming and ventilation of tunnel.
- Checking misfires, if any.
- Scaling of loose material
- Removal of excavated muck.
- Erection of suitable appropriate rock supports applicable for the rock.
- Drilling of drainage holes wherever necessary.
- Laying of invert concrete and lining (if necessary)

10.3 Precautions during tunneling

Drilling and blasting operations and excavations shall be carried out to meet the following requirements:

- Minimum loosening at the excavation surface and tunnel walls.

- The least possible vibration to be imparted to all tunnel supports or lining (especially the concrete lining) and neighbouring tunnels,
- The least possible amount of over break.
- Minimize rock falls in fault zones.

10.4 Tunnel blasting design

Drilling pattern depends on the size and shape of tunnel and the quality of the rock to be excavated. Rock that is fractured may require lesser number of holes than massive rock. Every blast must be designed considering the existing conditions of the rock formation & overburden and to produce the desired final result. Initial excavation shall start with trial blast and the blast design is to be optimized to yield maximum pull with minimum charge.

10.4.1 Explosives and Detonators

Explosives producing minimum toxic fumes in order to facilitate quick and effective ventilation are preferred and used.

10.4.2 Drilling pattern

Type of holes	:	1st square, 2nd square etc, wall holes, roof holes, stopping holes.
Charge per hole	:	Ranges from 0.5kg to 3kg.
No of holes per face	:	As decided, ranges upto 100.

10.4.3 Cycle time

A typical excavation cycle for 3m advance

Profile marking	: 0.5 hr
Drilling by boomer	: 2.0 hrs
Charging of explosive & blasting	: 2.0 hrs
Defuming & light connection	: 0.5 hr
Mucking	: 3.0 hrs
Total	: 8.0 hrs

Cycle time review

Continuous recording of cycle time on time scale of all operations and its regular review provides information required for corrective measures to keep the project on time.

Smooth blasting

All underground blasting shall utilize "Smooth – blasting" techniques by using appropriate number of micro-milli and half-seconds delay detonators, using suitable types of explosives, or change the blasting pattern by line drilling or pre-splitting.

10.5 Construction equipments

The following are the important construction equipments proposed to be deployed.

- Drill jumbos
- Air compressors
- Mobile cranes
- Tippers
- Pump trucks
- Jack hammers
- Road rollers
- Gas welding units
- Dewatering pumps with motors
- Excavators/Loaders/backhoes
- Pneumatic rock drills
- Shotcreting machine
- Grout pumps
- Dozers
- Batch plant
- Ventilation fans
- Hand winches
- Rock bolters

Electrical, Pneumatic or diesel driven equipment may be utilized for the different operations involved in the underground excavation. In case, diesel driven equipment is used, all the noxious gases resulting from the operation of the equipment should be removed. Electric power driven construction equipments are preferred over diesel driven equipments.

10.5.1 Selection of right type of equipment

Depending upon the length of tunnel to be bored from each face, selection of right tunneling equipment is required. Tunneling equipment comprises drilling equipment, mucking equipment, ventilation system, equipment for rock support, etc. Depending upon the scheduled time available for tunneling one boom, two boom or three boom drill jumbo may be used. Further pneumatic charging machine may also be used for reducing charging time. Ventilation system affects the cycle time to a large extent. Clean tunnel provides efficiency to men and machinery working in the tunnel, thus resulting in more out put. Well-designed ventilation system helps in obtaining the scheduled cycle time. Generally, drill jumbo/rock bolters is used for installation of rock anchors/rock bolts. Use of rock bolters will result in reduction of cycle time particularly in adverse geological conditions. Selection of right equipments also means effective spares management and repair so as to aim for zero downtime.

10.6 Problems generally faced during tunneling

- Undercuts
- Misfires
- Squeezing ground
- Cavity and chimney formation
- Occurrence of shear zone.
- Roof collapse
- Heavy seepage of water

10.7 Method of tunnelling

10.7.1 Portal Location

A tunnel portal is the face from where the Access tunnel starts.

10.7.2 Tunnel Excavation

For the present case top heading and benching method is more suitable and the same is recommended. In this method, top heading is excavated first followed by removal of benching.

The method of excavation of any tunnel depends upon the following factors:

a) Length and shape, size and slope of the tunnel.

b) Quality of rock along the alignment
c) Access and number of Additionally driven Intermediate tunnels (ADIT).
d) Type of requirements and amount of labourer.

Keeping in view of above factors, the Access tunnel is proposed to be excavated by conventional drilling and blasting method (DBM) which may be economical when compared to Tunnel Boring Machine (TBM). This method is used for all types of rock and in all sizes of tunnels and caverns. This method is suitable for Indian conditions.

10.8 Cavern excavation

After completion of excavation of Access tunnel, in-situ stress measurement is proposed to be carried out to measure the magnitude and direction of the principle stresses apart from other rock mechanic studies.

Based on the direction of the principle stresses, the orientation of major axis of the caverns will be fixed.

Excavation of the Cavern-1 is to be carried out from top by conventional drilling and blasting method. The ADIT to reach the top heading is aligned through one end of the cavern from the Access tunnel at suitable gradient. The excavation of cavern involves huge volume of rock blasting, mucking and disposal. A top central drift is to be excavated through this ADIT for the entire length of the cavern. This is followed by side slashing to the full width for the entire length of the cavern. Cavern below the top heading is to be excavated by benching operations. Benching down is to be done in stages with appropriate bench height (not more than 3m) at a time. Suitable ramps and glory holes may be provided to facilitate mucking and disposal using dump trucks. Suitable drilling pattern with controlled blasting may be adopted for obtaining smooth vertical wall profile.

Suitable size of drainage holes at suitable spacing may be drilled in the crown/side walls if necessary to drain the seepage water.

The instrumentation works shall go simultaneously with excavation for monitoring the stability of the cavern.

Rock support measures are to be taken at the right time and finished before commencing the excavation of the next stage.

10.9 Construction stage investigation

Systematic construction stage geo-technical investigation is to be carried out by an Engineering Geologist to record 3D geological features of the tunnel and related problems along the entire alignment of the tunnel and cavern including rock mass classification. To ensure, validate and optimize the rock support system, such exploration/investigation shall be done according to day- to- day requirement of the projects. This may also serve as a tool for the solution to the post construction problems.

10.10 Instrumentation in tunnels and underground caverns in rock

During the construction of tunnels and underground openings, the rock mass is disturbed and it undergoes redistribution of stress accompanied by a change of shape. These adjustments are reflected in deformation, displacement, pressure, loads, stress, stains etc. Construction of a tunnel may also change the pattern of ground water movement and therefore pre measurement becomes an important parameter. The accurate pre-estimation of these parameters for actual design is another difficult task and hence designs cannot be precise and the element of empiricism is inevitable. In general, the preliminary designs of tunnels and underground openings are based on rock load estimation by Terzaghi's, Barton's or Bieniawski's rock mass classification system.

The effect of a number of factors which influence the behavior and stability of rock, such as three dimensional influence of discontinuities, method of excavation, type and stiffness of supporting system, rate at which rock yields etc., are seldom accounted by these systems. Similarly in tunneling, undetected or uncontrolled rock adjustments can cause special problem. As even the minor defects can result in major problems and hazards, increased cost and construction delays. Hence, it is, necessary to evaluate tunneling condition, as they are encountered and optimize tunneling procedure accordingly. Timely identification and evaluation of actual rock mass conditions by proper in situ-instrumentation can help to improve both safety and economise the tunneling cost during construction.

Parameters that are required to be monitored are stress, strain, water pressure, displacement, load, etc.

The instrumentation system recommended for this project include the following instruments:

- Load cells
- Measuring tape
- Tape convergence points
- Single and multi point bore hole extensometers
- Pore pressure meters (piezometers)
- Readout units (remote reading)
- Total pressure cells, stress meter
- 3D crack monitor

10.11 Rock mechanics study

10.11.1 Estimation of Rock load

Whenever underground cavities are excavated in rocks, the weight of the overlying rock layers will act as a uniformly distributed load on the deeper strata and consequently on the roof of the cavity excavated. The load acting thus is referred to as 'rock load' or 'rock pressure'. *(Refer Table* 10.1*)*

Table 10.1 Rock load on tunnels as per Terzaghi

Sl. No	Rock condition	Rock load	Remarks
1.	Hard and Intact	0 to 0.25 B	Requires no supports
2.	Massive, Moderately jointed	0 to 0.5 B	Requires rock bolts or light supports
3.	Hard stratified	0 to 0.5 B	Required rock bolts or light supports
4.	Moderately blocky and Seamy	0.15B to 0.35 (B+H1)	Requires light to heavy ribs
5.	Very blocky and Seamy	0.35 to 1.10 (B+ H1)	Required heavy supports
6.	Completely crushed but chemically intact	1.10 (B+ H1)	Heavy ribs-conversion to circular section recommended

7.	Squeezing rock at moderate depth	1.10 to 2.10 (B+ H1)	Heavy ribs-conversion to circular section recommended
8.	Squeezing rock at great depth	2.10 to 4.50 (B+ H1)	Heavy ribs conversion to circular section recommended
9.	Swelling rock	75m of rock load irrespective of the value of (B+ H1)	In extreme cases use yielding support.

B - Width of the opening H_1 – Height of opening

The determination of the magnitude of this rock load or rock pressure is one of the most intricate problems in rock mechanics. This complexity is due not only to the inherent difficulty of predicting the primary stress conditions prevailing in the interior of the non-uniform rock mass, but also to the fact that, in addition to the strength properties of the rock, the magnitude of secondary pressures developing around the cavity after excavation is governed by a variety of factors such as size of cavity, method of excavation, rigidity of support and length of period during, which the cavity is left unsupported. *(Refer Table 10.2)*

Table 10.2 Rock pressure – Types and Reasons

Sl. No.	Type of Rock pressure	Reasons for the development
1.	Loosening pressure	Loosening of the rock mass on account of blasting, scaling, mucking etc.
2.	Genuine mountain pressure	Weight of the overlying rock mass, ground water etc. and tectonic forces.
3.	Swelling pressure	Volume expansion of the rock mass, swelling due to physical and/or chemical action.

10.11.2 Rock mass classification

Immediately after excavation, the rock media may be evaluated based on Q-system advocated by Barton and Grimstad (1993). According to Q-system, the rock mass quality is expressed by

$$Q = \frac{RQD}{J_n} \times \frac{J_r}{J_a} \times \frac{J_w}{SRF}$$

Where,

RQD : Rock quality designation

J_r : Joint roughness number

J_w : Joint water reduction factor

J_n : Joint set number

J_a : Joint alteration number

SRF : Stress reduction factor

Based on Q values, the entire rock mass may be classified into four categories Good rock, Fair rock, Poor rock and Very poor rock. Rock support applicable for each classification may be provided as in *Table 10.3.*

Table 10.3 Rock mass quality advocated by Barton and Grimstad

Type of rock support	Rock mass classification			
	Good	**Fair**	**Poor**	**Very poor**
Rock bolt (25mm dia. Grouted, expansion shell type)	Individual rock bolt of 3.5m long as required	3.5m long rock bolt @1.75m centre to centre.	3.5m long rock bolt as required	---
Steel support	--	--	ISMB 300@ 1m centre to centre with concrete lagging blocks in between steel ribs	ISMB 300@ 0.5m centre to centre with concrete lagging blocks in between steel ribs.
Shotcrete with chain link	50mm thick as required	50mm thick as required	50mm thick	50mm thick

10.12 Rock supporting system

The rock support system for the cavern/tunnel mainly comprises the following:

a) Spot or systematic rock bolting

b) Shotcreting with fibre reinforced shotcrete

c) Rock support by cable anchors if necessary.

d) Permanent steel supports.

Rock support system, by way of steel ribs may be classified into the following:

a) Continuous rib
b) Rib and post
c) Rib and wall plate
d) Rib, wall plate and post
e) Full circle rib
f) Invert strut

10.12.1 Rock Bolting, Shotcreting & Grouting

Any rock opening can be self supporting permanently, if the rock around it is suitably reinforced, so that the reinforced rock becomes a competent structural entity and this is called as rock bolting.

Shotcreting, which is defined as pneumatically applied mortar or concrete to protect and support zones of fractured, crushed, disintegrated or spalling rocks and to preserve and prevent further time dependent deterioration caused by the action of water or atmosphere or the effects of time. Wire mesh and shotcrete applied to the surface of the rock in conjunction with rock bolts form part of the rock reinforcement system and have a very real structural significance.

In order to fill up the interstices between concrete and excavated rock surface and to fill up the joints and discontinuities in the rock up to the desired depth, grouting is recommended. There are two types of grouting (viz.) Backfill grouting (contact grouting) and Pressure grouting (consolidation grouting). The purpose of grouting is to fill up the interstices/voids between excavated surface and the linear portion/support.

The process of grouting involves

a) Drilling holes
b) Cleaning & washing of holes
c) Testing holes
d) Grouting holes
e) Testing the grouted zone for efficiency of grouting.

10.13 Requirement of facilities during cavern construction

10.13.1 Lighting underground

During construction, lighting should be provided in the underground structures. Within 150m of the working face, all lighting systems and electrical equipment shall be in compliance with internationally recognized standards for underground excavation.

10.13.2 Ventilation system

The ventilating system shall be of sufficient capacity to maintain an adequate supply of uncontaminated air in underground structures throughout the construction period.

The ventilation system may be of the forced extraction type, or local air movers, or any combination thereof.

The design of ventilation system shall take into account all categories of construction equipment to be used underground. For each person working underground, a minimum amount of $3m^3$/ min of fresh air shall be provided.

If diesel-powered equipment is used, then the minimum quantity of fresh air to be supplied shall be $3m^3$/ min for each KW of DG set kept underground, in addition to the requirements for personnel.

In case of failure of ventilators, an emergency system shall come into operation to allow safe evacuation of personnel and equipment.

10.13.3 Traffic lights

Where tunnel cross-sections are too small to warrant two-lane traffic, an adequate traffic light system shall be provided, maintained and operated. The same applies to tunnel junctions or crossings.

10.13.4 Lighting and power

Besides the general lighting system, special lighting shall be provided for the excavation front, wherein any work is being executed, or inspection is carried out. This lighting system shall consist of floodlights or any other approved type.

All power and lighting wires shall be installed and maintained in optimal conditions of insulation and safety.

Power and lighting cables shall be installed on one side of the tunnel and the detonator wires shall be installed on the opposite side at a sufficient distance away from telephone or communication system wires.

The temporary lighting shall remain until completion of tunnel construction.

For any installation of lighting, power and signaling, following have to be observed

- Tunnel lighting supply shall be independent of the power supply for any plant or small tools.
- All lamp holders shall be of approved non-conductive material.
- All wiring shall be properly insulated with vulcanized rubber or other approved material.
- All wiring shall be securely fixed, clear of any moving plant, man access, source of heat or other likely damage.
- All circuits shall be sub-divided and protected by fuses of appropriate current rating.
- Lighting in running tunnels shall generally consist of not less than one 60 Watt lamp at 6m interval centres or equivalent with proportionate increase in enlargements.
- Power supplies to the plants & equipment, tunneling machines and the like shall be protected adequately against unauthorized or accidental damage. All cables shall be fool-proof to continuous immersion in water, contact with hydraulic fluid vibration from moving machinery, heat, abrasion and mechanical damage.

10.14 Safety measures

Use of Combustion engines

Underground use of internal combustion engines burning gasoline or liquefied petroleum gases (Propane, butane, propylene) is forbidden.

Lightning indication system

An approved lightning indication system has to be installed in the vicinity of the tunnel portals. In case of lightning alarm, charging and blasting activities shall be interrupted for the duration of a thunderstorm.

Communication

Minimum communication system has to be maintained throughout all underground works. A robust two-way telephone system shall be installed between each working face, each fire point and other important facilities, as deemed necessary.

Firefighting

- Firefighting equipment shall be in compliance with internationally recognized standards.
- Vulnerable areas such as material stores, shall be provided with individual fire points.
- An alarm procedure shall be developed for any type of emergency that they may be called upon to tackle.
- Burning and welding underground shall be kept to a minimum and propane shall be used in preference to acetylene. Gas cylinders shall not be stored below ground and shall be removed after use. Sand buckets and extinguishers shall be immediately available when gas cutting/ welding is carried out.
- Storage of combustible materials below ground shall be kept to that required for immediate use only. Waste shall be removed at the end of each shift.
- A site fire squad shall be designated and trained to use apparatus, monitors its readiness and check & report on unsafe practices.
- Vehicle shall be maintained at all times to access site during emergency.

CHAPTER - 11

TUNNELS AND CAVERNS

11.1 Tunnel portal, Cut & Cover reach and Weathered rock tunnel reach

The entry portal of Access tunnel should be constructed in Reinforced Cement Concrete (RCC) to protect the tunnel entry face from falling of loose overburden and to avoid any possible block of entry portion.

From the Rock profile of the Access tunnel portion, the hard rock with 2D cover is available at Ch 197only. Hence, the pucca hard rock tunnel will be formed from Ch 197 only. For the portion between Ch 0 and 157, the stretch will be cut & cover reach (viz) the stretch has to be opened up to form the tunnel in RCC and the excavated material will be filled over the tunnel formed. During this construction phase, slope stability open cut has to be ensured.

As the reserved forest boundary starts from Ch 177 and also considering the fact that no surface forest land should be used for this project, the stretch between Ch 157 and Ch 197 will be formed as in the case of Earthen tunnel, as the rock strata over the tunnel is less than 2D and also of weathered rock variety. In this stretch of 40 m, the progress will be comparatively slow as 45cm thick RCC 'D' shaped tunnel has to be formed gradually after controlled blasting.

11.2 Access tunnel (Refer *Drg. No. INO/DPR/ 6* and *Drg. No. INO/DPR/ 7*)

11.2.1 Design aspects

Shape - 'D' shaped tunnel is proposed, as it is preferable in all types of rock.

Size - Governed by the maximum size of package to be transported inside and also for two way traffic.

Slope - A slope of 1 in 12 is acceptable for the fully loaded vehicles to travel in the upward slope. However, for this project, a comfortable downward slope of 1 in 13.5 has been proposed.

The majority of consignment is steel plates of size of 4mx2mx0.056m, each 3.5 tonne. Access tunnel is the only way for the movement of construction vehicles and the disposal of 2.3 lakh m^3 excavated muck from tunnels and caverns.

Hence it has been proposed to have a 7.5 m dia 'D' shaped tunnel which will ensure smooth two way traffic. The length of Access tunnel is 1966m.

Conventional drilling & blasting method is adopted in the tunnels and caverns excavation.

Tunnel Boring Machine (TBM) is not considered as

(i) It is 3 to 5 times costlier than the conventional drilling & blasting method

(ii) Tunnel length is only 2 km, whereas TBM is generally employed where tunnel length is 10 km more.

(iii) In this case cavern excavation is also involved which cannot be done by a TBM.

(iv) The shape that can be formed by a TBM will be circular, which has to be modified to 'D' shape, which involves additional work and cost.

11.2.2 Vehicle Pockets

Vehicle Pockets of 10 m x 5 m at 250m interval along one side of the Access tunnel is proposed for construction vehicles to take reverse and turn around. The vehicle pocket at 1000m from the Tunnel portal will be enlarged to the size 29 m x 15 m x 3.5 m as Cavern – 4 so as to accommodate one additional Intermediate Lab for NDBD II

11.2.3 Routing of Service lines and ventilation duct

50 cm width trays at different heights are provided on both sides of Access tunnel to carry the required service lines to the caverns. *(Refer Drg. No. INO/DPR/ 7)*

- Power and control cable
- Detector gas line
- Drinking and common water supply line
- Dewatering line
- Cooling water line
- Sewage line
- Communication cable
- Cable for fire protection
- Air line

11.2.4 Drains to collect the seepage water

Drains will be provided on both sides. As the slope is downward, the seepage water collected will be pumped out through Booster pumps.

11.2.5 Surface Treatment

Rock bolting & shotcreting will be provided for the arch portion and the sides of the tunnels. Reinforced Concrete lining will be provided instead of shotcreting where good rock is not available.

11.2.6 Sill level

The sill level of Access tunnel at the entry is +432.4 m and at the Loading bay it is +286.77m. This loading level is referred as basic floor or Floor – 0 based on which all other floors will be referred as +1, -1, -2, -3. *(Refer Drg. No. INO/DPR/ 9)*

11.3 Auxiliary tunnel

The Auxiliary tunnel of 7.5m 'D' shaped, branches from Access tunnel at Ch 1966 m at the sill level of +286.77 m leads to Cavern-2 through intermediate tunnel at the same level and also to the bottom level of Cavern 1 at +271.77m, at downward slope 1 in 13.5. The Auxiliary tunnel will be extended beyond the ICAL experimental Hall (Neutrino Research Lab) for about 50m to facilitate for additional experimental halls to be developed in future *(Refer Drg. No. INO/DPR/ 6)*. Considering the future development, the Auxiliary tunnel size has been kept at 7.5m.

11.4 Interconnecting tunnel

The interconnecting tunnel of 3.5m dia 'D' shaped branches from Auxiliary tunnel at Ch 2020.55 m & at level +282.730 m interconnects Cavern-2 to Cavern-1.

11.5 Additionally driven intermediate tunnel (ADIT)

To facilitate the excavation of spring level portion of Cavern-1, an additionally driven tunnel 5.5 m dia 'D' shaped, with an upward slope so as to coincide with the crown of ADIT that of Cavern-1 is to be formed. This tunnel branches from the Access tunnel at Ch 1854.32 m and at level +295.040m and will be having the upward slope of 1 in 13.5. *(Refer Drg. No. INO/DPR/ 6)*

11.6 Cavern - 1

11.6.1 Location of Cavern-1

The most important aspect of this project is to locate Cavern-1 (which will house the ICAL detectors) under the minimum al-round rock cover of 1000m. Hence the entire Cavern - 1 is proposed to be located underground between the contours of 1579 m and 1560 m and along North West - South East direction. *(*Refer *Drg. No. INO/DPR/ 3)*

- Minimum vertical rock cover available = 1560m – 280.77m = 1279.23m *(From middle of ICAL detector – Refer Drg. No. INO/DPR/ 9)*
- The Geographical co-ordinates of Cavern - 1 are

  Latitude : 77º 15′ 0” to 77º 30′ 0”
  Longitude : 9º 57′ 30” to 10º 0′ 0”

- The axis of the Cavern - 1 is 23°28’26”.
- The highest peak adjoining to the Cavern -1 top surface + 1587.32 m

11.6.2 ICAL Detector hall

(i) Cavern-1 houses the ICAL detector. This is the major component of this project. Two stacks of ICAL detectors of size 48m x 16m x 16m will be installed for research purpose.

(ii) These ICAL detectors will be placed over the RCC foundation of 1m depth and top of detectors will be 2m above loading bay floor level.

(iii) Free Access of 3m width will be provided al-round the ICAL detector stacks for the withdrawal of 2m long detectors.

(iv) Apart from the above, 1m width for Electronic panels and 1m width for access during maintenance have to be provided al-round.

(v) This hall will have structural platforms on either side along the length of hall at 3.5m intervals for the entire height from the Detector stack bottom to the Access tunnel/Loading floor area.

(vi) A mobile Trolley/ Platform with ladders will be provided for handling the detectors in the clear space of 3m on either side.

(vii) RCC Structure 16mx16mx12m (3 floors) will be provided between the ICAL detectors for housing Air Handling Units (AHUs).

(viii) A EOT crane of 25 Tonne /5 Tonne will be provided to lift the steel plates.

(ix) The clearance between ICAL detector top and spring level of the arch is maintained above 9m for easy handling of detector plates by EOT crane.

(x) Hence the clear measurements of ICAL detector stack hall in Cavern-1 are 132m x 26m X 32.5 m

Length	-	132m (2m+3m+48m+16m+48m+3m+2m)
Breadth	-	26m (2m+3m+16m+2m+3m)
Height above loading bay level	-	10m upto the spring level of the Cavern
Depth below loading bay level	-	15 m

(xi) Cantilever slabs of 2m wide will be provided al-round Cavern-1 to house the Electric panels.

(xii) The levels of the structural platform will be as follows: *(Refer Drg. No. INO/DPR/ 9)*

- Platform floor +1 (3.5m above loading bay) : EL +290.27 m
- Platform floor - 0 (loading bay) : EL +286.77 m
- Platform floor - 1 (3.5m below the loading bay) : EL +283.27 m
- Platform floor - 2 (7.0 m below loading bay) : EL +279.77 m
- Platform floor - 3 (10.5 m below loading bay) : EL +276.27 m
- Foundation level of ICAL detectors (15 m below loading bay) : EL +271.77 m

(xiii) A Lift (Capacity - 5 persons) and staircase will be provided for access to the above structural platforms. The lift and staircase will be located between the two ICAL detector stacks. One more lift will be provided on the opposite side of this lift and staircase. The outer face of lift and staircase will be flush with the rock face (viz.), the rock has to be suitably excavated in this portion for locating the lift and staircases.

(xiv) RCC columns of size 1.0m x 0.5m will be provided at 6m interval along length wise on both sides of ICAL detector hall from EL 271.770m (floor level) to EL 294.77m to support the EOT beam and crane assembly. At the

location of RCC columns, the free width in the structural platforms will be 1m only and so panels or other equipments should not be placed here.

(xv) Loading bay size for the loaded trucks to position, for the lifting of steel plates by EOT crane is 25m x 15m

(xvi) RCC lining of Cavern - 1

The vertical cover/over burden is 1279.23m over Cavern-1 and the width of Cavern-1 is 26m.

An opening of such a huge cavity in the rock system will develop high stress in the side walls and arches. This will result in rock falling or rock bursting out. Moreover, the ICAL experimental hall (i.e.) Cavern-1 has to be free of moisture, sweating or seepage of water as it will affect detector performance . In view of the above requirements, after rock bolting 1 m thick Reinforcement cement concrete is proposed for the arch portion. The ends of the arch portion of the slab will be keyed into the rock for a width of 2 m on both sides for the transfer of rock stresses.

The inner rock faces of Cavern-1 will be provided with RCC lining of 30cm thick from floor level of ICAL detectors (EL+271.77m) upto the EOT Crane top level EL +296.770m to prevent the moisture and for good appearance. The structural platforms and the floor level of ICAL detectors will be provided with ceramic tiles.

(xvii) The loading bay side of the Cavern -1 will be closed with concrete blocks with door opening, once the two ICAL detector stacks are erected and commissioned. Gates at the front side at +286.770 and on the rear side at +271.770 will be provided.

(xviii) A dewatering sump will be provided on the rear side of Cavern-1 to collect all the seepage water and this will be pumped out.

(xix) During cavern formation, the cavern size will be 0.5m extra of the clear dimension of ICAL detector experimental hall. The Cavern-1 (i.e.) 132 m x 26 m x 31.6 m will be air-conditioned as the ICAL detector has to be maintained at $21^{o} \pm 3^{o}$ C and at relative humidity < 55%.

(Refer Drg. No. INO/DPR/ 6, Drg. No. INO/DPR/ 8, and *Drg. No. INO/DPR/ 2)*

(xx) Cavern Design

The services of the Engineering Geology Division/ Geological Survey of India, Chennai and National Institute of Rock Mechanics (NIRM)/Kolar Gold Fields, Karnataka for the design of support system will be availed in the design of Caverns. From the rock core samples, from the drilling of Cavern- 1 arch portion the following properties will be investigated by NIRM, based on which the design and computer modeling of Cavern -1 will be evolved.

a) Uniaxial compressive strength with elastic constants
b) Tensile strength
c) Shear strength (Cohesion) and friction angle from triaxial compression test.
d) Density

11.7 Cavern - 2

Cavern-2 of size 55mx12.5mx8.6m will be constructed to house:

(i) NDBD - I Lab of size 10 m x 10m.
(ii) Control room with computers for Neutrino Research Laboratory of size 17 m x 10.0 m.
(iii) Air conditioning and ventilation system room (6m x 10.m)
(iv) Electrical Distribution Transformers and panels for Caverns 1 & 2(12m x 10 m)
(v) 2 Office rooms with change/ wash room facilities for Gents & Ladies. (4.3 m x 8.4 m) each .

Out of the above 5 compartments in Cavern-2, NDBD-I Lab and Control room will be air-conditioned and the remaining area will be ventilated with minimum air charges required for human comfort.

This Cavern-2 is approachable from Access tunnel through Auxiliary tunnel and then through intermediate tunnel.

When Caverns-1 & 2 are taken up for excavation, a rock cover equivalent to width of Cavern-1 + width of Cavern-2 will to be given in between the two caverns in order to avoid collapse of rock mass during blasting.

Width of Cavern-1	-	26.0m
Width of Cavern-2	-	12.5m

		38.5m
		---
	or say 40m	

The control room and NDBD-I in Cavern -2 will be provided with RCC roof slab at 5 m height over concrete blocks wall. The remaining four compartments (viz.) office room, AC and ventilation system room and transformer room will be open to cavern arch portion and provided only with concrete blocks partition walls.

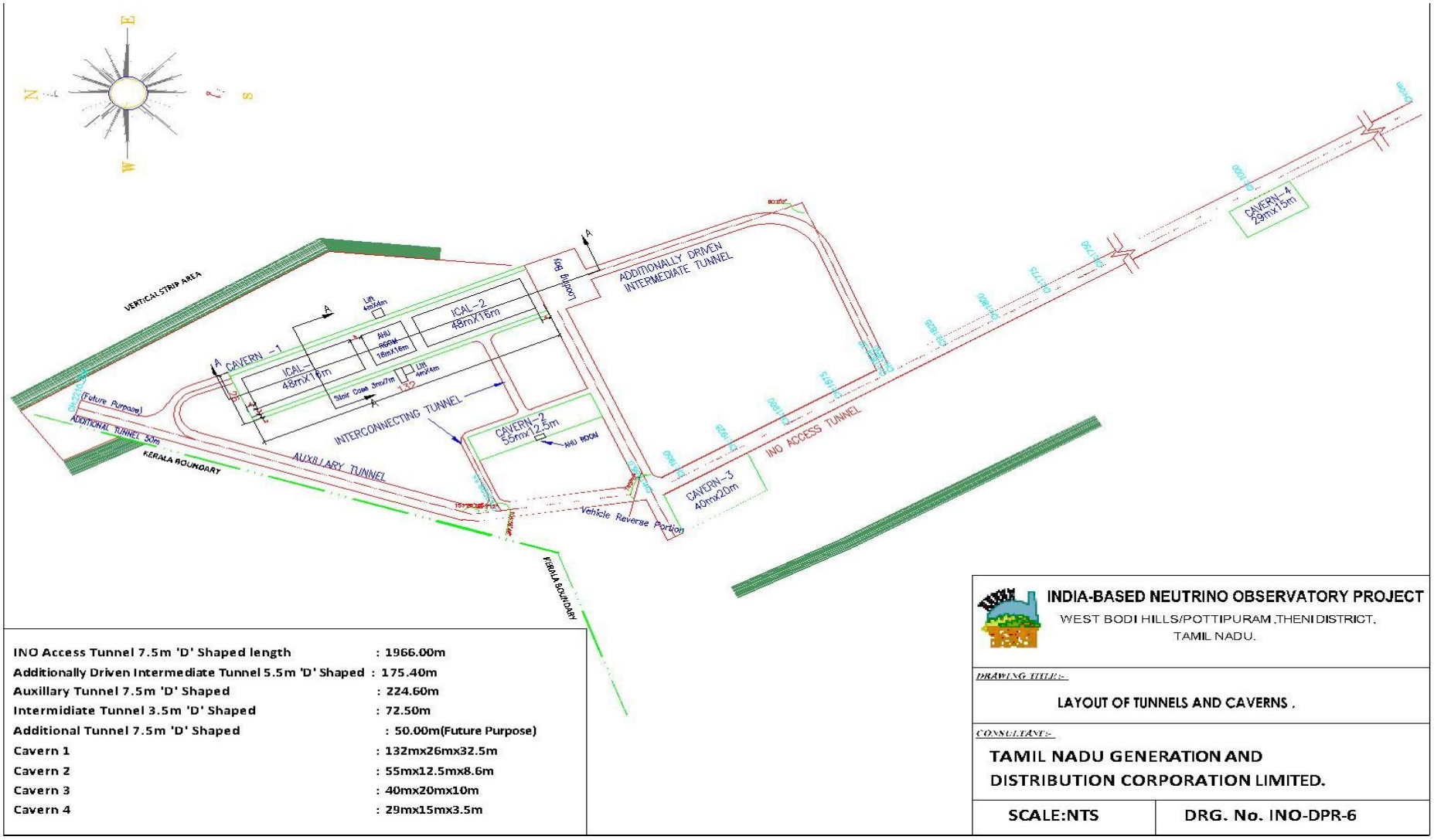
In the NDBD I area, a pit of 8 m x 6 m x 6 m will be made in the floor for cryostats, associated pumps and vibration isolators. A passenger lift (5 persons) will be provided to travel from the floor level to the bottom of the pit. Water collected in the pit if any, has to be pumped to Cavern-1 dewatering sump.
*(*Refer *Drg. No. INO/DPR/ 11* and *Drg. No. INO/DPR/ 12)*

11.8 Cavern - 3

Cavern-3 of size 40m x 20m x 10m will be provided along the Access tunnel before take-off point to Cavern-1, for providing space for future research.
*(*Refer *Drg. No. INO/DPR/ 6)*

11.9 Cavern - 4

The vehicle pocket at 1000m from the Cavern – 1 will be excavated to the size of 29 m X 15 m X 3.5 m to accommodate NDBD- II
*(*Refer *Drg. No. INO/DPR/ 6)*
NDBD I and NDBD - II are detailed in *Appendix - 3*



INO Access Tunnel 7.5m 'D' Shaped length	: 1966.00m
Additionally Driven Intermediate Tunnel 5.5m 'D' Shaped	: 175.40m
Auxillary Tunnel 7.5m 'D' Shaped	: 224.60m
Intermidiate Tunnel 3.5m 'D' Shaped	: 72.50m
Additional Tunnel 7.5m 'D' Shaped	: 50.00m(Future Purpose)
Cavern 1	: 132mx26mx32.5m
Cavern 2	: 55mx12.5mx8.6m
Cavern 3	: 40mx20mx10m
Cavern 4	: 29mx15mx3.5m

INDIA-BASED NEUTRINO OBSERVATORY PROJECT

WEST BODI HILLS/POTTIPURAM,THENI DISTRICT, TAMIL NADU.

DRAWING TITLE:-

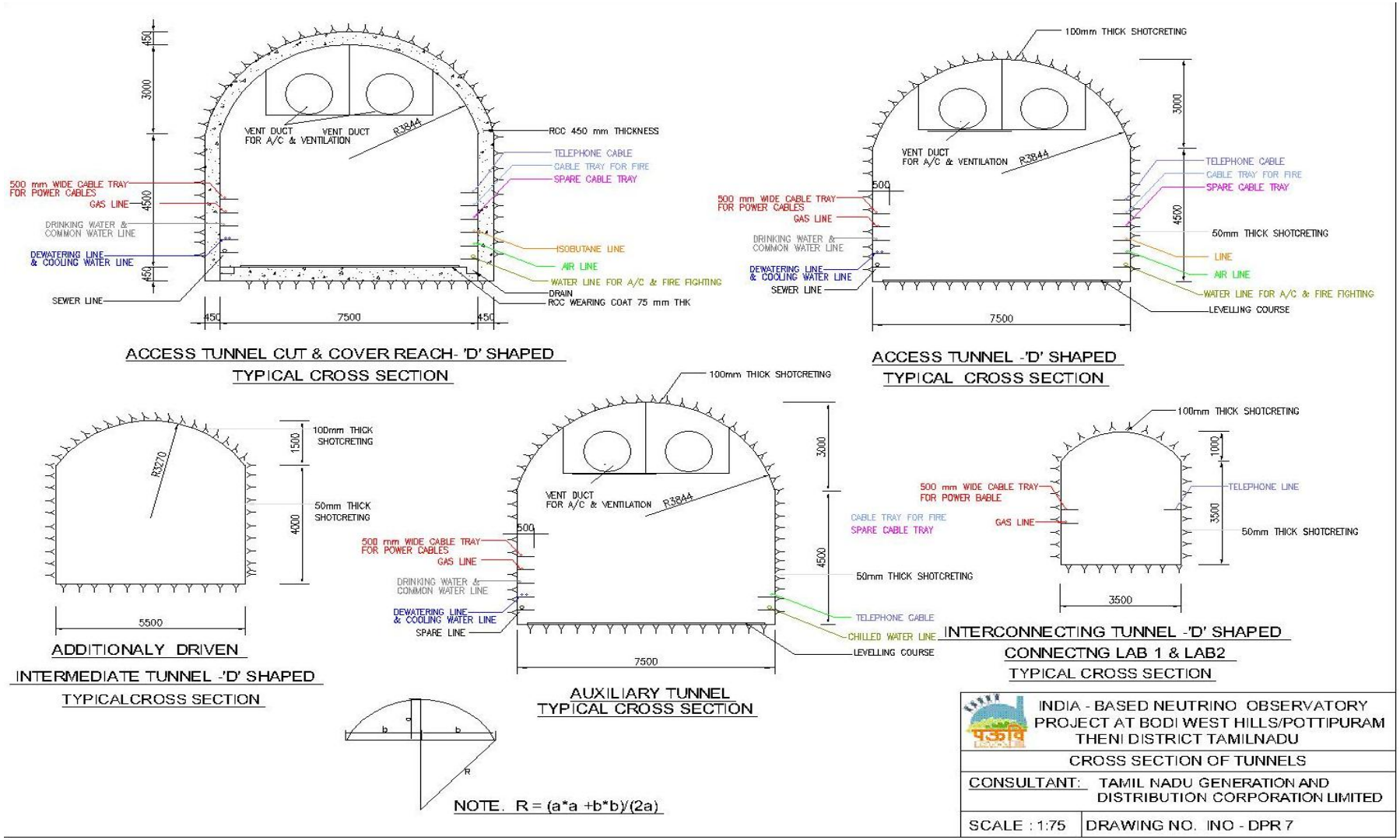
LAYOUT OF TUNNELS AND CAVERNS .

CONSULTANT:-

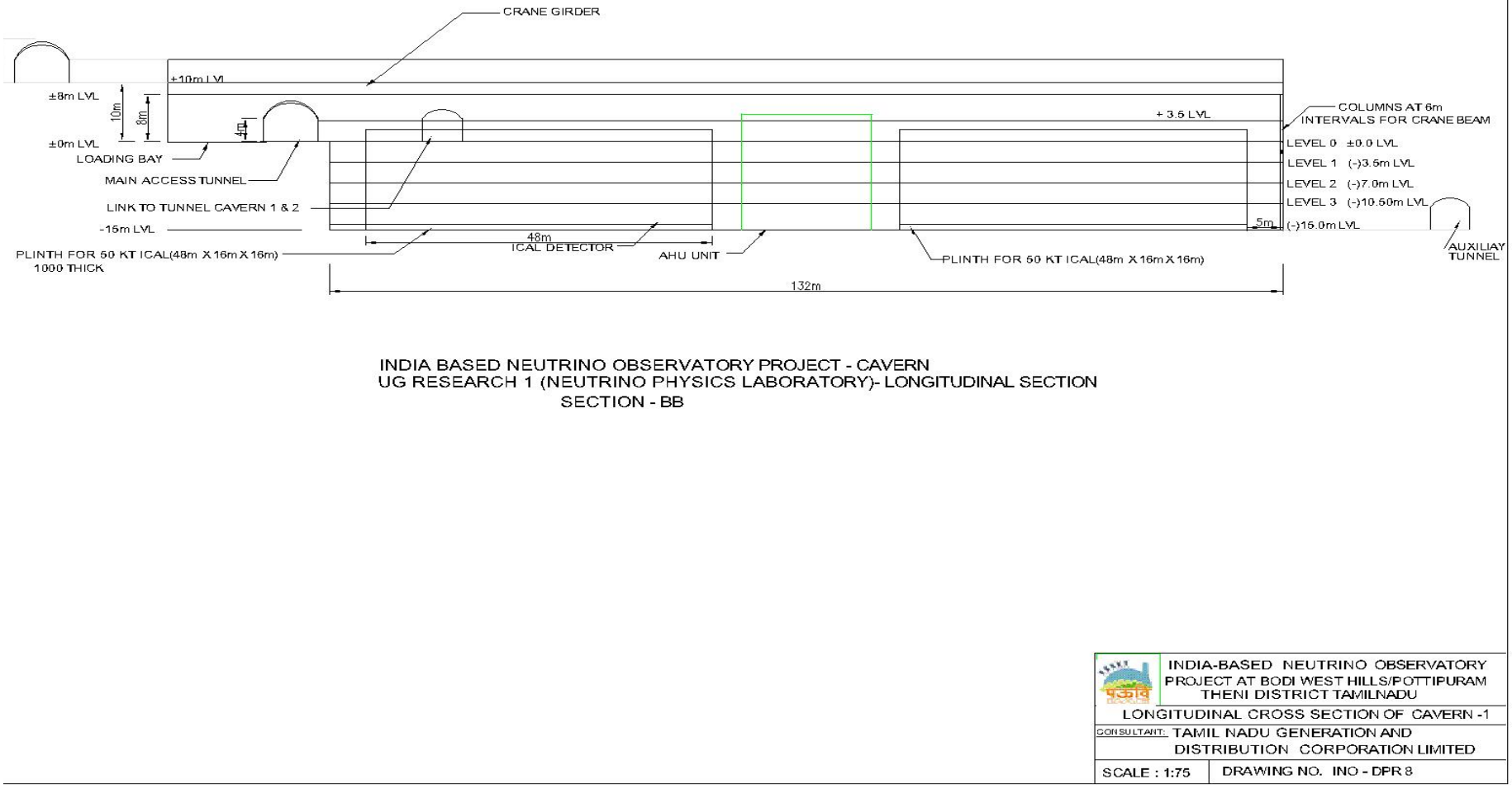
TAMIL NADU GENERATION AND DISTRIBUTION CORPORATION LIMITED.

SCALE:NTS	DRG. No. INO-DPR-6

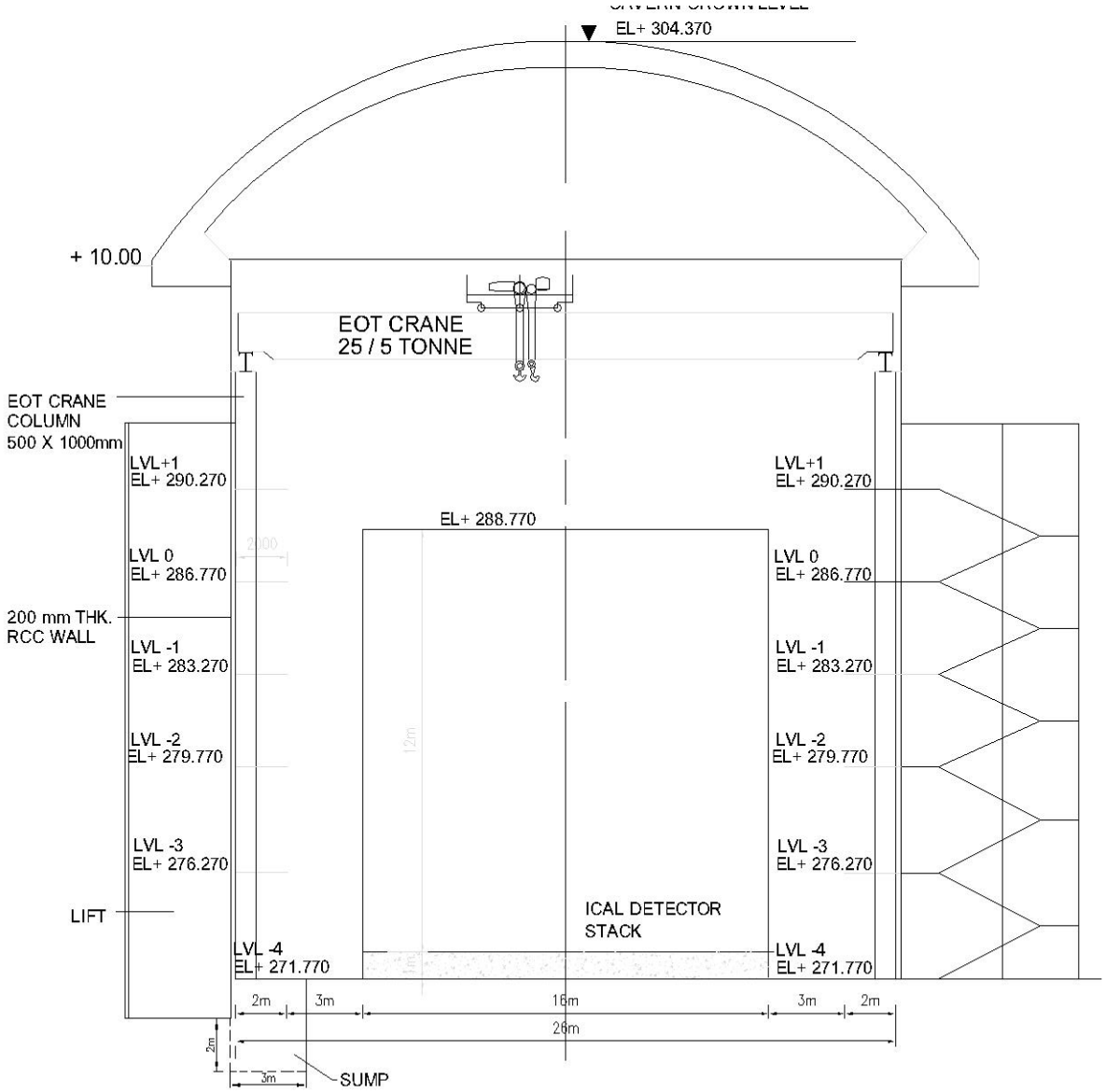
Drg. No. INO/DPR/ 6 Layout of Tunnels and Caverns



Drg. No. INO/DPR/ 7 Cross section of tunnels



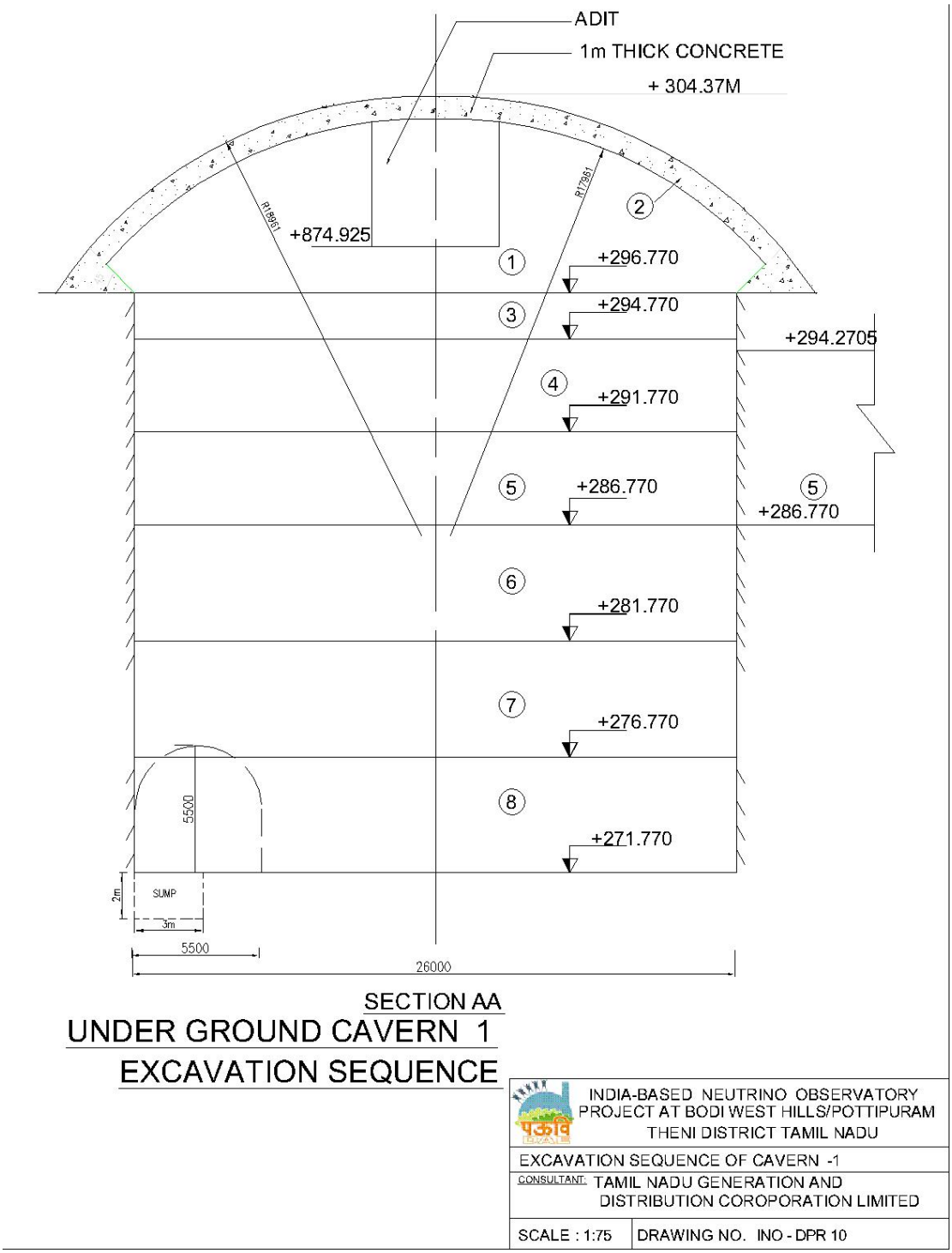
Drg. No. INO/DPR/ 8 Longitudinal cross section of cavern - 1



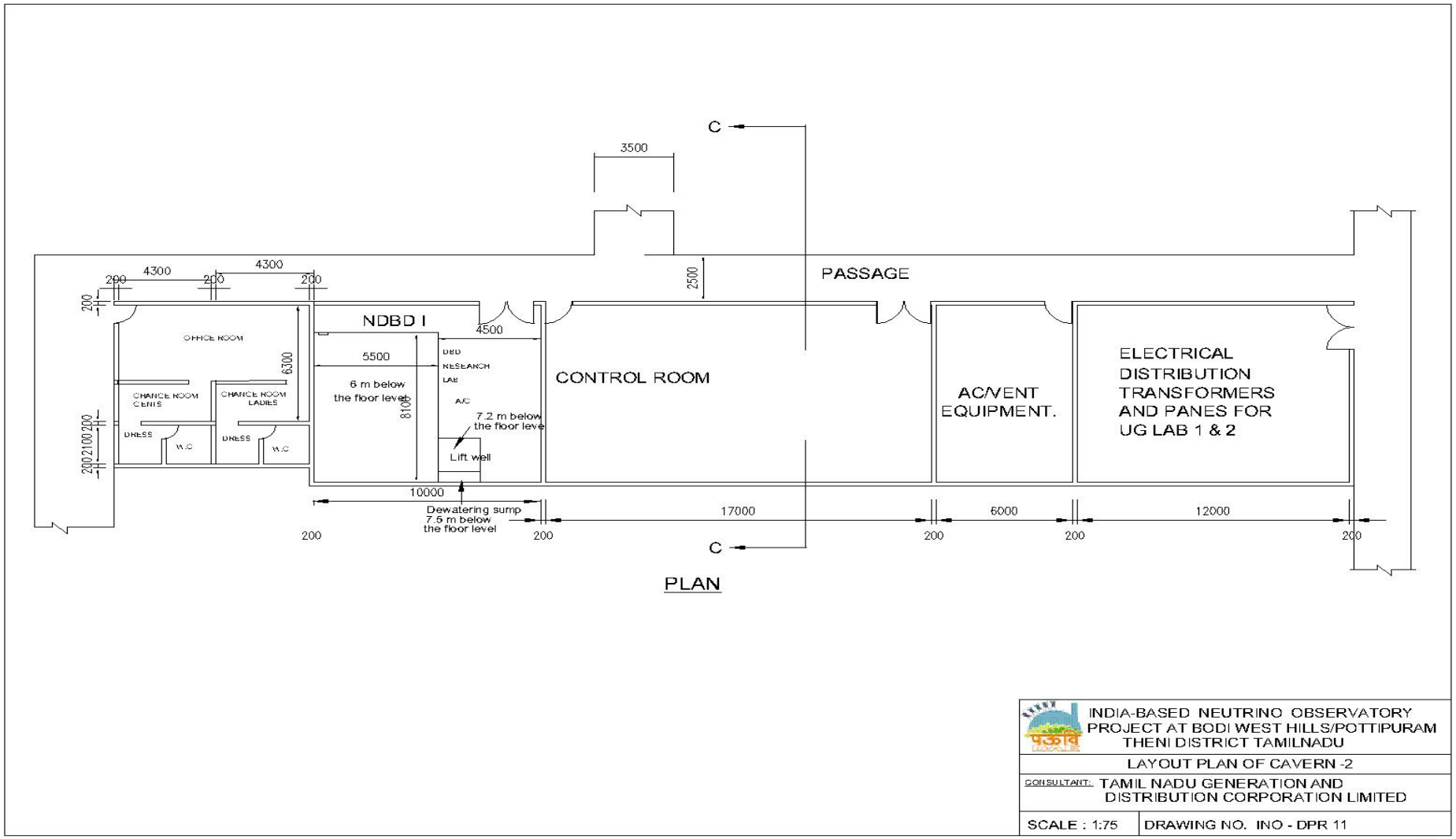
CROSS SECTIONAL VIEW OF CAVERN - I

INDIA-BASED NEUTRINO OBSERVATORY PROJECT AT BODI WEST HILLS/POTTIPURAM THENI DISTRICT TAMILNADU	
CROSS SECTION OF CAVERN -1	
CONSULTANT:- TAMIL NADU GENERATION AND DISTRIBUTION CORPORATION LIMITED	
SCALE : 1:75	DRAWING NO. INO - DPR 9

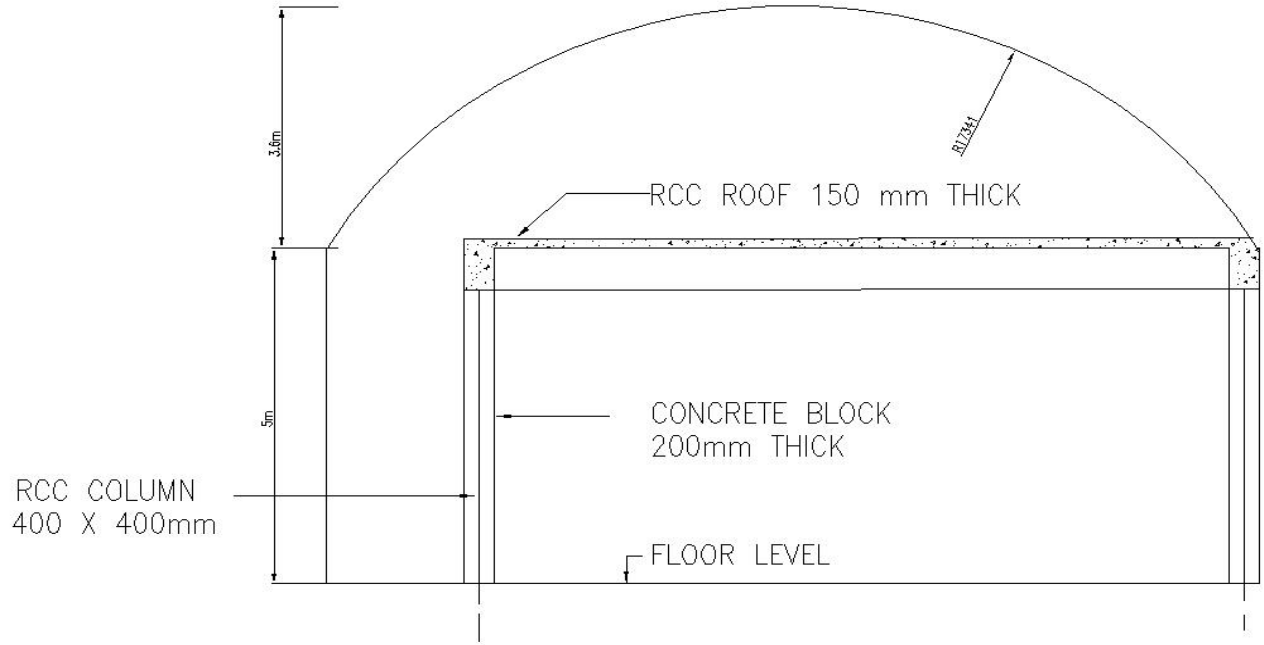
Drg. No. INO/DPR/ 9 Cross section of cavern – 1



Drg. No. INO/DPR/ 10 Excavation sequence of cavern - 1



Drg. No. INO/DPR/ 11 Layout of plan of cavern - 2



CAVERN - 2 TRANSVERSE SECTION

SECTION CC

INDIA-BASED NEUTRINO OBSERVATORY PROJECT AT BODI WEST HILLS/POTTIPURAM THENI DISTRICT, TAMILNADU	
TRANSVERSE SECTION OF CAVERN -2	
CONSULTANT: TAMIL NADU GENERATION AND DISTRIBUTION CORPORATION LIMITED	
SCALE : 1:75	DRAWING NO. INO - DPR 12

Drg. No. INO/DPR/ 12 Transverse section of cavern - 2

CHAPTER 12

MAIN SURFACE FACILITITES

12.1 Utility building

The utility building is proposed near the Access tunnel Portal.

*(*Refer *Drg. No. INO/DPR/ 13)*

This building will comprise of the following facilities:

(i) Equipment room of size 12m x 30m, for power receiving and main Power distribution

(ii) Main Air conditioning & ventilation equipment including Filter bank – Chiller/Blow room of size 20mx 30m.

(iii) Office cum store room of size 12m x 5.77m

(iv) 2 Nos. 500 KVA DG sets cum compressor room of size 12mx16m

12.2 Administrative building cum workshop

For the overall functioning of the research laboratories and for office functions, an Administrative building is proposed.

The INO laboratory requires goods, services and spare parts on a short notice for equipments like front end loads, drills, fork lifts etc. In addition, other tools/materials are required to attend to the repair and maintenance of mechanical & electrical system. Hence, a workshop is also considered as essential.

Administrative building cum workshop comprises the following facilities in ground floor and first floor.

*(*Refer *Drg. No. INO/DPR/ 14 & Drg. No. INO/DPR/ 15)*

12.2.1 Ground floor of Administrative building

a)	Repair bay	-	18 m x 14.25 m –It will house an EOT crane of 10T capacity
b)	Workshop	-	6mx6m *(also served by above EOT crane)*
c)	Store Room	-	6m x 6m

d)	Tool crib	-	3m x 6m
e)	Engineer work shop	-	3m x 6m
f)	Telephone exchange and electrical panel	-	6m x 6m
g)	Toilets	-	2 toilets for gents &
		-	1 toilet for ladies
h)	AC Chiller room	-	6m x 8m
i)	Surface lab	-	15m x 12.25m
j)	Lecture hall	-	12m x12m

Out of the above facilities, the ceiling height of workshop & repair bay will be 7m and height of lecture hall will be 5m. The lecture hall will have seating arrangements for 100 persons. The ceiling height for the rest of the facility rooms will be 3.5m.

12.2.2 First floor of Administrative building cum workshop

The First floor will be constructed over the entire building except the lecture hall and that of work shop/ repair bay. The first floor will function as office area. This entire first floor area will be divided into 25 compartments/cabins to accommodate Scientists, Administrative and Accounts staff. The surface lab will support the activities of Caverns-1 and 2.

12.3 Detector Assembly building

A detector assembly building of size 20 m x 125 m is proposed near portal with a provision of 10 tonne capacity crane. RPC detector will be assembled, tested here and then taken to Cavern 1.

12.4 Steel store shed

Steel store shed of size 25m x 40m is proposed near Access tunnel portal. This will have 2 numbers 10 Tonnes EOT crane for handling detector steel plates.

12.5 Guest house cum hostel

(Refer Drg. No. INO/DPR/ 16 & Drg. No. INO/DPR/ 17)

The Guest house cum hostel complex will have

(i) 6 Numbers of double bed guest suits of 44 m^2 plinth area each with attached toilet, dressing area

(ii) 20 numbers single bed hostel rooms of 25 m^2 plinth area each with attached toilets

(iii) Common work out room of 50m^2 plinth area

(iv) Kitchen of 15m^2 plinth area

(v) Dining area of 70 m^2 plinth area

(vi) Lounge of 10m^2 plinth area

The Guest suites and hostel rooms will have Telephone, TV and computer connection.

12.6 Residential quarters

(Refer Drg. No. INO/DPR/ 18, Drg. No. INO/DPR/ 19, Drg. No. INO/DPR/ 20, Drg. No. INO/DPR/ 21 & Drg. No. INO/DPR/ 22)

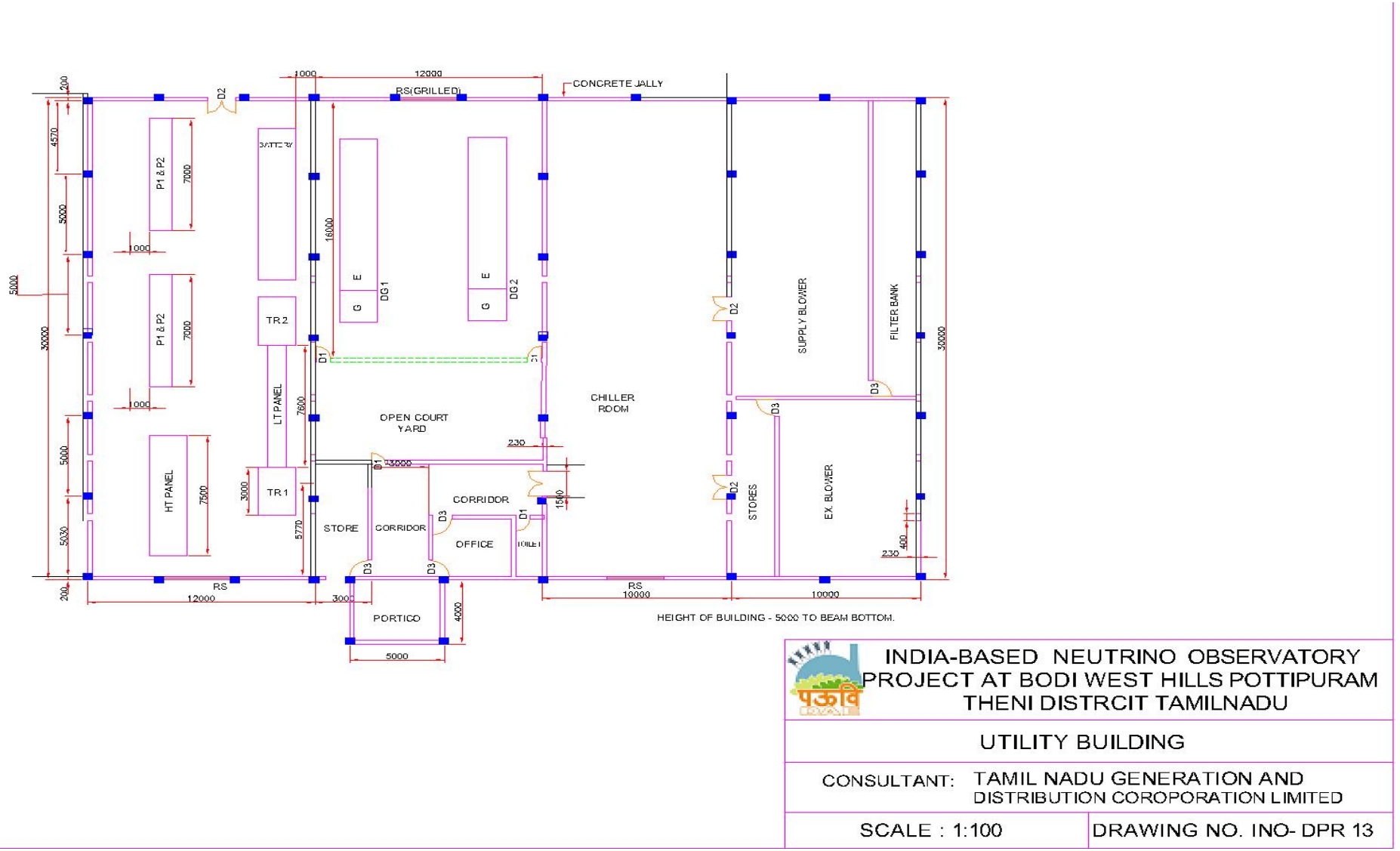
Table 12.1

Sl.No	Type	Nos	Plinth area	Total Plinth area
1	Type B	9	66m^2	594m^2
2	Type C	5	77m^2	385m^2
3	Type D	5	104m^2	520m^2
4	Type E	1	153m^2	153m^2
	Total	**20**		**1652m^2**

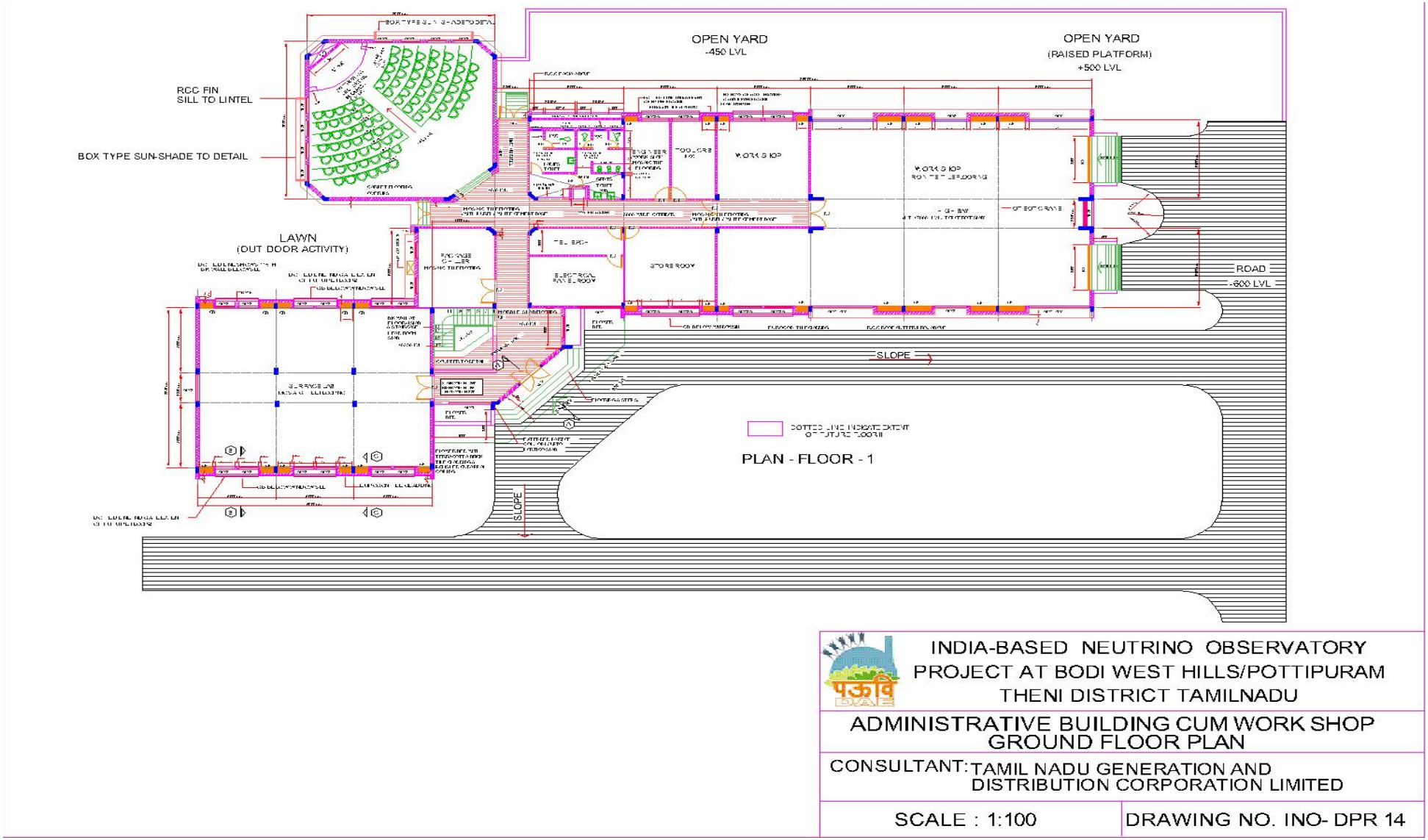
12.7 Green Building concept

Green Building concept will be adopted in the design of Guest House Cum Hostel & Residential Quarters to make them Energy & Water efficient buildings. Rainwater harvesting will be ensured for all the buildings. Provision will also be given for installing Solar heaters.

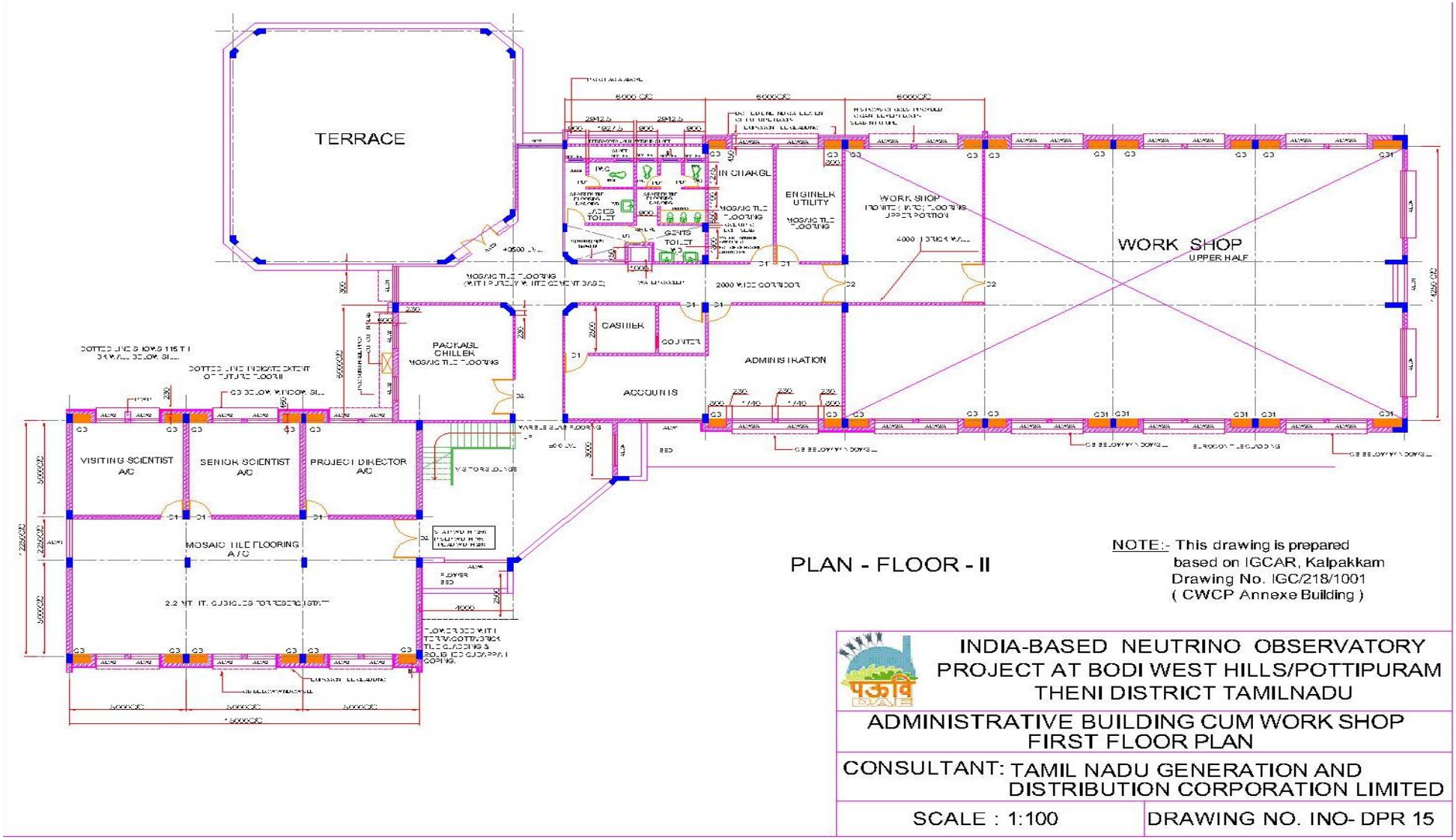
(For disposition of all surface facilities in Survey No. 4/1 Refer Drg. No. INO/DPR/ 2)



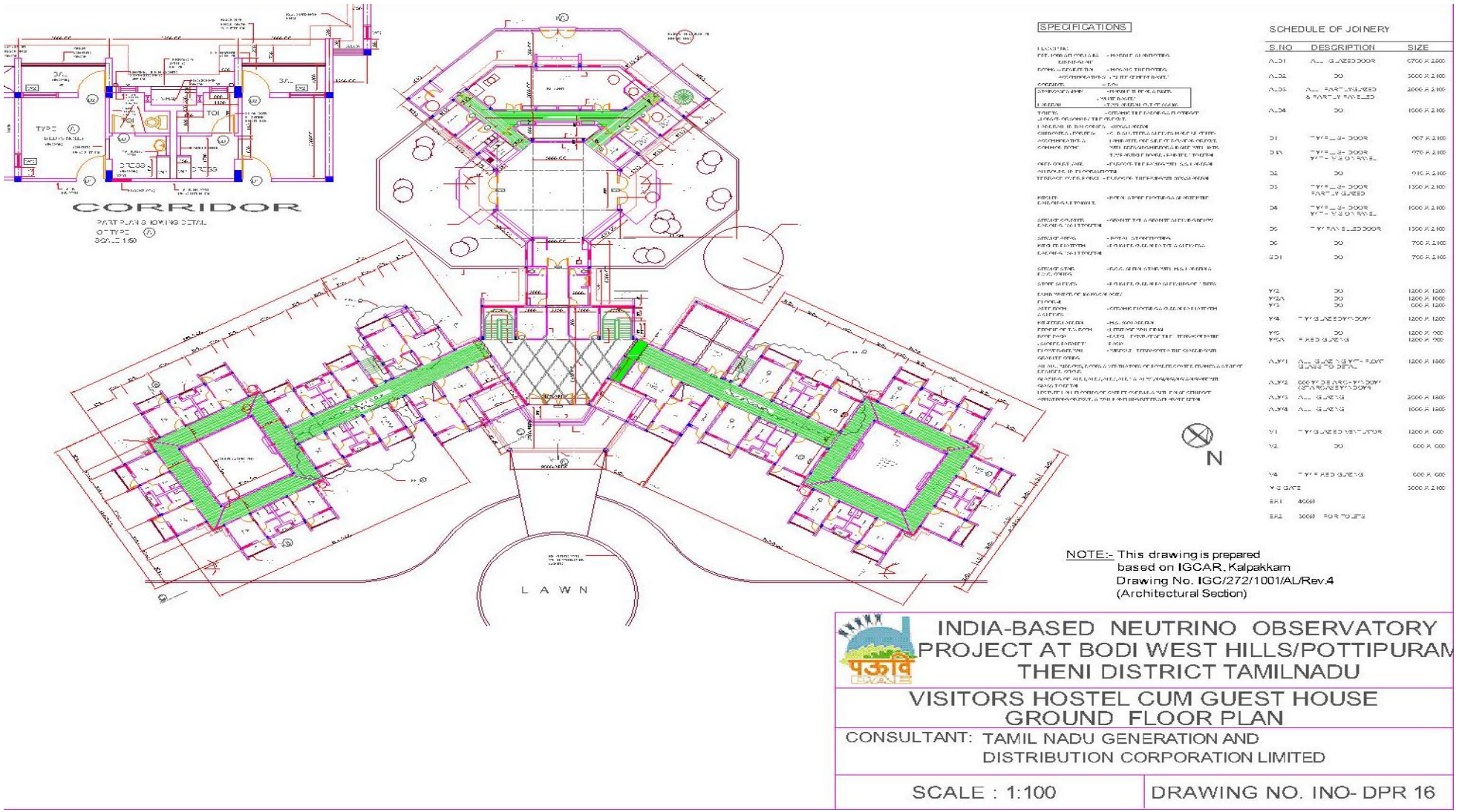
Drg. No. INO/DPR/ 13 Utility building



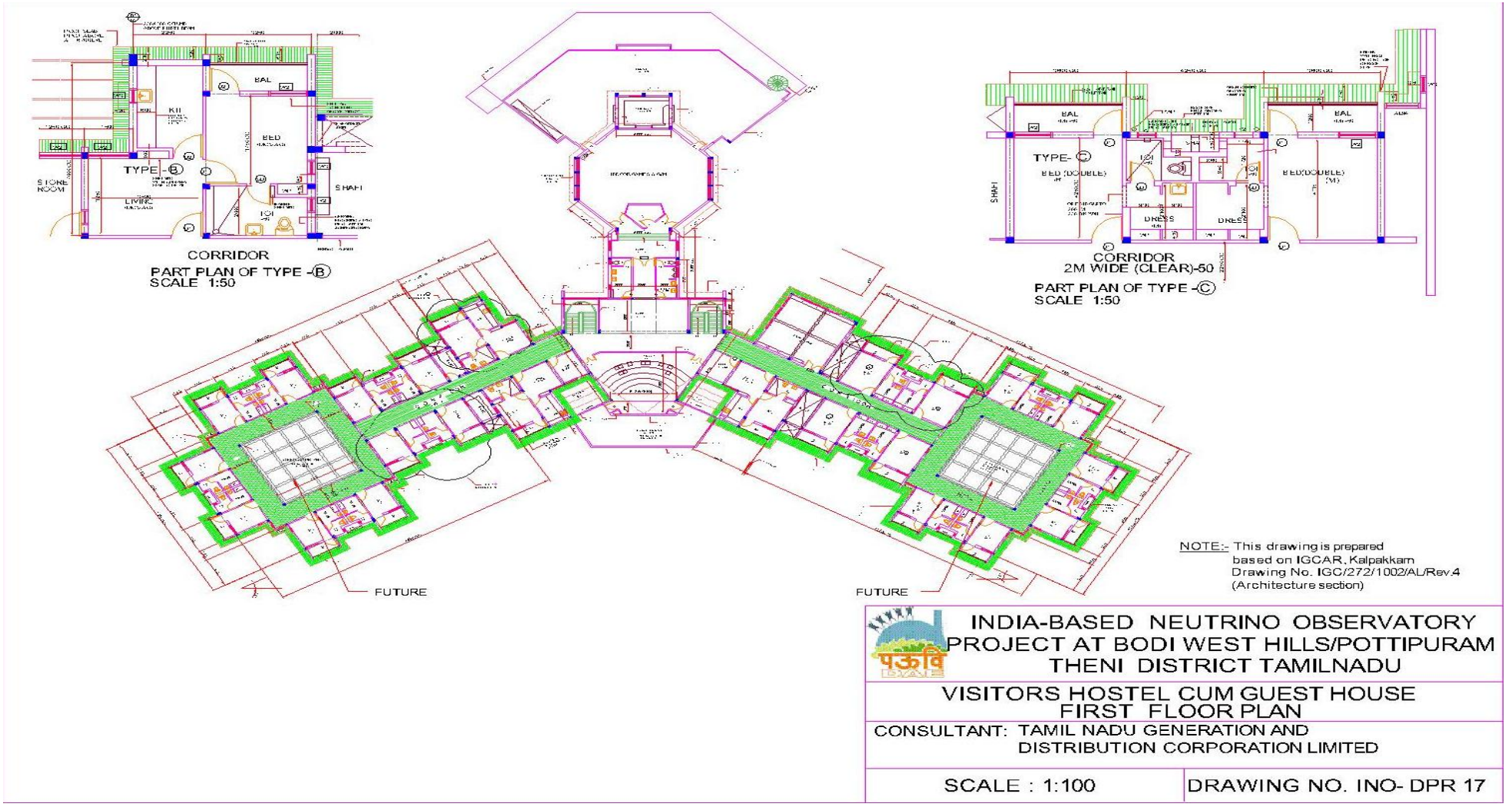
Drg. No. INO/DPR/ 14 Administrative building cum workshop (Ground floor Plan)



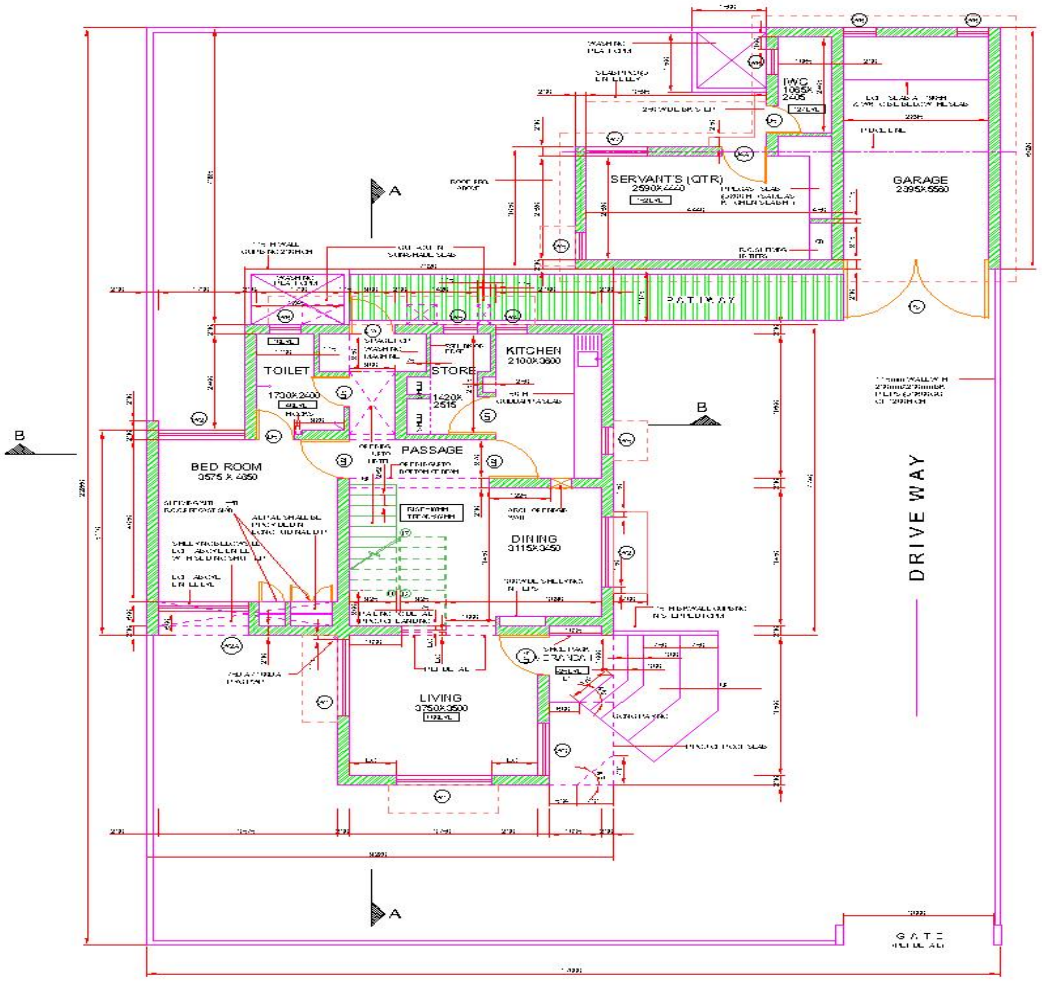
Drg. No. INO/DPR/ 15 Administrative building cum workshop (First floor Plan)



Drg. No. INO/DPR/ 16 Visitor's hostel cum guest house (Ground floor Plan)



Drg. No. INO/DPR/ 17 Visitor's hostel cum guest house (First floor Plan)

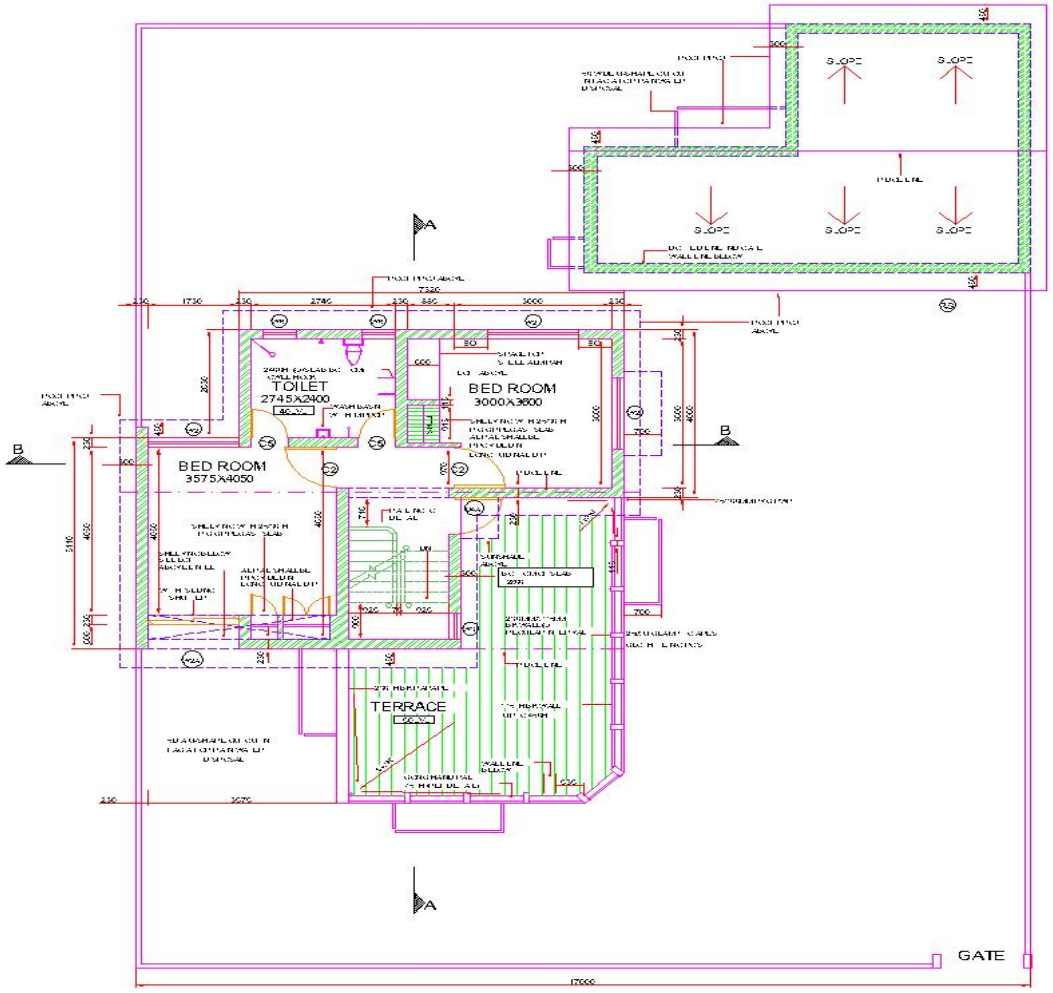


PLAN (GROUND FLOOR)

NOTE:- This drawing is prepared based on IGCAR, Kalpakkam Drawing No. IGC/TYPE SE/2001/AL/Rev.12 (Architecture Division)

INDIA-BASED NEUTRINO OBSERVATORY PROJECT AT BODI WEST HILLS/POTTIPURAM THENI DISTRICT TAMILNADU	
RESIDENTIAL QUARTERS - TYPE 'E' GROUND FLOOR PLAN	
CONSULTANT: TAMIL NADU GENERATION AND DISTRIBUTION CORPORATION LIMITED	
SCALE : 1:75	DRAWING NO. INO- DPR 18

Drg. No. INO/DPR/ 18 Residential quarters - Type – E (Ground Floor Plan)

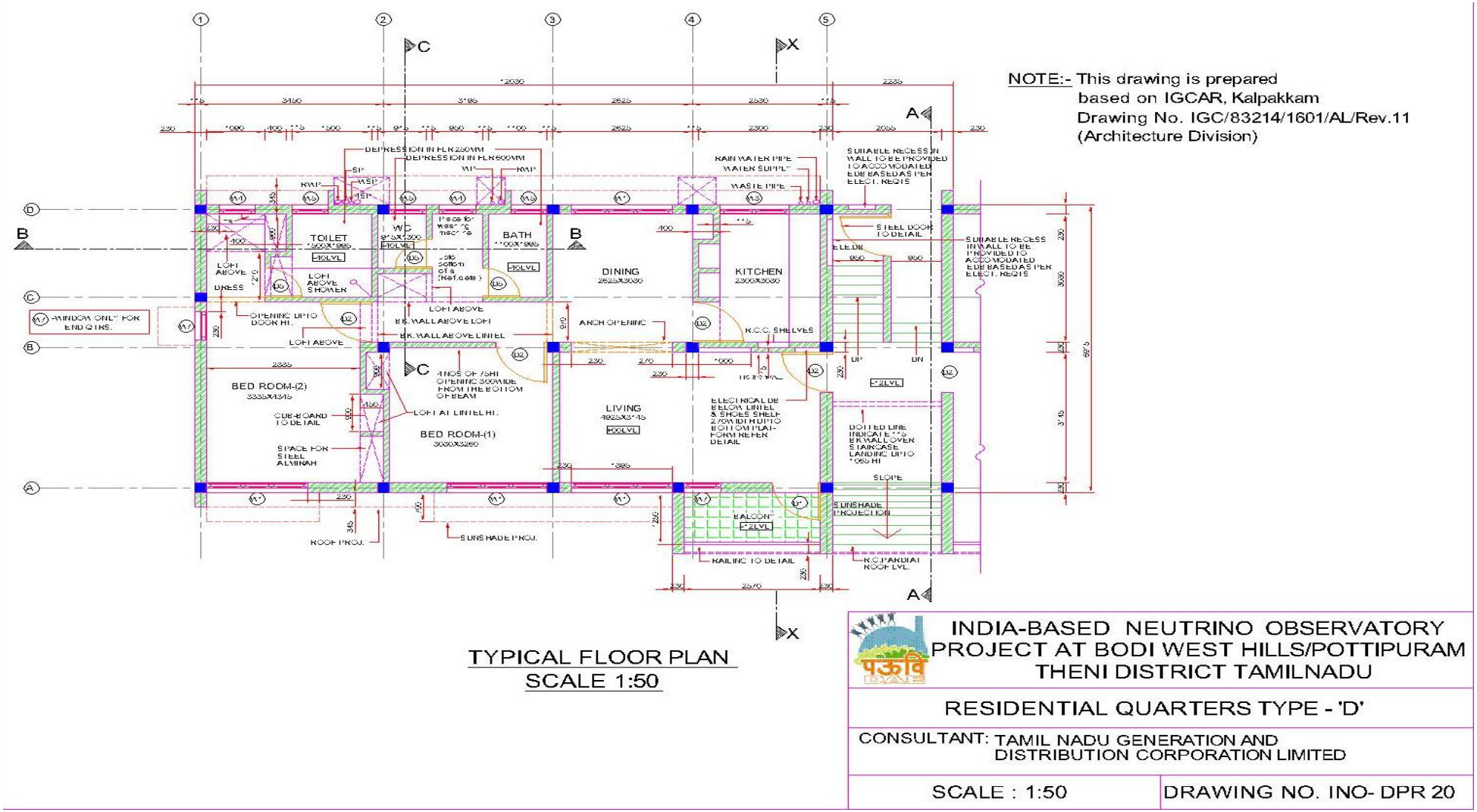


PLAN (FIRST FLOOR)

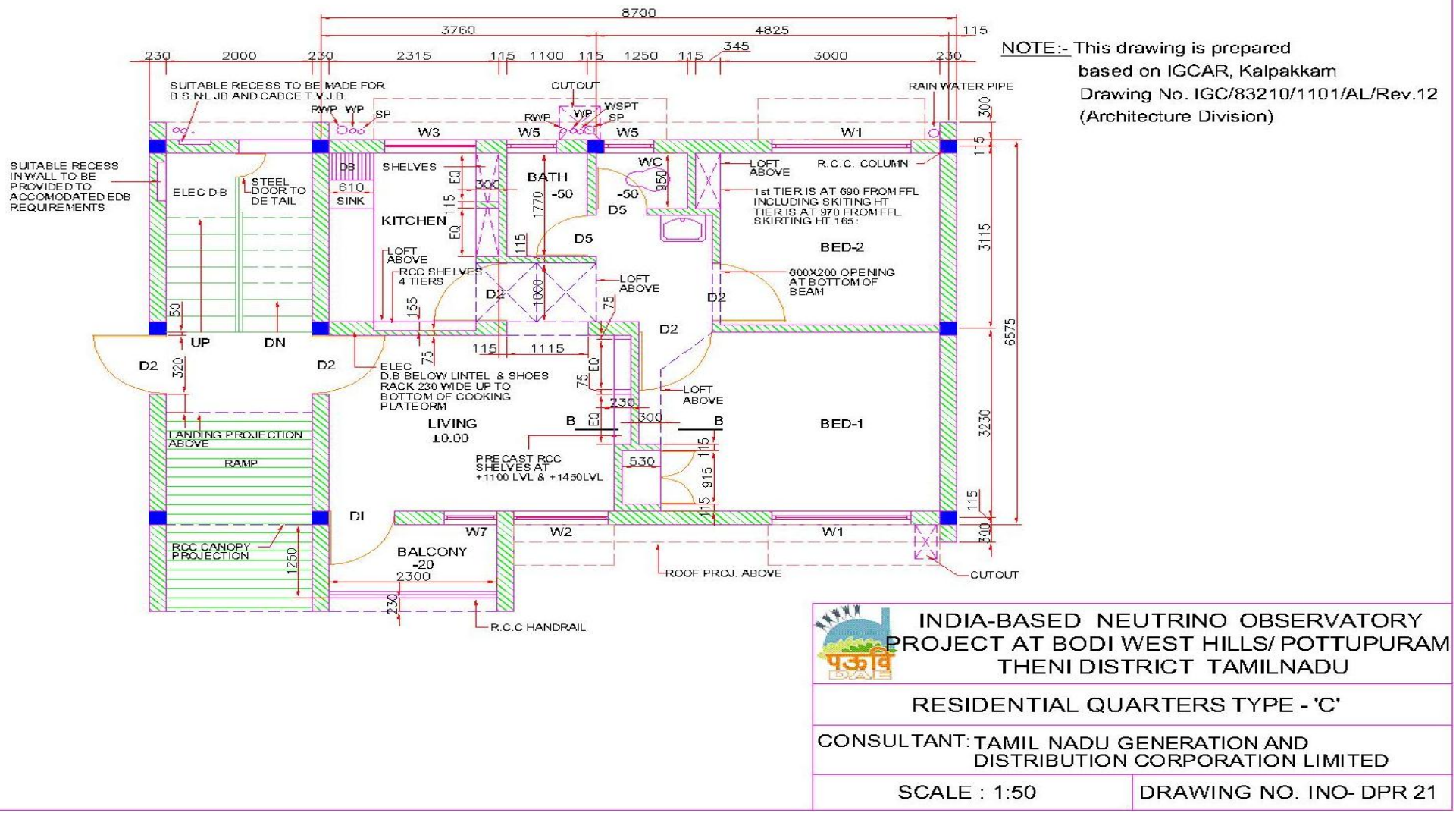
NOTE:- This drawing is prepared based on IGCAR, Kalpakkam Drawing No. IGC/TYPE SE/2002/AL/REV.12 (Architecture Division)

INDIA-BASED NEUTRINO OBSERVATORY PROJECT AT BODI WEST HILLS/POTTIPURAM THENI DISTRICT TAMILNADU	
RESIDENTIAL QUARTERS - TYPE 'E' FIRST FLOOR PLAN	
CONSULTANT: TAMIL NADU GENERATION AND DISTRIBUTION CORPORATION LIMITED	
SCALE : 1:75	DRAWING NO. INO- DPR 19

Drg. No. INO/DPR/ 19 Residential quarters - Type – E (First Floor Plan)



Drg. No. INO/DPR/ 20 Residential quarters - Type – D



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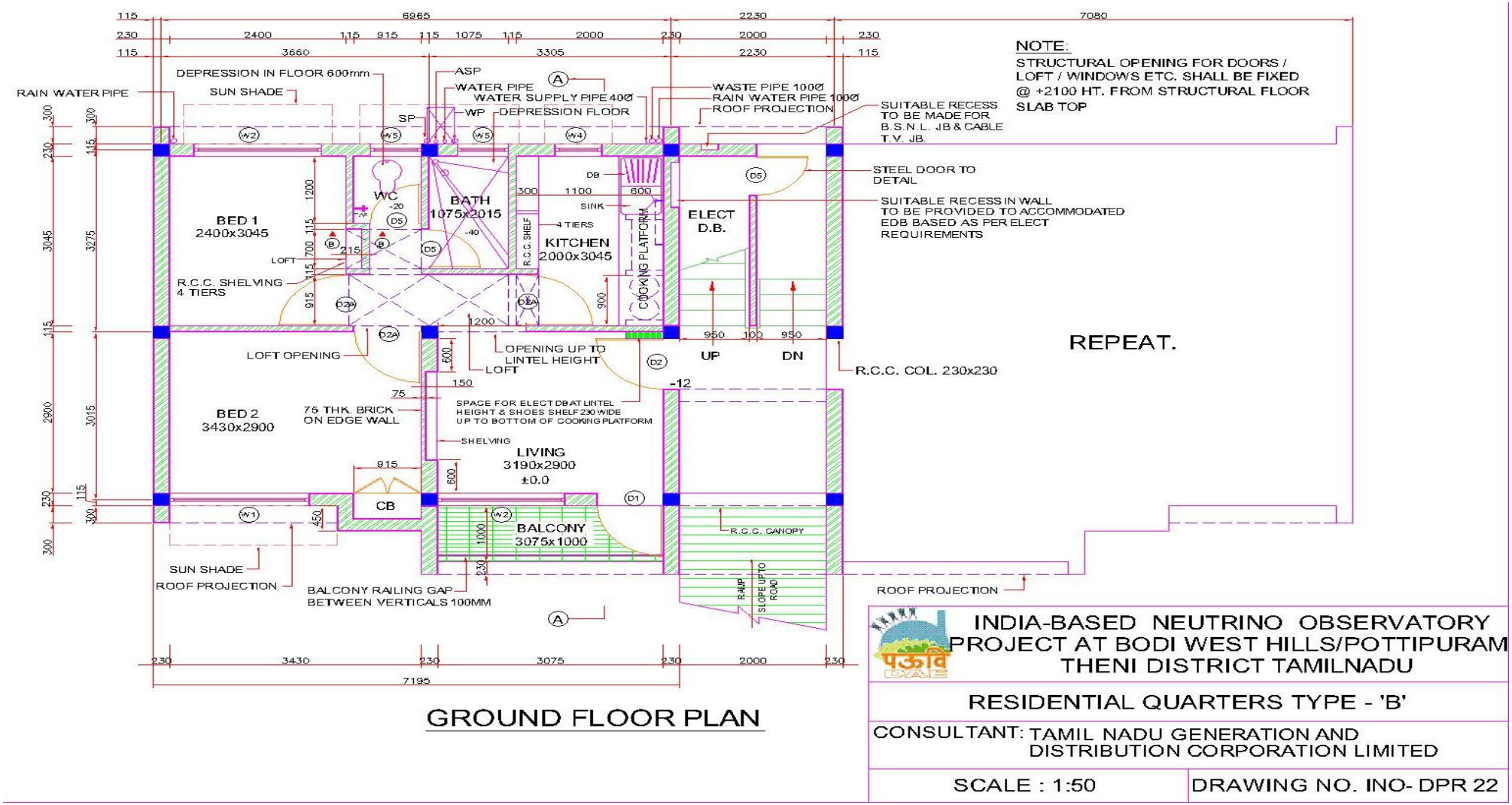


Drg. No. INO/DPR/ 22 Residential quarters - Type – B

Part IV Technical – Engineering Services

CHAPTER 13

POWER SUPPLY AND DISTRIBUTION SYSTEM

13.1 Power supply

13.1.1 Study of alternatives for Power Supply

INO Project requires 4 MW reliable and uninterrupted power supply during its operation phase.

The following three proposals/ alternatives were studied to select the best from reliable power supply without any interruption point of view as well as on economical aspect.

Proposal – I : ***By extending 110 KV Supply from 110 KV Theni – Periyar feeder – I***

Proposal – II : ***By extending 22 KV supply from 110/22 KV Rasingapuram SS***

Proposal – III : ***By erecting Diesel Generator sets at INO site.***

The above proposals were studied as per the actual site conditions, standards adopted by TANGEDCO (TNEB), 11KV/433V Distribution transformer for uniform cost comparison for Proposal-III and based on the quotations received from the suppliers.

13.1.2 110 KV INO Sub-station

The initial cost for the Proposal- III is comparatively less. However even for continuous load of 1 MW, the running and maintenance cost will be high.

Hence the Proposal – I is the best option for extending power supply to INO project to ensure uninterrupted and quality power supply at the least cost of maintenance during the operation phase.

13.1.3 Point of Supply

The 5 MVA load will be met through a 110 KV double circuit over head transmission line tapped at location number 154 of Theni – Periyar DC line and extended through INO 110 KV Sub-station.

13.1.4 110KV sub station equipments - Technical parameters

(i) 110KV SF6 Breaker:

Sl. No.	Items	Requirements
1	Rated voltage (KV rms) (nominal/max)	110 KV/132 KV
2	Frequency (Hz).	50
3	Neutral grounding	Solidly earthed
4	Continuous current rating	2000 A
5	Type	Outdoor SF6
6	Mounting	Hot dip galvanized/Epoxy painted steel support structure
7	Number of Poles	3
8	Type of operation	Gang Operated Poles
9	Clearances : (a) Centre to Centre distance between poles (b) Line to Ground clearance	 1700mm 4572mm
10	Height of concrete plinth (to be provided by the board)	300 mm
11	Minimum height of the lowest part of the support insulator from ground level (mm)	2550 mm
12	Operation mechanism	Spring - Spring (Motor operated spring charged)
13	Rated operating duty cycle as per IEC – 62271-100	0-0.3 Sec.-CO-3Min-CO
14	First pole to clear factor	1.3
15	Type of tripping	Trip free
16	Maximum closing time (ms)	150 ms
17	Maximum total break time (ms) At rated breaking capacity	60 ms
18	1.2/50 microsecond impulse withstand voltage (dry) (i) To earth (KVp) (ii) Across the open contacts with impulse on one terminal and power frequency	 550 550

	voltage on opposite terminal (KVp/KV rms)	
19	1 minute power frequency withstand voltage (KV rms) (wet)	230
20	Rated breaking current capacity : i) Line charging at rated voltage at 90 degrees leading power factor ii) Small inductive current (A) rms iii) Short circuit current : (a) AC component (KA) (b) % DC component	 50 A 0.5 to 10 without switching O/V exceeding 2.3 p.u. 40.0 Corresponding to minimum Opening time as per IEC - 56
21	Rated short circuit making current capacity (KA)	78.75
22	Permissible limit of temperature rise	As per IS.
23	Max. acceptable difference in the instants of closing/opening of contacts : (i) Within a pole (ms) (ii) Between poles (ms)	 5 10
24	Min. creepage distance of support insulator (mm)	3400
25	Short time current carrying capability for three seconds (KA)	40
26	Rating of auxiliary contacts	10 A
27	Breaking capacity of auxiliary contacts	10 A DC with the circuit time constant less than 20ms at the rated voltage.
28	Noise level at base and upto 50metres	140 dB (max.)
29	Seismic acceleration	0.3g
30	Capacitance Current switching Line Charging Cable Charging Capacitor Banks	Conforming to Class C1 as per IEC 62271-100
31	Mechanical Endurance Test	Conforming to Class M1 as per IEC 62271-100

ii) Current Transformer:

Sl. No	**Item**	**Specifications-110 KV CT**
1	Type of CT/Installation	Single Phase, Dead/Live tank, oil filled hermetically sealed, self cooled outdoor type
2	Type of mounting	Pedestal/structure mounting type
3	Suitable for system frequency	50 Hz

4	Highest system voltage	132 KV (rms)
5	Current ratio A/A (a) 1200-600-300/1A (5Core) (b) 600-300-150/1A (5Core)	(a) Core 1, 2& 3 – 1200-600–300 /1A Core 4 & 5 – 1200-600/1A (b) Core 1, 2& 3 – 600-300-150 /1A Core 4 & 5 – 600-300/1A
6	Ratio Taps	On Secondary side.
7	Method of Earthing system where the Current Transformer will be installed.	Effectively earthed.
8	Rated continuous thermal Current (A).	120% for higher two ratio taps and 200% for lower ratio taps.
9	Acceptable limit of temperature rise above the specified ambient temperature for continuous operation at rated Current.	As per IS- 2705.
10	Acceptable partial discharge level at 1.2 UM / root 3	Less than 5 pico coulombs.
11	Max. Radio interference voltage at 1.1 times the maximum rated Voltage/ Root 3	2500 micro Volts.
12	1.2/50 micro second Lightning Impulse withstand Voltage (KV peak).	550
13	1 minute power frequency withstand voltage(Dry) KV(rms)	230
14	Power frequency overvoltage withstand requirement for secondary winding(KV rms) for 1 min.	3
15	Min. creepage distance of porcelain housing (mm).	3625
16	Rated short time withstand Current for 1 second duration(KA rms).	31.5 - for 1200-600-300/1A, 5Core & 600-300-150/1A, 5 Core
17	Rated dynamic withstand Current (KA peak)	78.75- for 1200-600-300/1A, 5Core & 600-300-150/1A, 5 Core
18	Maximum dielectric dissipation factor at Um/ root 3	0.005
19	Number of terminals in control cabinet.	All contacts and control circuit to be wired upto control cabinet plus 20% extra terminals exclusively for purchaser's use.
20	Seismic acceleration (Horizontal)	0.3g.
21	Primary to earth insulation resistance at 30 C	Min 20,000 M Ohms.

iii) 110 KV Lightening Arresters:

1. The lightning arresters shall be self supporting and suitable for pedestal mounting.
2. The heavy duty outdoor station class zinc oxide lightning arrester should have a nominal discharge current rating of 10,000 amps and suitable for use in 3 phase 50 hertz AC system with effectively earthed neutral system.
3. The lightning arresters shall be suitable for operation under the following service conditions.
    a. They will be installed outdoor and exposed to direct sun.
    b. The ambient temperature will be within the range of +10 -50 centigrade
    c. The altitude will be less than 1000 meters.
    d. The frequency of supply will be 50 hz with a variation of plus or minus 3% (range 48.5hz to 51.5hz)
    e. The power frequency voltage between the line and earth terminals of the arresters will not exceed the rated voltage of lightning arresters.
    f. The maximum atmospheric humidity will be in the range of 95%
    g. Each individual unit of surge arrester shall be hermetically sealed and fully protected against ingress of moisture. The hermetic seal shall be effective for the entire life time of the arresters and under the specified service condition.
    h. The surge arrester shall be suitable for pedestal type mounting.
    i. All the necessary flanges bolts, nuts, clamps etc. required for assembly of complete arrester with accessories.
    j. Pressure relief Class- A Discharge class-III for 110kV

110KV
Highest - 132 KV
Rating - 96KV
10 KA
IEC - 99-4
IS - 3370 part I

iv) 110 KV Electromagnetic Voltage Transformers

1	Type	110 KV voltage transformer (Electromagnetic type) outdoor oil filled, self cooled, nitrogen filled, sealed type suitable for effectively earthed system.
2	Type of mounting structure TNEB scope	Pedestal/structure mounting type
3	Normal system voltage	110 KV
4	Highest system voltage	132 KV (rms)
5	frequency	50 c/s
6	Voltage ratio (a) rated primary voltage (KV RMS) (b)secondary voltage(V)	 110KV/√3 wdg – I : 110/√3 Wdg-II : 110 Wdg-III : 110/√3
7	Method of earthing system where the EMVT will be installed.	Effectively earthed
8	1.2/50 microsecond lightning impulse withstand voltage (KVP)	550
9	1 minute dry power frequency on the porcelain bushing withstand voltage (KV rms)	230
10	Min. creepage distance of porcelain (mm)	3400
11	Rated voltage factor	1.5 for 30 seconds 1.2 for continuous
12	Maximum dielectric dissipation factor at Um/√3	0.005
13	1 minute power frequency withstand voltage for secondary winding (KV) rms	3 KV rms for all winding
14	Partial discharge level at 1.2 Um / root 3 (pico coulombs)	Less than 5
15	Maximum temperature rise over ambient of 50 degree C	As per IEC-186
16	Rated total thermal burden	Wdg - I 200 VA Total Wdg - II 100 VA 500 VA Wdg - III 200 VA
17	Seismic acceleration (Horizontal)	0.3g.

v) 5 MVA, 110/11 KV Power Transformers with OLTC.

Sl. No.	Description	Requirement	
1	Maximum continuous rating (MVA)		
	(a) HV	5	
	(b) LV	5	
2	Type of cooling	a) ONAN	
3	Temperature rise over ambient of 45º C		
	(a) winding	55^0 C	
	(b) oil	50^0 C	
	(c) Limit of hot spot temperature with weighted average ambient temperature of 32^0C	98^0 C	
	d)) Maximum hot spot temperature	140^0 C	
4	Maximum flex density at normal voltage and frequency	1.6 Tesla	
5	(i) Rated system voltage (KV)		
	a) H.V. winding	110	
	b) L.V. winding	11	
	(ii) Variation in the system voltage	± 10%	
6	Number of phases	3	
7	Rated frequency	50 ± 5%	
8	Voltage ratio (KV)	110/11	
9	(i) Type of connection		
	(a) HV	Delta	
	(b) LV	Star	
	(ii) Vector group	Dyn11	
	(iii) Neutral	Effectively earthed	
10	Type of winding		
	(a) HV	Continuous disc	
	c) LV Max	Continuous disc/Helical	
11	Max current density of winding	300A/cm^2	
12	Insulation levels	HV	LV & Neutral
	(1) Winding Voltage KV (RMS)	110	11
	(2) Highest system voltage KV (RMS)	132	12
	(3) Lighting impulse withstand voltage KV (PEAK)	550	75
	(4) Power frequency rated short duration with stand voltage (KV rms)	230	28
13	Duration of short circuit withstand capacity	2 seconds	
14	(a) Tap changer	OLTC with remote control panel	
	(b) Tapping range	On HV winding for HV variation of (+) 5% to (-) 15% in steps of 1.25%	

15	D.C. voltage for relays etc.	110 Volts	
16	Percentage impedance	6 % 10% tolerance	
17	Cooling medium/insulating oil	EHV grade transformer oil conforming to IS 335.	
18	Losses	Losses as per specification	
	(a) No-load loss	5.0 KW (Max)	
	(b) Load loss	24.0 KW (Max)	
19	Termination	HV Outdoor Bushing LV Cable box two numbers 3½ X 180 Sq.m Al. UG cable	
20	Terminal Bushing	HV	LV and Neutral
	System voltage	110	11
	(a) Voltage rating (KV rms)	145	36
	(b) Current rating (Amps)	320	2000
	(c) Impulse withstand voltage (KV Peak)	650	75
21	Tank		
	i) Type	Conventional	
	ii) Thickness (mm) a) Bottom b) Sides c) Top	 12 10 10	
	iii) Pressure release device a)Type b) Number	 Safety valve type spring operated One	
22	Clearances (mm)	Bushing	
		HV	LV
	a) Phase to phase	1200	280
	b) Phase to Earth	1050	140
23	Noise level	Less than 70 db	
24	Oil preservation (Main conservator) (OLTC conservator)	2 Nos. silicagel breather associated with oil seal closing valve and 1 No. silicagel breather with oil seal.	
25	Expected life period of the transformer	25 years	

vi) 110 KV Yard Equipment Protection:

Incoming line feeder	-	Distance protection (1, 2 ,3 Zone) IDMT OC and Earth fault
Transformers	-	IDMT over current with high set instanous element and earth fault. Bucholtz relay magnetic oil level gauge.
Bus coupler	-	IDMT overcurrent with high set instanous element and earth fault

13.2 Alternative source of power supply

Two numbers 500KVA(1W +1S) DG sets will be installed in Utility building at the Project site to feed the essential loads in the case of failure of the mains

1	Emergency lighting	:	60KW
2	NDBDI-1	:	100KW
3	NDBDI- 2	:	20KW
4	Exhaust blower	:	75KW
5	Dewatering pumps	:	50KW
6	Detector Assembly building	:	100KW
	Total	**:**	**405KW**

13.3 Power distribution

11 KV Power received from TNEB will be stepped down to 440 V, 50 Hz, TPN system at 2 locations, to feed all the loads. Transformers will be located in the INO campus:

i) Caverns (2 Nos Dry type transformers)

ii) Utility Building (3 Nos Dry type transformers)

Refer Drg No. *LD-INO-DPR- 1* to *LD-INO-DPR- 15.*

13.3.1 Envisaged electrical loads and transformer rating

Caverns

a) ICAL Electronics	: 400 KW (for both phases)
b) ICAL Magnets	: 500 KW (for both phases)
c) Air Handling Units	: 80 KW
d) Booster Pumps	: 23 KW
e) AHU Heaters	: 117 KW
f) De-watering Pumps	: 15 KW
g) Lighting	: 60KW
h) Crane	: 30 KW
i) Lift	: 5 KW
j) Cooling Water Pumps	: 75 KW
k) General Power Outlets	: 30 KW
l) Cavern – 3	: 100 KW
m) Future Expansion	: 100KW
Total	1535 KW

2Nos 2000 KVA Transformer will be provided (1W+1S)

13.3.2 Surface facilities

a) AC Chillers	: 360 KW
b) Chilled Water Pumps	: 75 KW
c) Condenser Water Pumps	: 45 KW
d) Cooling Tower Fans	: 36 KW
e) Supply Blowers	: 225 KW
f) Exhaust Blowers	: 225 KW
g) NDBD-I	: 100 KW
h) Water pumps	: 30 KW
i) NDBD - II	: 50 KW
	1279 KW

13.3.3 Surface facilities

a) Workshop loads	: 30 KW
b) Kitchen Equipment	: 40 KW
c) Water Heater	: 35 KW
d) General Power Outlets	: 200 KW
e) Lighting	: 120 KW
f) Water Pumps	: 30 KW
g) Surface Lab	: 20 KW
h) Residential Loads	: 50 KW
i) Water & sewage treatment	: 20 KW
j) Detector Assembly building	: 100 KW
k) AC load	: 150 KW
l) Future Expansion	: 300 KW
	1075 KW

Total (1279+1075) = 2359KW, 3Nos 2000KVA transformer will be provided (2W+1S)

Essential loads (safety related, critical to experimental set up, minimum ventilation and approximately 30% lighting at strategic locations) will be segregated from the normal loads and automatically fed by the DG sets in case of Mains failure.

The AC voltage will be further stepped down to different lower levels and also rectified to feed the different types of loads associated with experimental set up. This will be taken care of by the user at the time of experimental laboratory set up.

110 V, 120AH DC batteries will be used for protection and monitoring of electrical systems.

Critical instrumentation loads will be connected to independent Uninterrupted Power Supply System (UPS) of required capacity and Voltage. This requirement will be taken care of by the user at the time of experimental set up.

13.4 Salient features/specifications of power distribution equipments

(i) Transformers

i)	Location	Utility Building	Cavern
ii)	Capacity	3 x 2000 KVA	2 x 2000 KVA
iii)	Type & Insulation	Dry, Class "F"	Dry, Class "F"
iv)	No Load voltage ratio	11 KV/433 V	11 KV/433 V
v)	Phase, Frequency	3 Ph, 50 Hz	3 Ph, 50 Hz
vi)	Winding type	Copper Double wound	Copper Double wound
vii)	Vector Group	Dyn11	Dyn11
viii)	Tapping on primary side	± 5% in steps of 2.5% (Off load tap changer)	± 5% in steps of 2.5% (Off load tap changer)
ix)	% Impedance	5.5%	5.5%
x)	Cooling	ON AN	ON AN
xi)	Terminal arrangement		
	HV	Cable Box	Cable Box
	LV	Bus duct flange	Bus duct flange
xii)	Enclosure	IP 23	IP 23
xiii)	Installation	Indoor	Indoor

(ii) DG Set

The DG set will be turbocharged, water-cooled radiator type, over load capacity 1 hr in every 12 hrs of continuous operation. The set will be within the acoustic enclosure. The DG set will be capable of taking up the load within 20 seconds from start up (including allowance for multiple cranking) and take full load in 40 seconds.

Acoustic Enclosure

The enclosure shall be designed to get a sound level not more than 70 db (at 3m from DG set). Acoustic material will be Resin bonded rock wool (for sound insulation and as heat barrier).

(iii) Emergency Supply

The following scheme will be incorporated in the emergency back up system (Panel EP).

On mains failure (total failure, single phasing, low frequency or low voltage), the DG set will start. On build up of voltage, the Mains CB will trip and then DG CB will close. On Mains resumption, after preset time delay, the DG CB will open and the Mains CB will close. The DG set will stop, after running idly for preset time. In case, the main supply fails during this period, the DG will resume feeding the bus immediately.

Switching of motor loads to DG will be manually initiated. While changing over to Mains, the motor loads are not expected to be effected due to fast transfer.

(iv) 11 KV Switchgear

	Description	**HTP1**	**HTP2**
a)	Location	Utility Building	Cavern
b)	Type	Horizontal isolation, Horizontal draw out	Horizontal isolation, Horizontal draw out
c)	Fault Rating	25 KA	25 KA

d)	Circuit Breaker	630A/25 KA VCB	630A/25 KA VCB
e)	Bus Bars	Al, insulated	Al, insulated
f)	Enclosure	IP 54	IP 54
g)	Control & Indication	110 v DC	110 v DC
h)	Installation	Indoor	Indoor

(v) 415 V Main Switch Board

	Description	**MP1**	**MP2**
a	Location	Utility Building	Cavern
b	Type	Horizontal isolation, Horizontal draw out	Horizontal isolation, Horizontal draw out
c	Fault Rating	50 KA	50 KA
d	Current ration		
	i) Incoming & Bus coupler	3200 A	3200 A
	ii) Out going	630 A	630 A
e	Bus Bars	Al, insulated	Al, insulated
f	Enclosure	IP 54	IP 54
g	Control & Indication	110 V DC	110 V DC
h	Installation	Indoor	Indoor

(vi) Other 415 V switchgear/Motor Control center

	Description	**Emergency Panel (EP)**		**Others**
a	Location	Utility Building Pottipuram INO SS		Other Load center
b	Type	4 pole draw out		4 pole draw out
c	Fault Rating	50 KA		50 KA
d	Feeders			
	i. Incomer & Bus coupler	630 A, 50 KA 4 pole ACB		Fuse switches
	ii. Out going	Fuse switches		Fuse switches
e	Bus Bars	Al, insulated	Al, insulated	Al, insulated
f	Enclosure	IP 54	IP 54	IP 54
g	Control & Indication	110 v DC for CBs & 240 V AC for others		240 V AC
h	Installation	Indoor	Indoor	Indoor

(Fuse switches will be rated for 630 A, 400 A, 250 A, 100 A, 63 A as per schematic and fused appropriately for the load/application)

(vii) Protection

a	Circuit Breaker Feeders		
i.	Incomer feeders:	:	IDMT OC & EF
ii	Bus coupler	:	IDMT OC with HS element for phase fault and instantaneous element for EF.
iii	Transformer	:	IDMT OC with HS element for phase fault and inst. Element for EF on primary, IDMT OC & EF on Secondary, Rotor EF, Additional IDMT EF relay (connected to CT in Neutral to Ground path), winding temperature alarm & Trip.
iv	Other outgoing	:	IDMT OC & EF
b	DG Set	:	Over load, under voltage, earth leakage, under frequency, over speed, low lubricating oil pressure, high cooling water temperature, fuel level low (alarm).
c	Motor feeders		
i	Chiller Motors	:	Over Current, Earth fault, stalling. Winding temperature, phase reversal and single phasing
ii	Blowers	:	Over current, Earth fault, single phasing with digital relay
iii	Other motors	:	Bimetal thermal overload protection with built in differential single phasing protection

All relays (except BMR) will be numerical type with remote programming facility.

(viii) Starting gear for motors

All chiller motors and blower motors above 50 KW will be provided with Variable Frequency Drive for smooth starting and energy savings. All motors above 20 KW, connected to emergency supply will be provided with soft starters. Motors rated above 20 KW, connected to the normal supply will have Star/Delta starters. All other smaller motors will have direct online starters.

(ix) Cable

11 KV cables will be 3 core 185 sq.mm Aluminium conductor XLPE insulated, extruded inner sheathed, single round wire armoured and with fire retardant PVC overall sheathing.

440 V cables will be 1100 V grade XLPE insulated, extruded inner sheathed, strip wire armoured and with fire retardant overall sheathing.

440 V cables will have copper conductors upto 10 sq.mm and aluminium conductors above 10 sq.mm size.

All cables will be provided with fire retardant sheathing and suitable identification tags at regular interval of 10 m. Fire barrier will be provided along cable routes at appropriate locations.

(x) DC Power supplies

DC Power Supplies for Electrical system control are as detailed bellow:

(a) Charger

i)	Input Voltage	:	440 V ± 10%, 3 phase, 50 Hz.
ii)	Output Voltage	:	110 V±2 % DC
iii)	Ripple content	:	< 2%
iv)	Output Current	:	60 A continuous
v)	Type	:	Fully automatic, static switching, digital control with float cum boost circuits

(b) Battery

i)	Type	:	Maintenance free sealed Lead Acid VRLA Batteries
ii)	Capacity	:	120 AH (10 hr discharge)

(xi) Earthing

Separate earthing system will be provided for

a) *System Neutral (Insulated) from the Transformer Neutral terminal to the earth pit.*
b) *Electrical Equipment body*
c) *Signal grounding*

For body grounding, 2 nos. (50 x 10 mm) GI strip main earth bus will be run along the tunnel wall, connecting 50 x 6 mm copper earth ring in Electrical distribution room (at cavern end) and similar ring in Switchgear room in utility building. 185 Sq strand copper conductor will be used for conducting the equipment to the 50x10mm GI earth bus.

Separate GI strip will be run to connect the earth terminal of power distribution transformers to the respective earth pits. The second earth connection for the transformer body will be from the pipes connected to the copper earth ring.

For grounding of neutral of Transformers in cavern, 3 GI strips will be run along the tunnel walls.

The GI strips for earthing will have welded straight joints.

For signal grounding of electronics circuits in the cavern complex, a 7 core 2.5 sqmm stranded tinned copper PVC insulated UG cable will be run along the tunnel, from signal grounding pit to control room. All the cores will be paralleled at either end (single point earthing).

For signal grounding copper rod earth electrode will be used. For transformer neutral & body (substations) copper plate electrodes are proposed. The feeder pillars and residential distribution panels will have GI pipe earthing.

(xii) Lightning protection

Lightning protection is proposed for utility building and Administrative block which also houses the surface lab.

Horizontal and down conductors will be of 70 sq.mm tinned stranded copper. Copper rod earth electrodes will be adopted.

Lightning protection will be provided in the 110 KV yard by suitably located lightning masts. Overhead ground wires will be avoided

(xiii) SCADA for utility equipment

The SCADA system proposed will cover supervision, monitoring and setting of limits for parameters (speed, current etc,) and building logics for interlocking and safe operation of

a) All circuit breakers

b) Chillers

c) Air handling units

d) Pumps

e) Heater banks in utility building and cavern.

The remote control operation will be done from the INO substation in utility building.

(xiv) Illumination system

Illumination system for proposed for the Cavern 1, 2, 3 & 4 and Access/Intermediate/Auxiliary tunnels includes the normal AC supply lighting and emergency AC supply lighting as well as emergency DC supply lighting in selected areas during the emergency conditions. The emergency AC lighting will provide about 30% of the total AC lighting in selected areas.

a) Normal AC supply for lighting

Normal supply for lighting load will be stepped down from 11 KV to 440 V AC through a step down transformer. Power supply for lighting will be distributed in the underground research laboratory (1) and (2) through wall mounted AC Distribution Board. Miniature circuit breaker will be provided for protection tripping as the fault level will not be high.

b) Emergency AC supply for lighting

Whenever the Main supply fails, Diesel Generator set will start automatically and the Emergency bus will get the supply. Suitable interlock will be provided for starting of DG set. The emergency AC supply will be extended through a separate AC Distribution Board. This will provide supply for illumination provided at strategic location. This system will account for about 30% of normal lighting. Whenever 11 KV resumes, DG set will be tripped automatically.

c) Emergency DC Supply for lighting:

In addition to the above, it is proposed to provide emergency DC lighting in specific areas like control rooms, diesel generator room and other areas where lighting is required for safe movement of personnel. A separate DC source will also be provided. Whenever both 11 KV system and DG set fail, the DC system will provide DC supply for lighting through DC Distribution Board. DC lightings will also be provided only at strategic location. Whenever AC supply resumes, the DC Emergency will go off automatically.

d) Lighting & Power Outlet

The 11 KV AC supply will be stepped down to 440 V AC through a transformer and this will be connected to lighting distribution Board. Power outlets and lights will be connected to MCB distribution Boards with 63 A TPN ELCB as the incomer. LDB will have adequate number of single phase outgoing feeders controlled by miniature circuit breakers.

At least one 5 Amps and 15 Amps receptacles will be provided in each cabin room/enclosed area. In other areas, adequate number of receptacles will be provided. All receptacles will be 3 pin type and will be controlled with a switch.

Concealed wiring will be adopted every where except in the tunnels and caverns. Rigid PVC conduits will be used in the residential buildings including guest house/hostel complex. In all other areas rigid flow coated/Galvanised MS conduits will be used. Fire retardant PVC insulated earth conductor will run along with phase and neutral wires in the conduit. Fire retardant Modular wiring accessories will be used.

e) Technical Data

The illumination Lux requirements proposed are as given below:

Sl No.	Description	Illumination Level (Lux)	Lighting Proposed
(i)	Cavern-1	200	Metal Halide
(ii)	Cavern-2,3,4	200	Industrial Fluorescent Lamps
(iii)	Main access tunnel	10	CFL Fitting
(iv)	Switchgear room	300	Industrial Fluorescent Lamps

(v)	Office Building	300	Mirror optic Fluorescent
(vi)	Control Room	400	Mirror Optic Fluorescent Lamps
(vii)	Landing in caverns	300	Fluorescent Lamps
(viii)	Corridors	100	CFL/ LED Lamps
(ix)	Street Lighting a. Main road> 6 m b. Small roads	 15 10	 Post top lantern (Multiple CFL) Solar lights with CFL
(x)	Kitchen	200	Vapour proof fluorescent
(xi)	Dining	250	CFL Decorative
(xii)	Bath & Toilet	150	CFL wall mounted
(xiii)	Blower rooms/AC Package room	200	Wall mounted fluorescent

(xv) Power outlet / lighting wiring

Power outlets and lights will be connected to MCB distribution boards with 63 A TPN ELCB as the incomer (Mains control).

Concealed wiring will be adopted everywhere except in the tunnel and cavern.

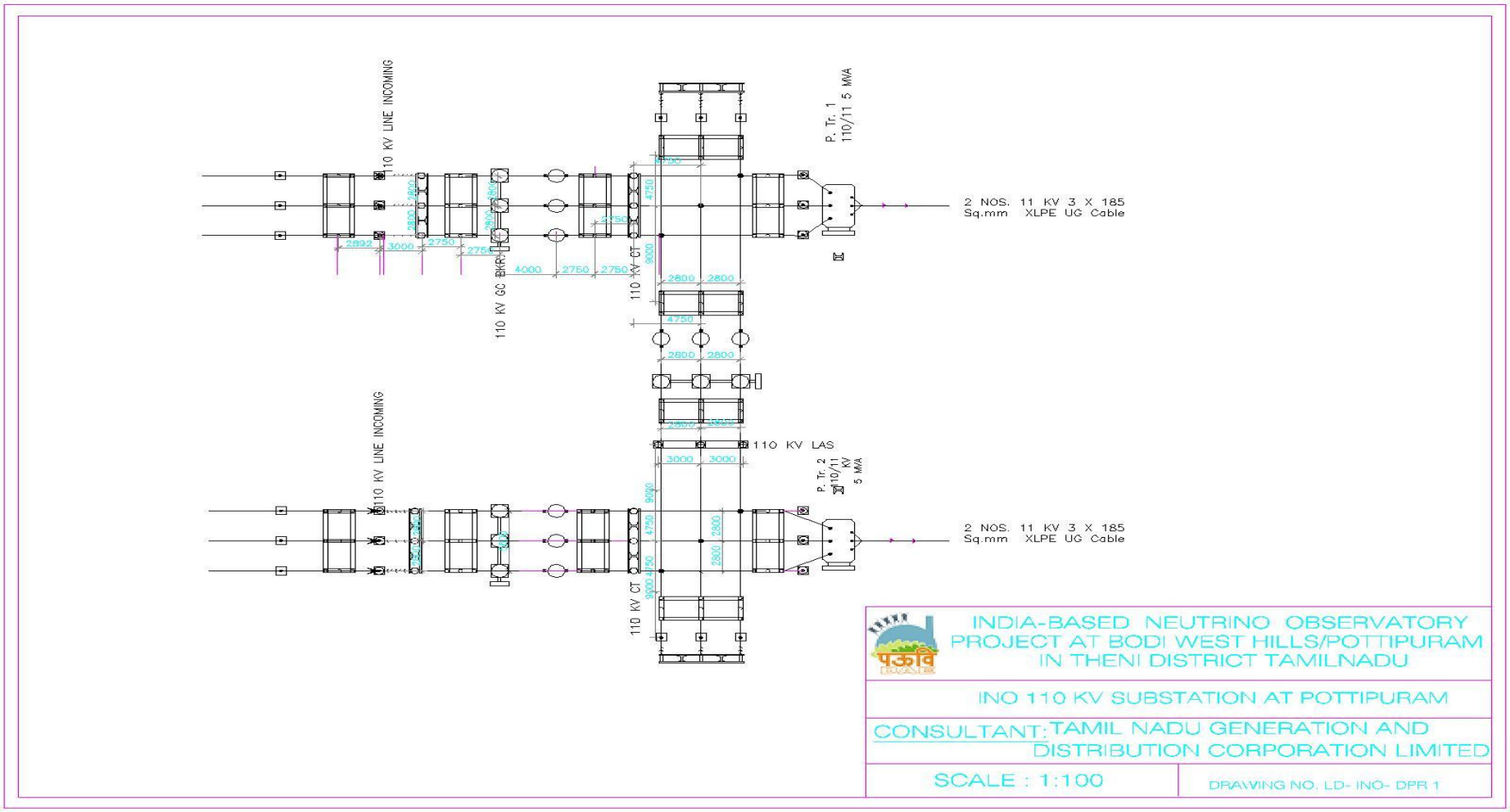
Rigid PVC conduits will be used in the residential buildings including guest house/hostel complex. In all other areas rigid flow coated/galvanized MS conduits will be used.

Fire retardant PVC insulated, copper multi stranded wires will be used. Insulated earth conductor will run along with phase and neutral wires in the conduit.

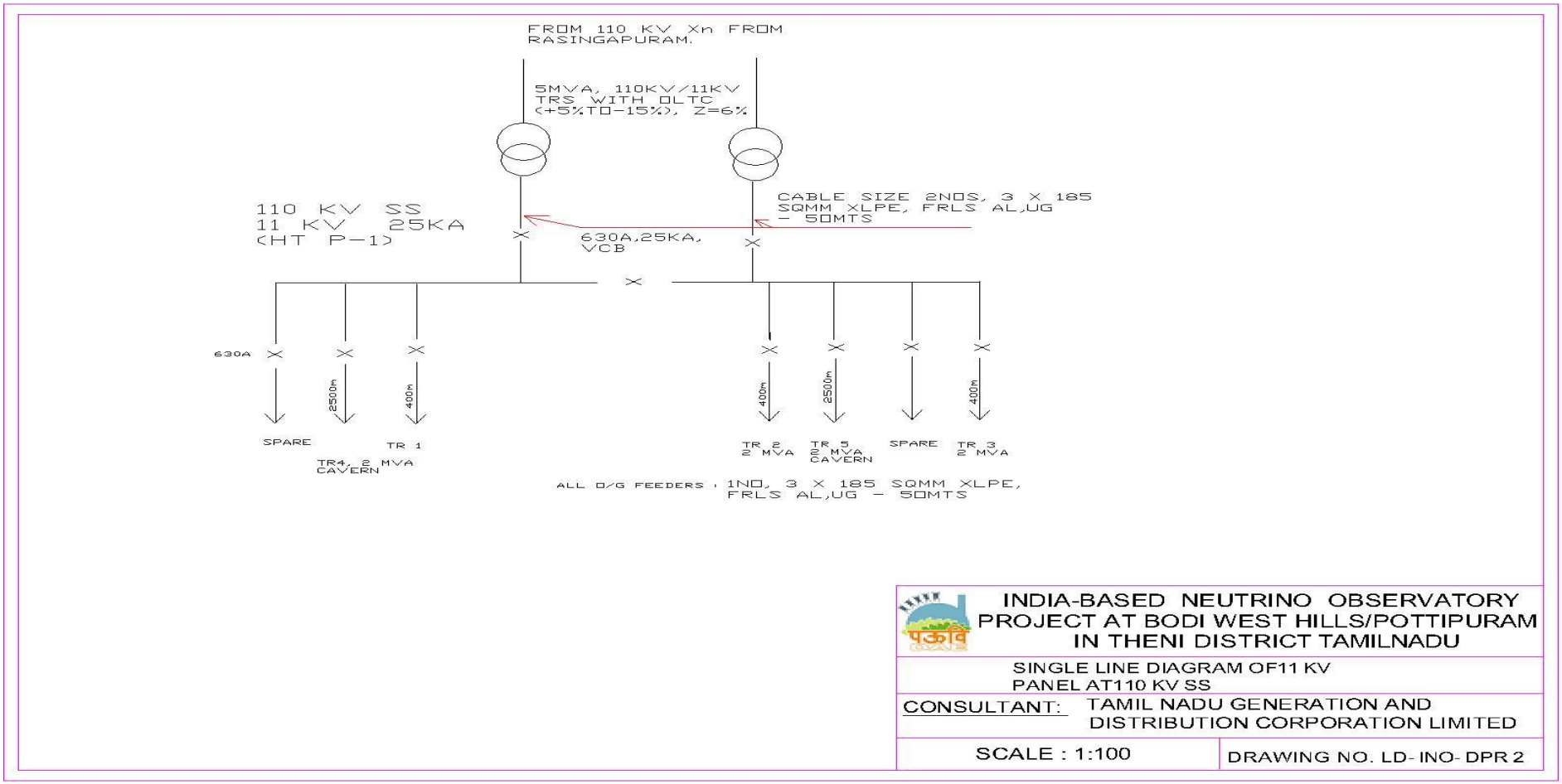
Fire retardant Modular wiring accessories will be used.

(xvi) Capacitor Banks for Power factor improvement:

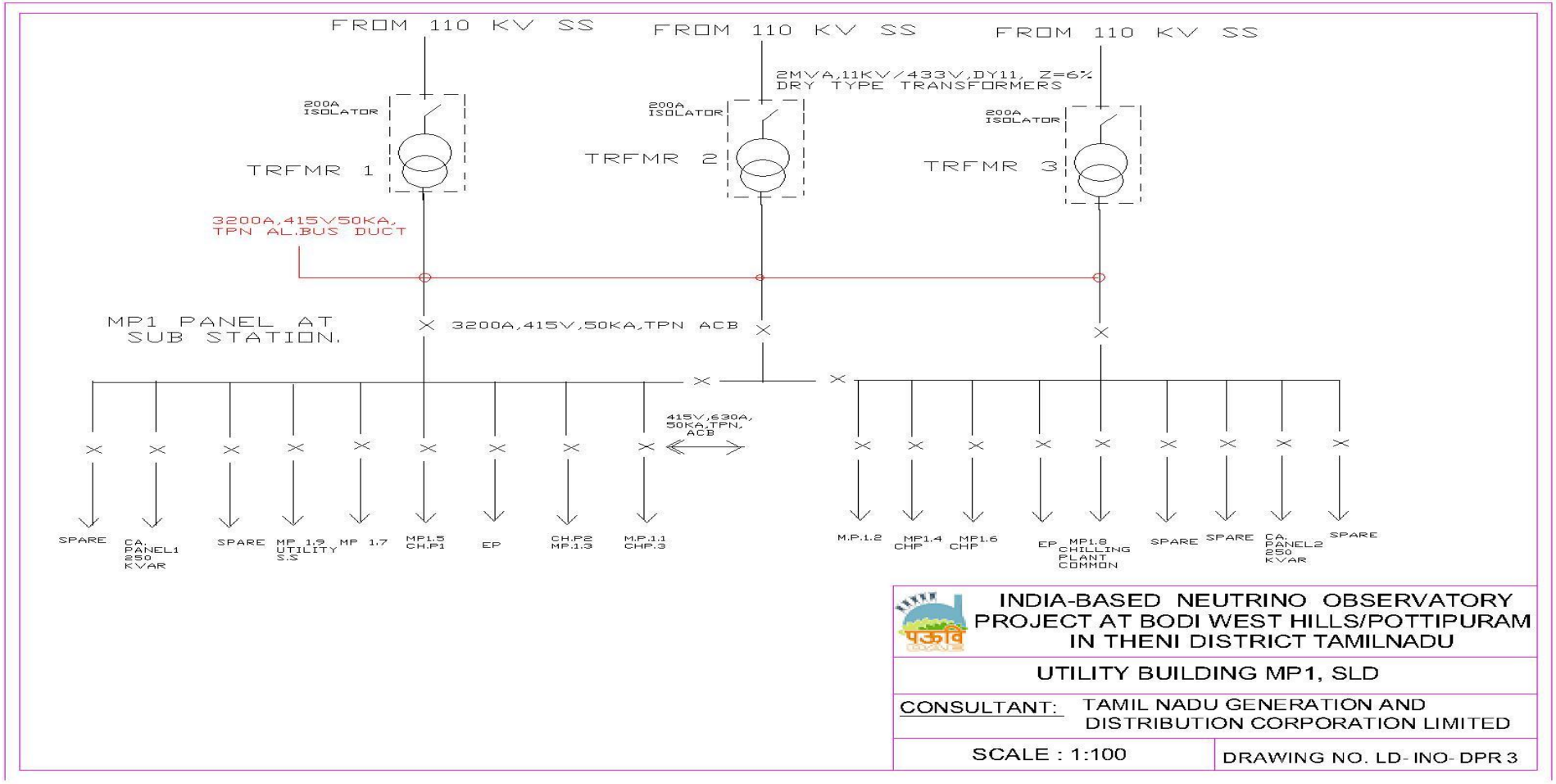
Capacitor banks of adequate capacity (2 Nos 250 KVAR in Utility building and 2 Nos. 159 KVAR in Cavern-2) with automatic power factor controls will be provided in INO SS to improve power factor.



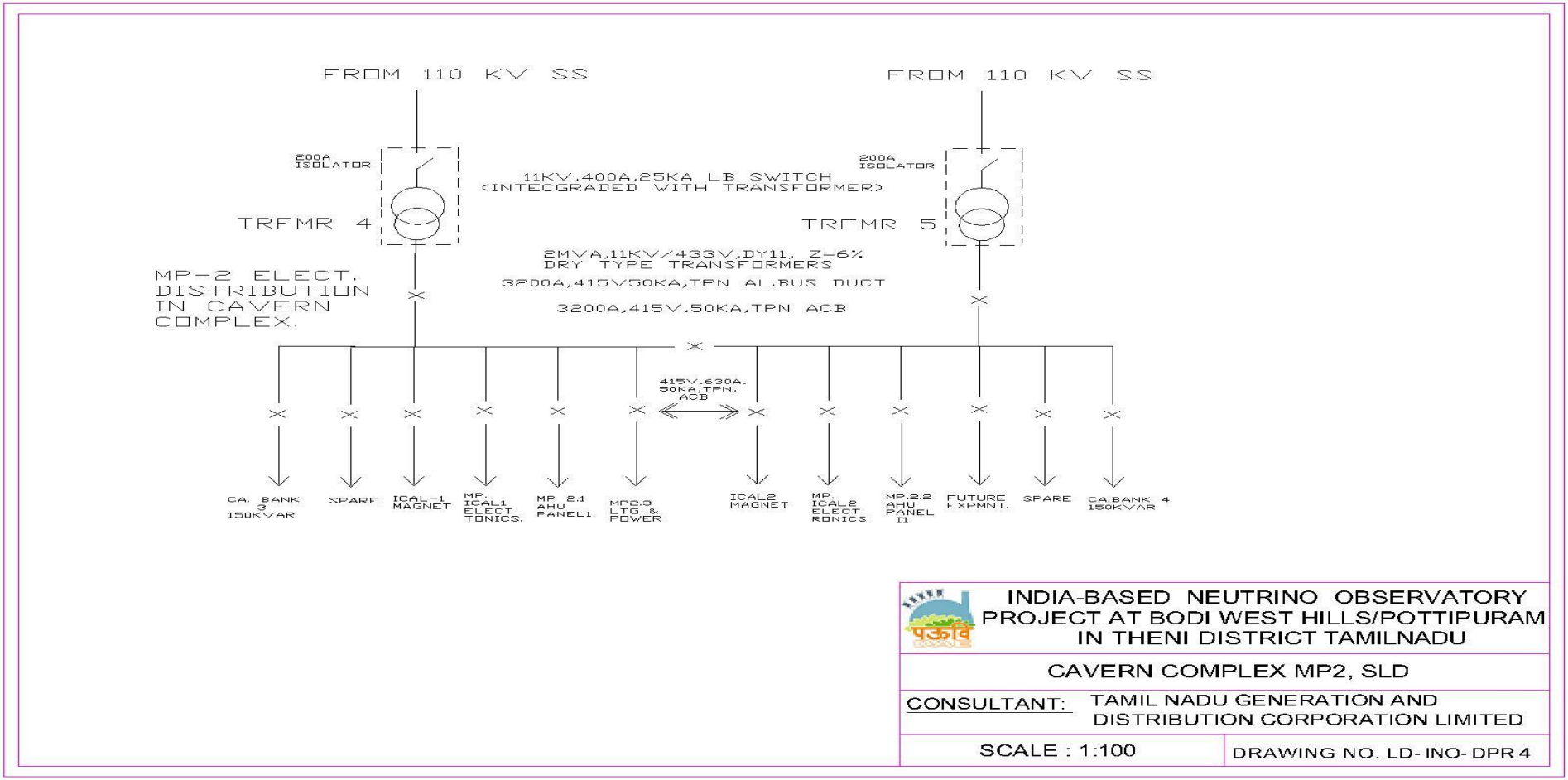
LD-INO-DPR- 1 INO 110 KV Sub-station at Pottipuram



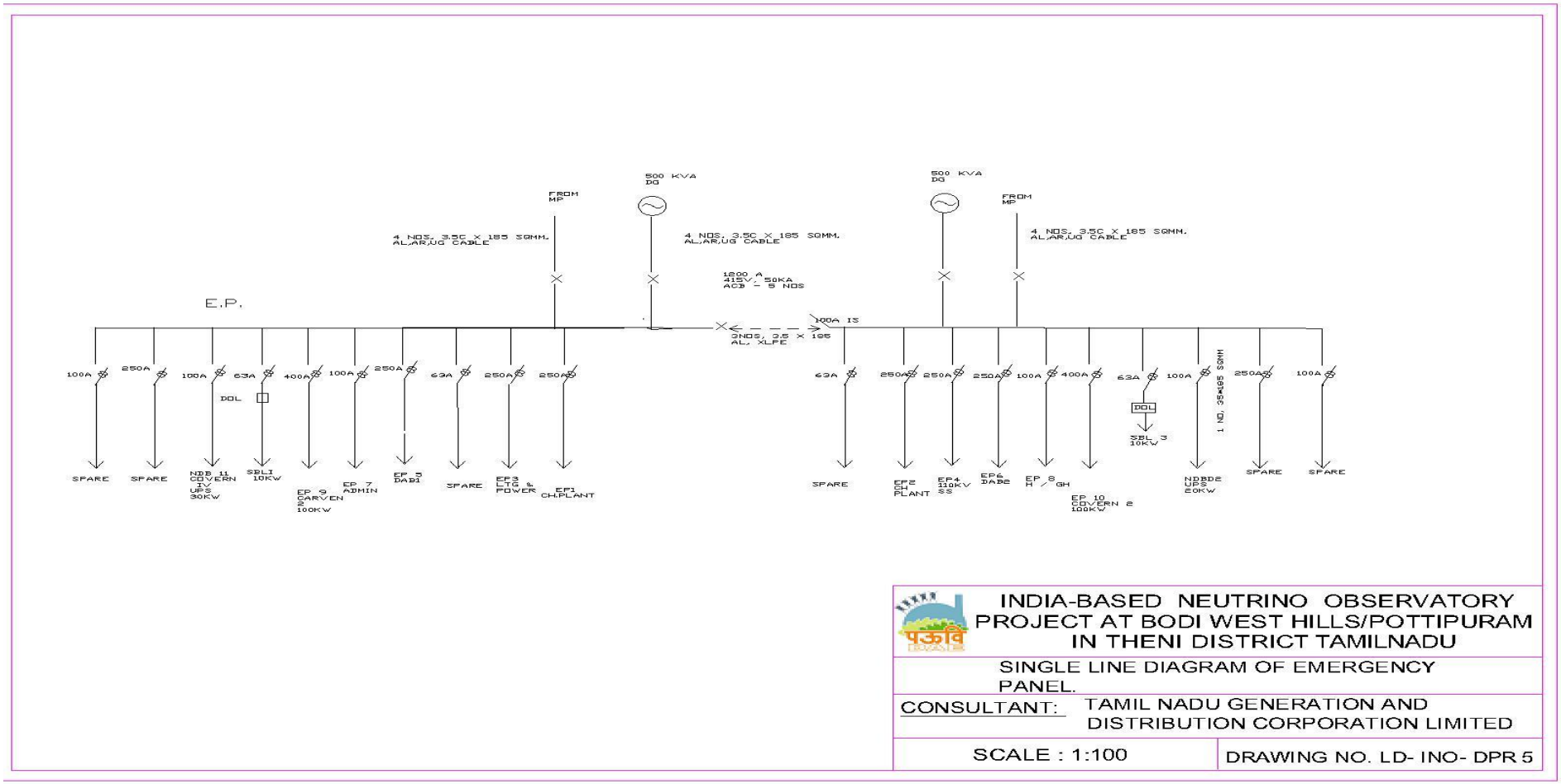
LD-INO-DPR- 2 11 KV Panel at 110 KV SS



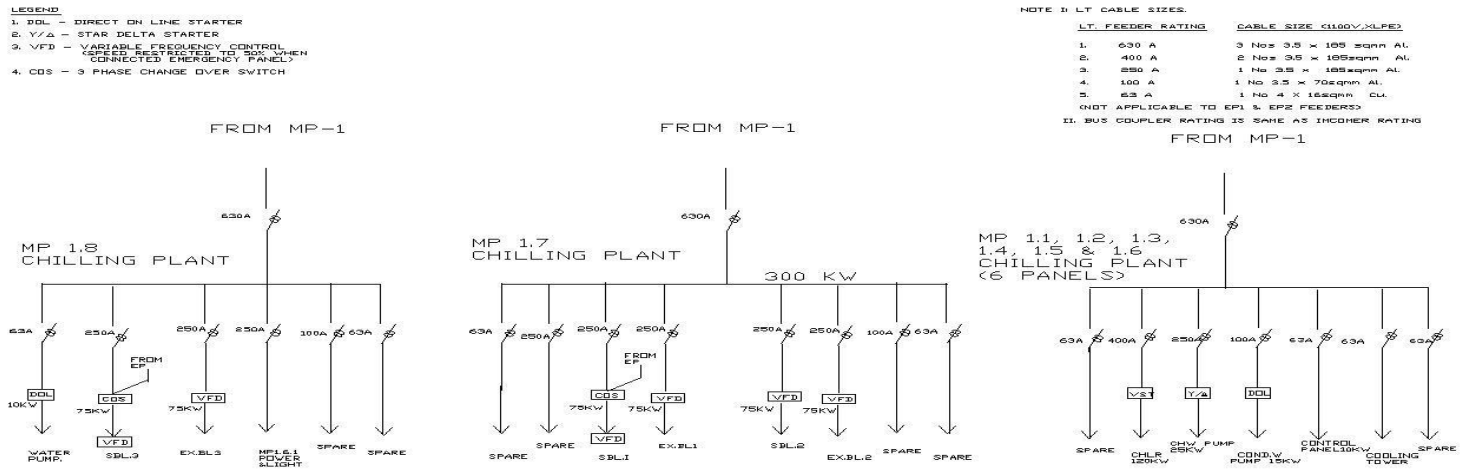
LD-INO-DPR- 3 Utility building MP1



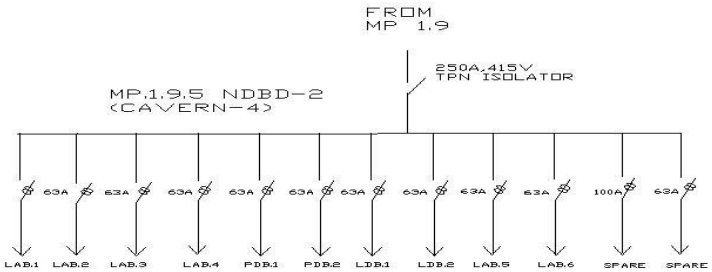
LD-INO-DPR- 4 Cavern complex MP2

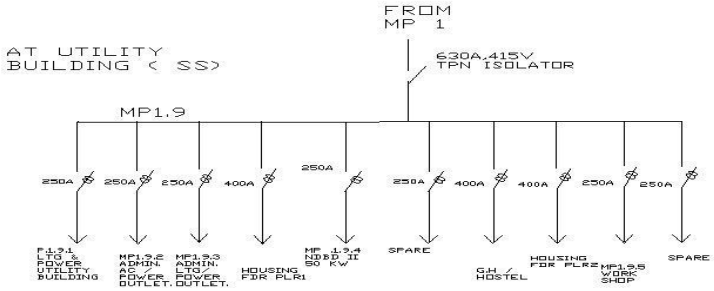


LD-INO-DPR- 5 Emergency panel



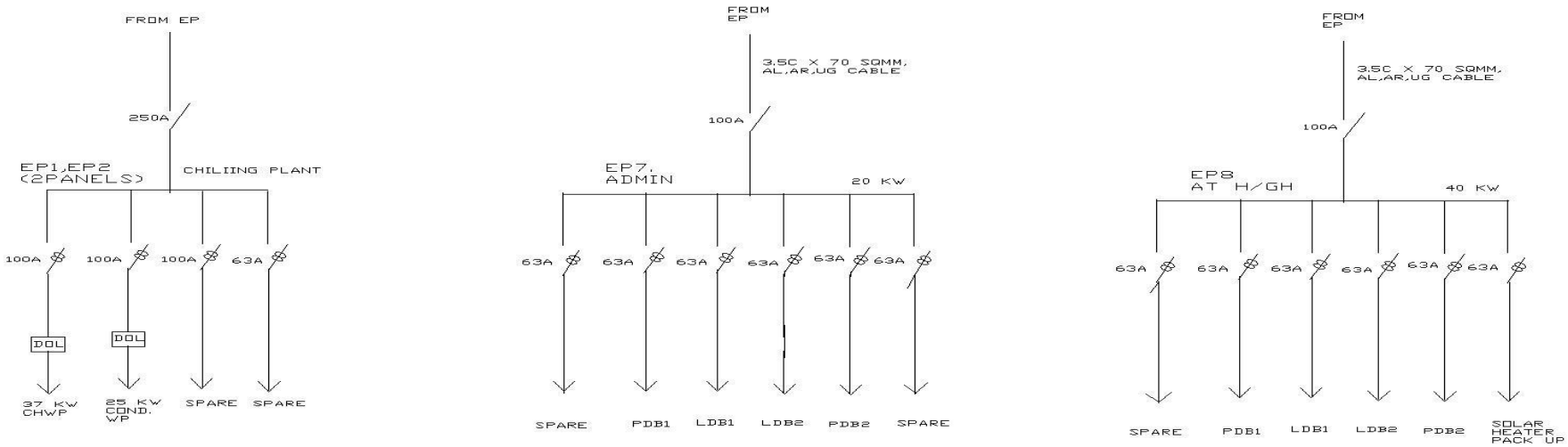
LD-INO-DPR- 6 Electrical distribution at utility building chilling plant



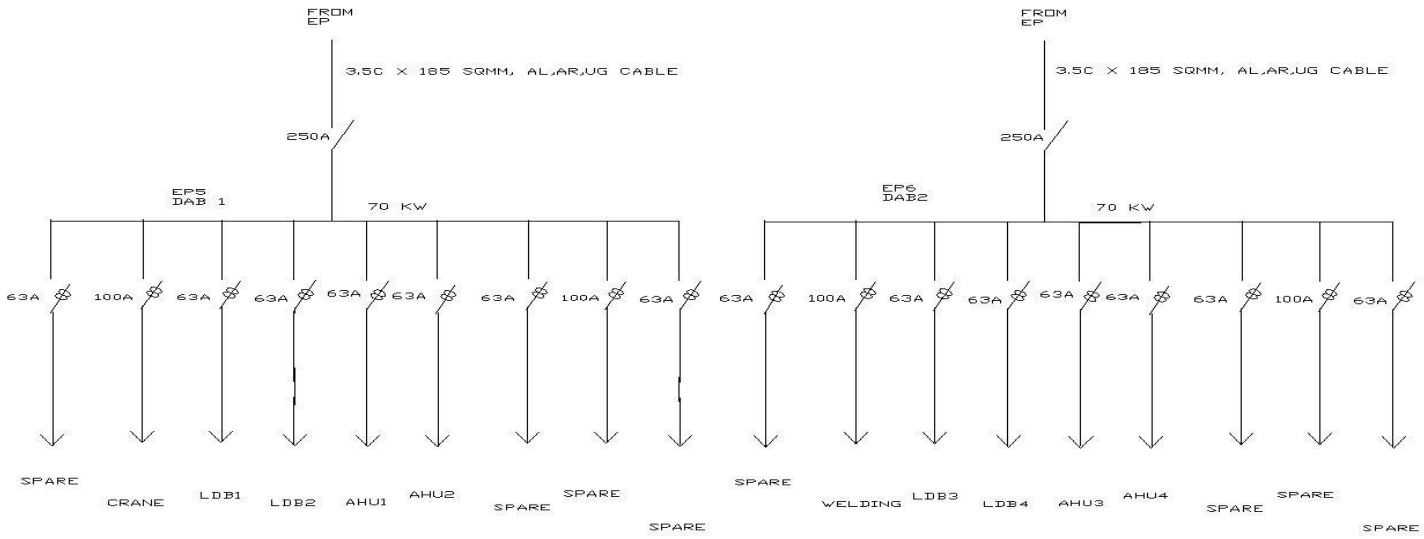


INDIA-BASED NEUTRINO OBSERVATORY PROJECT AT BODI WEST HILLS/POTTIPURAM IN THENI DISTRICT TAMILNADU	
SINGLE LINE DIAGRAM OF UTILITY BUILDING MP 1.9, MP1.9.5	
CONSULTANT: TAMIL NADU GENERATION AND DISTRIBUTION CORPORATION LIMITED	
SCALE : 1:100	DRAWING NO. LD- INO- DPR 7

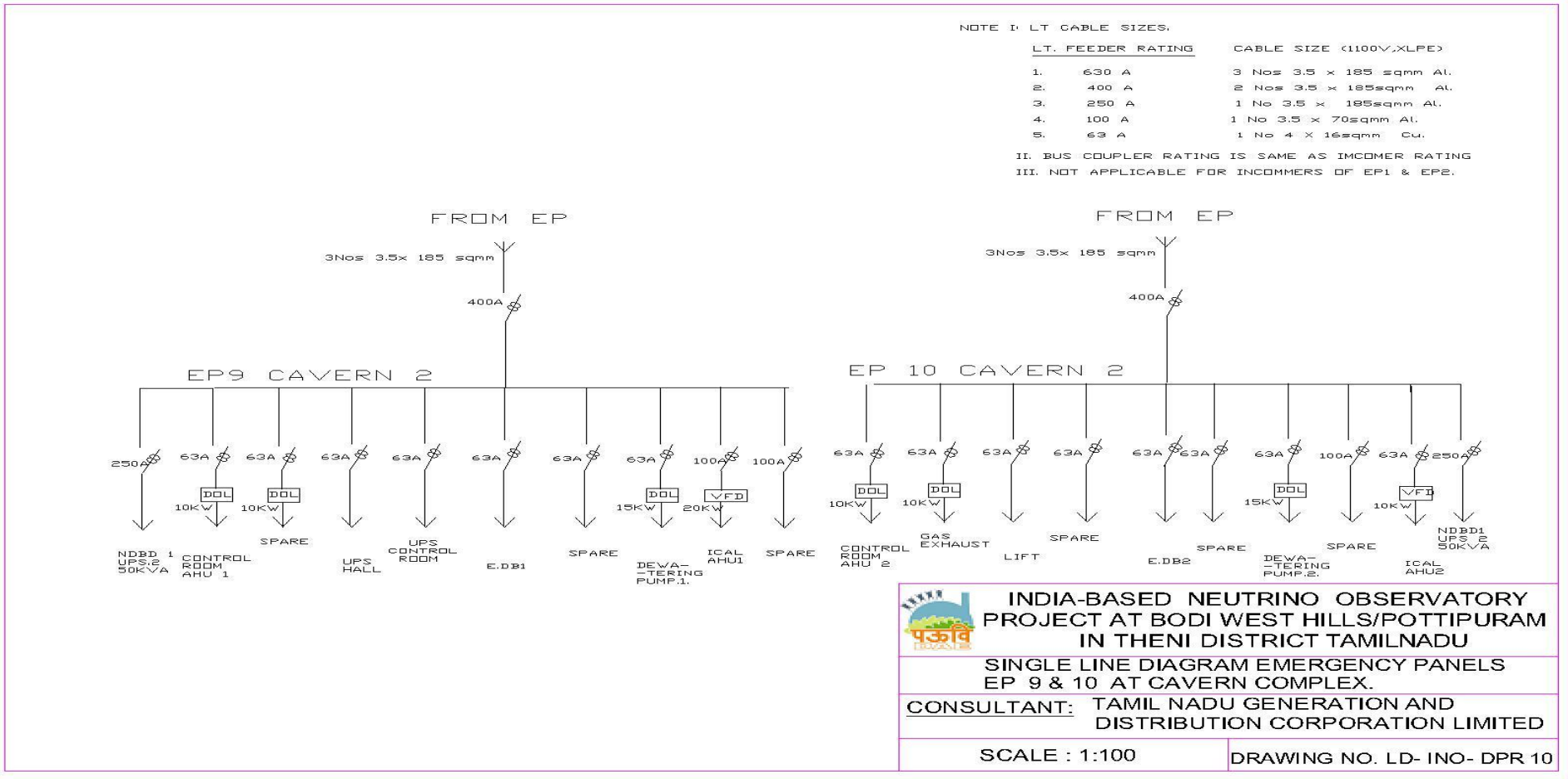
LD-INO-DPR- 7 Utility building MP 1.9, MP 1.9.5



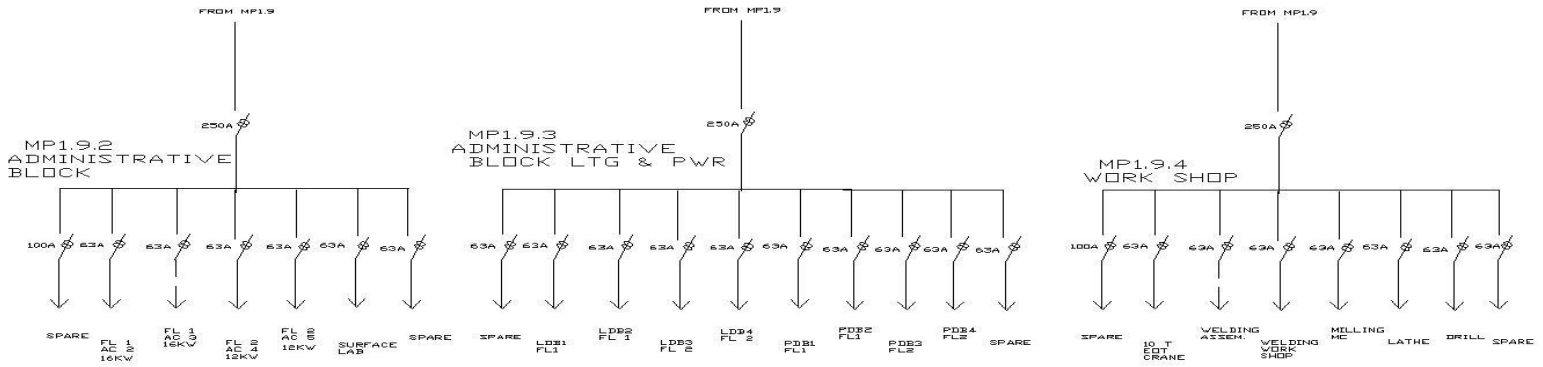
LD-INO-DPR- 8 Emergency panel EP – 1, 2, 7 & 8



LD-INO-DPR- 9 Emergency panel EP – 5 & 6



LD-INO-DPR- 10 Emergency panels EP – 9 & 10 at cavern complex



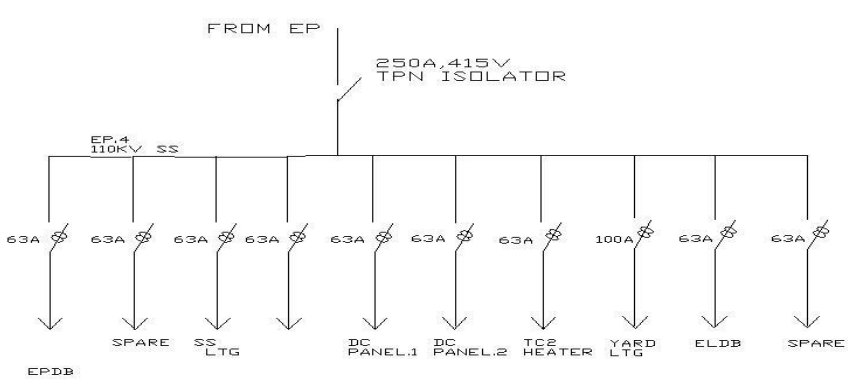
INDIA-BASED NEUTRINO OBSERVATORY
PROJECT AT BODI WEST HILLS/POTTIPURAM
IN THENI DISTRICT TAMILNADU

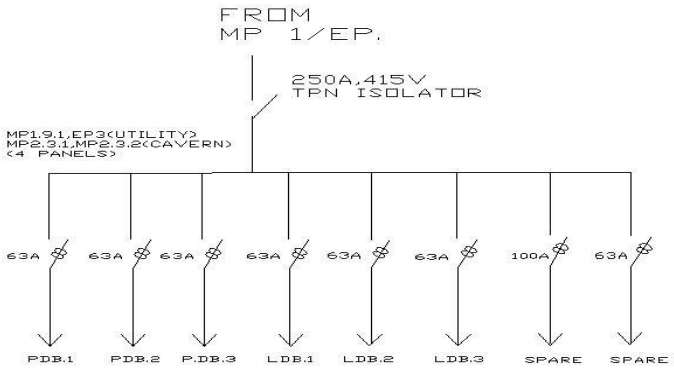
SINGLE LINE DIAGRAM OF ELECTRICAL
DISTRIBUTION AT HOUSING AREA.

CONSULTANT: TAMIL NADU GENERATION AND
DISTRIBUTION CORPORATION LIMITED

SCALE : 1:100 | DRAWING NO. LD- INO- DPR 11

LD-INO-DPR- 11 Electrical distribution at housing area





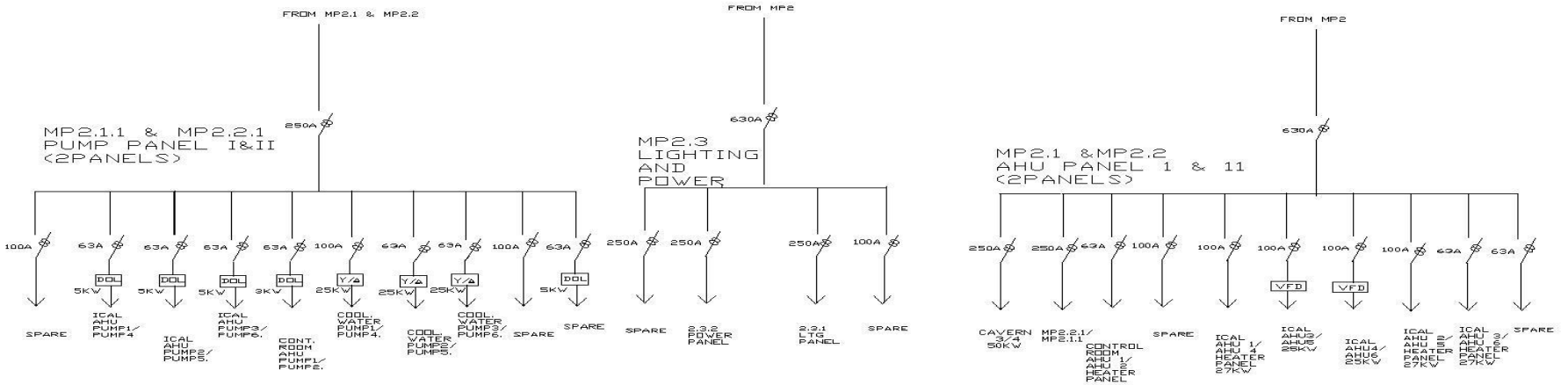
INDIA-BASED NEUTRINO OBSERVATORY
PROJECT AT BODI WEST HILLS/POTTIPURAM
IN THENI DISTRICT TAMILNADU

SINGLE LINE DIAGRAM OF EP 4, 110 KV SS AND
MP 1.9.1, EP 3, MP2.3.1, MP2.3.2

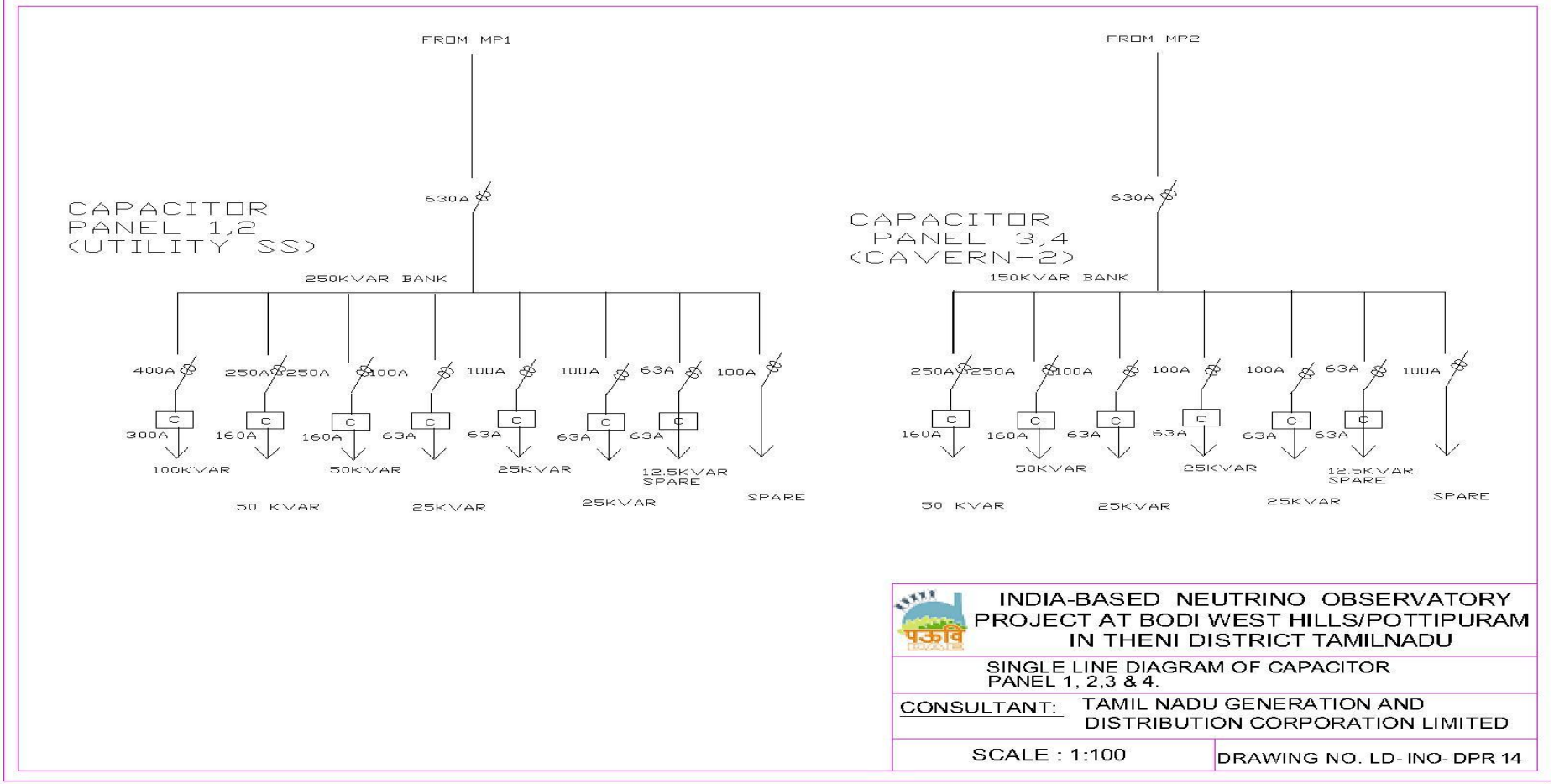
CONSULTANT: TAMIL NADU GENERATION AND
DISTRIBUTION CORPORATION LIMITED

SCALE : 1:100 | DRAWING NO. LD- INO- DPR 12

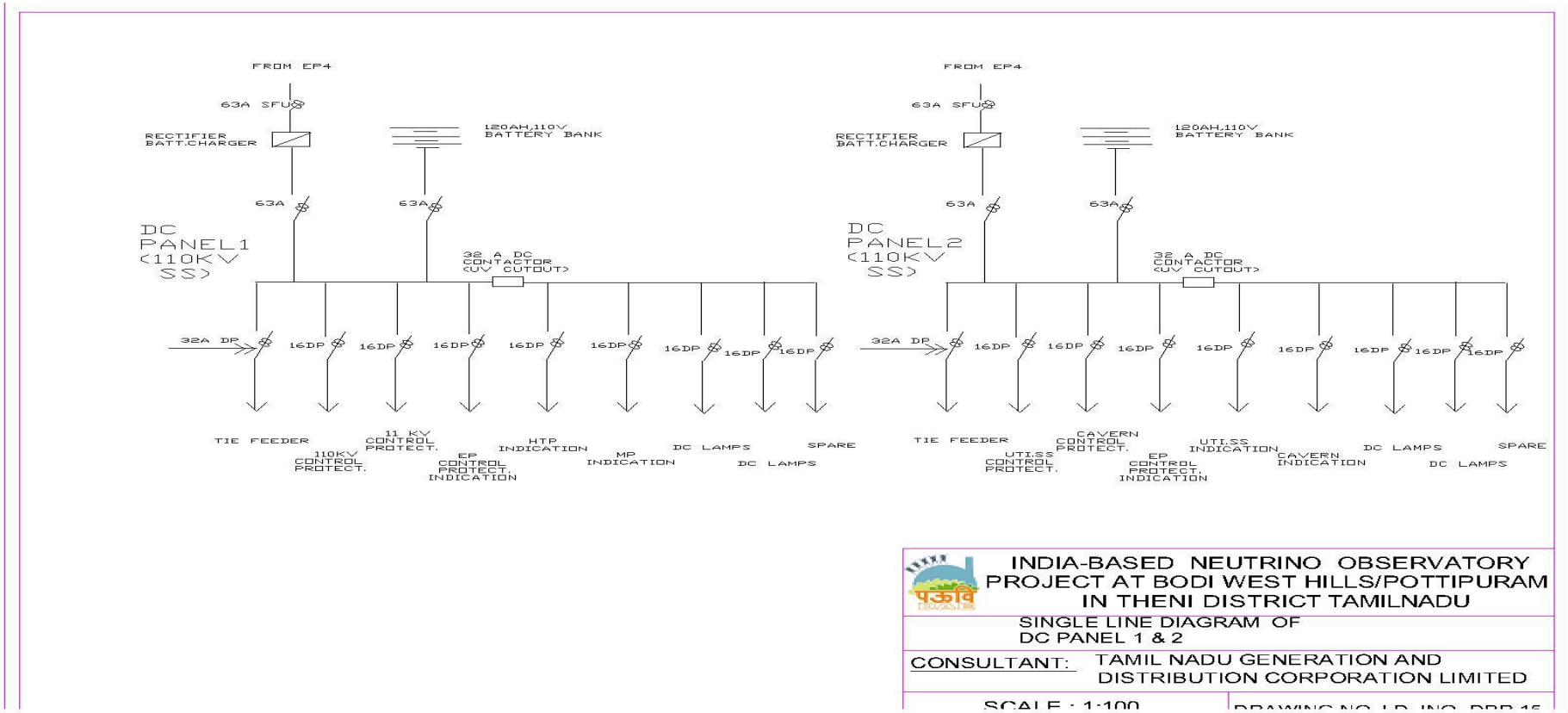
LD-INO-DPR- 12 EP4, 110 KV SS and MP 1.9.1, EP 3, MP2.3.1, MP2.3.2



LD-INO-DPR- 13 Electrical distribution in cavern complex



LD-INO-DPR- 14 Capacitor panel 1, 2, 3 & 4



LD-INO-DPR- 15 DC panel 1 & 2

CHAPTER - 14

AIR-CONDITIONING AND VENTILATION SYSTEM

14.1 Air - Conditioning

It is proposed to provide centralized air conditioning to the entire Cavern-1, Control room & NDBD-I of Cavern-2, Part of Cavern 3 and 4, Guest house, Administrative building, Detector assembly building and selected locations of surface facilities.

14.1.1 Cavern-1 and Part of Cavern 2, 3 & 4 Air-conditioning

(i) Preamble:

Re-circulatory type air conditioning will be adopted for Cavern-1 and Part of Cavern-2, 3 & 4 (intermediate) by using Air Handling Units (AHU). AHU will be located in the Cavern-1 between two ICALS and will occupy 2 structural platforms from bottom. In Cavern-2, a small AHU room will be provided adjacent to the Electrical panel room. (Refer *Drg. No. LD-INO-DPR- 7*)

Chilled water is essential since it is the cooling medium in AHU. Chiller plant with cooling towers will be housed in the Utility building.
(Refer *Drg. No. LD-INO-DPR- 9*)

Insulated chilled water pipes will be routed from Chiller plant to AHU inside for the supply of cooling water. Chilled water booster pumps may be required to ensure flow of chilled water through AHU. An expansion tank for chilled water (make up water) will be provided.

Minimum air conditioning at all times will be ensured in the air conditioned areas by running 1 AHU out of 6 AHUs' using emergency (DG) power.

(ii) Inside conditions design requirements:

Dry bulb Temperature	:	21° ± 2° C
Relative humidity	:	50° ± 5 %

(iii) Ambient condition (assumed):

Dry bulb Temp	:	30° C
Relative Humidity	:	80 %

The temperature at portal has been observed as 25º C and anticipated increase in temperature inside the cavern is 5º C. Hence, ambient temperature inside the cavern is adopted as 30º C for design purpose.

During the detailed Engineering the exact temperature in the cavern will be known and based on the same the exact design parameters will be arrived at.

(iv) Total heat load estimate:

Heat Load estimation	Ton of Refrigeration (TR)
Cavern-1 Main experimental hall	230
Cavern-2 Control room	14
Lighting load	16
Human occupancy	2
Equipment load	150
Detector assembly building	180
Admn. building	60
Guest house	25
Cavern-3	45
Cavern-2&4 NDBD process cooling	25
Total	747

The total heat load is estimated as 750 TR.

(v) Selection of Air-handling Units (AHU):

Type: Double skin with thermal break profile and all accessories will be provided for effective control of temperature and relative humidity.

To meet the above heat load in Cavern 1, NDBD-I and Control room in Cavern-2, AHUs of capacity as below will be installed:

a) Cavern- 1 : 6 Nos X 80 TR each (5W +1S)

b) NDBD-I and Control room in Cavern-2 : 2 Nos X 20 TR each (1W + 1S)

The conditioned air will be distributed through ducts and grill in the Cavern-1 and control room in Cavern-2. Fresh air supply of about 10 to 15 % will be drawn from the tunnel area to the AHUs. Necessary controls and instrumentation will be provided for maintaining the relative humidity and temperature within the desired limits.

(vi) Selection of Chillers:

Water cooled type Screw chillers with all accessories will be installed in the plant room in the utility building outside the tunnel area. Necessary condenser and chilled water pumps will be installed in the plant room to meet the requirement of chilled water.

(Refer Drg. No.LD-INO-DPR- 16)

Chilled water temperature at the outlet of chiller : 7.2° C

Chilled water temperature at inlet to chiller : 11.7° C

No. of Chillers: 6 Nos. x 150 TR each (5 working + 1 standby).

(vii) Chilled water pumps:

Total Chilled water quantity required for satisfactory operation of 5 x 150 TR Chillers : 2250 USGPM

Type of Pump : Centrifugal pump with electrically driven motor

Pump Discharge : 450 USGPM

Head : 50 m

No of pumps : 6 Nos. (5 working +1 standby)

Chilled water booster pumps may be required for boosting chilled water through AHUs inside the plant rooms in the cavern area.

(viii) Condenser water pumps:

Total condenser water quantity required for satisfactory operation of 5 x 150 TR Chillers : 2625 USGPM

Type of Pump : Centrifugal pump with electrically driven motor

Pump Discharge : 525 USGPM

Head : 30 m

No of pumps : 6 Nos. *(5 working + 1 standby)*

(ix) Selection of Cooling Tower

Type of cooling tower : Induced draft cross flow wooden CT

Cooling tower capacity : 1125 TR (To meet refrigeration load of 750 TR)

No of cooling towers : As required

The cooling tower will be provided in the open space adjacent to the chiller plant room. These cooling towers will be connected in parallel with common headers. Provision shall be made for side stream filtration (flow capacity 10% of water under circulation) for partial filtering of re-circulated water to remove suspended particles.

14.1.2 Guest House – Air-conditioning

(i) Preamble:

Re-circulatory type is adopted for air-conditioning of Guest House at Pottipuram.

Guest rooms will be provided with a suitable capacity fan coil units served by chilled water from CWCP.

Meeting room at Guest house will be provided with multiple split air conditioners to meet the peak heat load in the meeting room.

(ii) Inside Design Conditions:

Dry bulb temperature	:	25° ± 1° C
Relative Humidity	:	55° ± 5%

(iii) Meeting room:

No of split Air-conditioners (Heat load 8 TR)	:	4 Nos x 2 TR each

(iv) Guest rooms:

Fancoil units with chilled water piping (Total 16 rooms)	:	16Nos x 1.5 TR each

14.1.3 Administrative building – Air-conditioning

(i) Preamble:

Re-circulatory type is adopted for air-conditioning of Administrative building. This building has three main areas for air-conditioning viz, Surface lab, Administrative office and Lecture hall. Lecture hall is not continuously occupied, but only whenever occasion arises. Other two areas are occupied on

regular basis. The laboratory and Administrative office buildings will be air-conditioned by providing air handling units with chilled water being supplied and returned from water chilling plant. Necessary chilled water piping and booster pumps will be provided at each facility.

(ii) Inside design requirements:

Dry bulb temperature	:	25° ± 1° C
Relative humidity	:	55° ± 5%

(iii) Area of conditioned spaces:

a) Surface laboratory	:	200 sq.m.
b) Office area	:	200 sq.m.
c) Auditorium	:	150 sq.m.

(iv) Air handling units	:	3 Nos. x 20 TR (each one AHU at each facility)

The lecture hall will be occupied as and when necessary. Other two areas will be in use on regular basis. Whenever lecture hall is occupied the respective AHU will be put into service

The chilled water supply and return piping network will be provided in the surface facility area with future tapping so that this can be utilized without disturbing the chilled water piping network.

The chilled water piping will be pre insulated and will have engineered tapping points for each facility.

14.1.4 Detector assembly building - Air-conditioning

Size of the building is 125m x 20m.

Approximate heat load will be 180 TR.

Air-conditioning of this building will be on recirculation basis.

A built-up system comprising filter frames, filter, cooling coils, blowers, ducting and grills will be provided to meet this load. The inside conditions to be maintained will

be 23° ± 1° C and relative humidity at 55° ± 5 %. Coarse and fine filters will be provided to the air entering the plant area to have better IAQ.

To install the AC equipment for this facility, suitable built up area will have to annexed adjacent to the Detector assembly building.

To cater this load, Chilled water supply and return piping will be provided from the Central water chilling plant.

14.1.5 NDBD II Lab

The laboratory rooms of NDBD II (around 250m²) will be air-conditioned through a suitably rated air handling units. Chill water will be taped from the chilled water pipes leading to the Cavern – 1 and 2.

14.2 Ventilation system

It is proposed to introduce ventilation system in the following areas

Access tunnel & Loading bay
Auxiliary tunnel
Intermediate tunnel
Cavern-2 – Other than the Control room, Part of Cavern 3 & Cavern-4 (Intermediate)

(i) Preamble:

Mechanical ventilation on once through basis is proposed for areas of Access tunnel, loading bay, Auxiliary tunnel, Intermediate tunnel, Cavern-2 – other than Control room NDBD-I, Cavern-3 & Cavern 4. A separate plant room is proposed for housing exhaust fans. The location will be adjacent to Chiller plant. Filtered outdoor air will be supplied from the supply fans in the plant room through GI ducts in the main Access tunnel area and Intermediate tunnel. The capacity of the supply and exhaust systems are being proposed so as to create positive pressure. Separate exhaust duct is necessary from loading bay area up to exhaust fans in the plant room. Exhaust air will be routed through the exhaust duct which will terminate at the plant room and will be discharged to the atmosphere through a stack/chimney.

(Refer Drg. No. INO/DPR/ 13)

No filtration is proposed for the exhaust air.

Total volume of tunnel : 1,40,000 m^3

No. of air changes considered : 0.5 /hr

(ii) Supply system:

Supply air quantity : 140000 x 0.5 = 70,000 m^3/hr.

Supply air fan:

Type : Centrifugal with airfoil type blades and electrically driven motor.

Fan capacity : Discharge 40,000 m^3/hr
Static pr 350 mmWG

No of fans : 3 Nos (2 working + 1 Standby)

Ducting and grills will be provided in the tunnel area for the distribution of fresh filtered air supply.

(iii) Exhaust system:

Exhaust air quantity : 60,000 m^3/hr.

Exhaust air fan

Type : Centrifugal with airfoil type blades and electrically driven motor

Fan capacity : Discharge 35,000 m^3/hr
: Static pr 200 mmWG

No of fans : 3 Nos (2 working + 1 Standby)

Ducting and grills will be provided in the tunnel area for the air return.

(iv) Filtration of fresh outdoor air for supply in to tunnel area:

Coarse and pre-filters will be provided for filtration of outdoor air 3 Nos. of filter bank are proposed. Two banks will meet the air quantity for the supply system and one will be a standby. These filter banks will be housed in the plant room of supply fans.

Coarse filter : 60 % efficiency down to 10 microns atmospheric dust

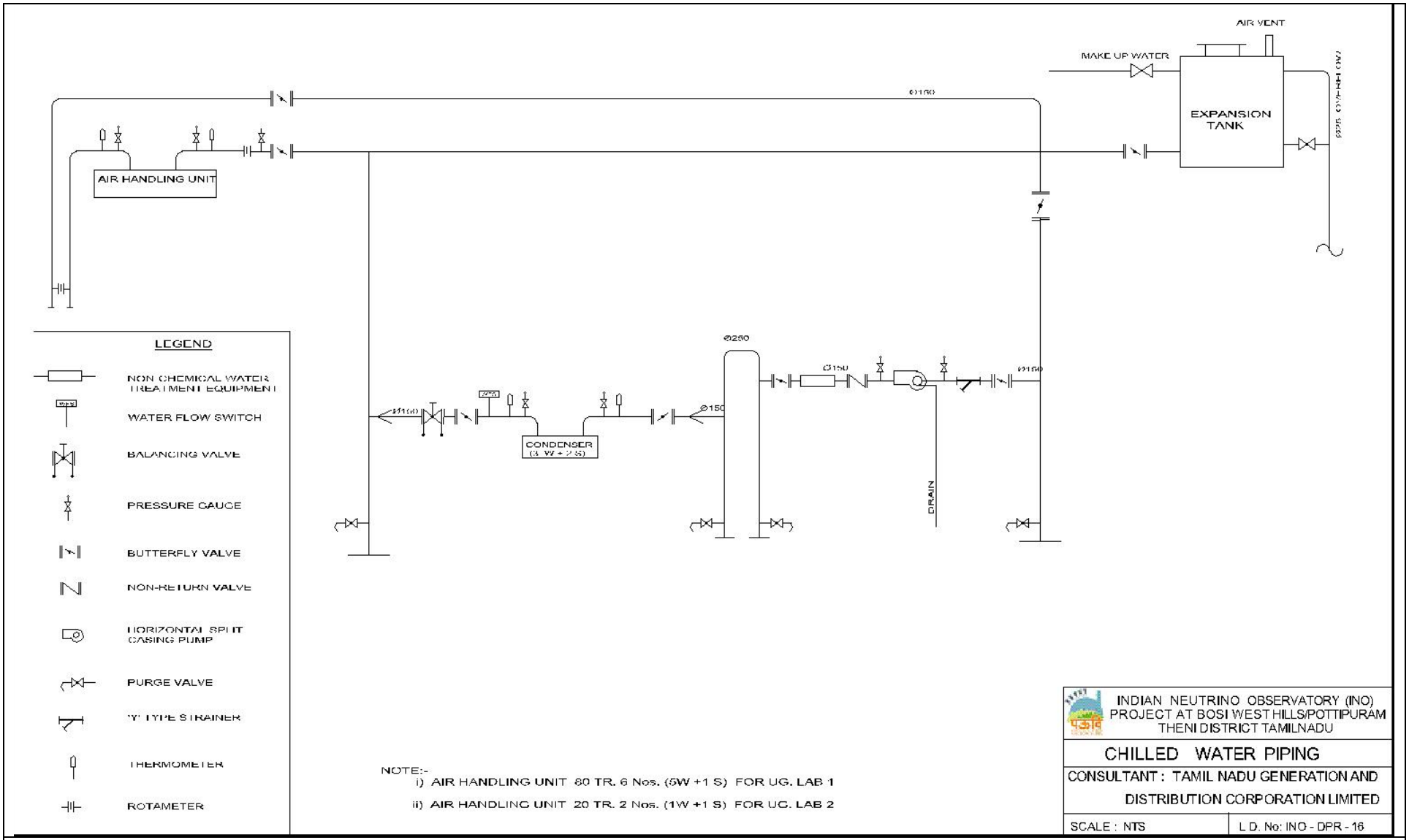
Pre filter : 80 % efficiency down to 5 microns atmospheric dust

Course and Pre-filters 24 numbers (matrix, 4 rows x 6 columns) each will be housed in a common frame for the filter bank. Coarse filters will enhance the life of pre-filters.

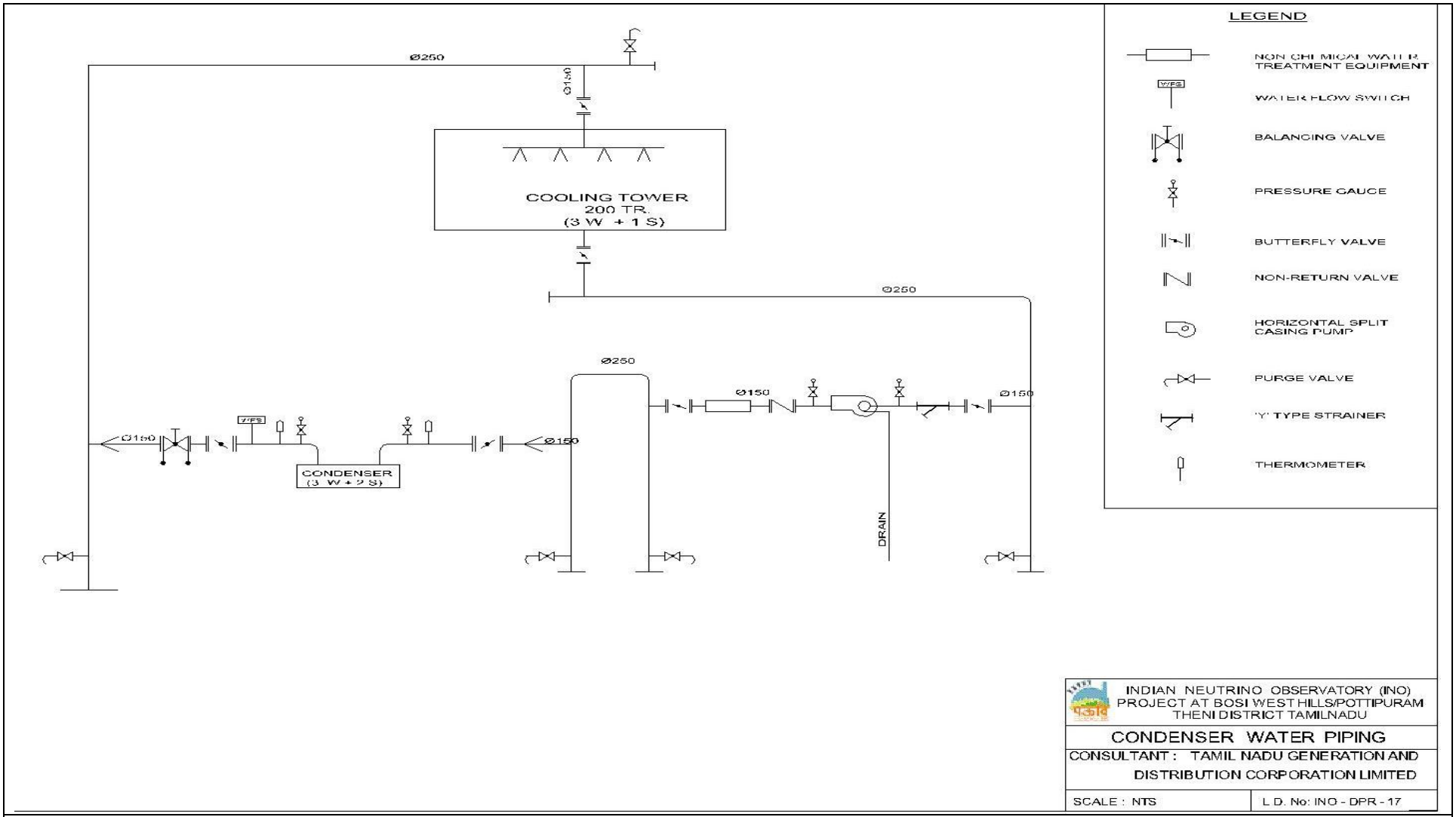
No. of filter banks : 3 Nos. (2 working + 1 Standby)

No. of filters per bank : 24 Nos. (Matrix, 4 rows x 6 columns)

Minimum air movement at all times will be ensured in the caverns and tunnels by running one supply fan at half the speed, using emergency (DG) power..



LD-INO-DPR- 16 Chilled water piping



LD-INO-DPR- 17 Condenser water piping

CHAPTER - 15

COMMUNICATION SYSTEM

The communication system is essential for the effective functioning of Research laboratories in Cavern 1, 2, 3 & 4. The system will consist of the following sub systems:

i) Telephone system
   a) Intercom telephone system
   b) Public telephone system
   c) Data transfer system

ii) Public address system

15.1 Telephone system

a) Intercom Telephone system

The underground and surface laboratories/ office will be provided with a sophisticated intercom telephone system to facilitate inter communication for the operational / administrative purposes.

In the administrative building, an automatic electronic digital IP compatible exchange is proposed with an initial capacity of 200 lines. The electronic exchange will have all the normal features (viz.), circuitry for interconnecting any extensions, Tone generators for ringing, ring back, ready for dial, extension, engaged etc. The electronic exchanges are recommended for their high flexibility, reliability, availability and requirement of little maintenance. The electronic exchange will be microprocessor based stored program control type.

Key pad type of telephone instrument will be provided for all subscribers. This will have push buttons with 0 to 9 digits and enable quick calling of the extensions desired.

"Auto dialing" feature enables calling of frequently required extension by dialing one or two digit numbers. This can also facilitate repeat dialing.

Following optional features can also be considered based on economic aspects of the system:-

i) Automatic call back / queue facility
ii) Call rerouting
iii) Call interruption / priority
iv) Emergency alert
v) Conference (upto eight party conferencing)

b) Public telephone system

To facilitate external communication, it is proposed to have atleast 30 incoming lines from the service provider (BSNL). These lines will be integrated with the intercom telephone system.

c) Data transfer system

A 24 fiber mono mode, multi tube, armored underground optical fiber cable (OFC) will connect the underground laboratories with the surface lab to transfer data through broad band connection given by the service provider. This facility will also be backed up by wireless connectivity. (OFDM technology with data and voice ports).

15.2 Public address system

Public address system will be provided to facilitate two way communications between all key points in cavern and utility building. Instructions, advise and orders can be transmitted to any or all personnel simultaneously. This public address system will have both paging channel and party channel.

In the paging channel, the required person may be called from any one of the hand set stations which will be heard through the loudspeaker connected to the system. This will be heard through all the loudspeakers connected to the system. The communication between the parties is established by called party responding from

another hand set provided at different locations. The communications through this channel will be heard through all the loud speakers. This channel can be used for making common announcements also.

In the party channel, the communication will be through concerned hand sets only and there will be no relaying of the conversations in any of the loudspeakers. It is also possible to have a group discussion with concerned parties through this channel.

CHAPTER - 16

LIFT AND HOISTING SYSTEM

16.1 EOT Cranes

16.1.1 Cavern-1 & Cavern-2

Lifting/hoisting facilities proposed in Cavern - 1:

One number 25T capacity pendant/remote operated EOT Crane is proposed to facilitate handling of steel plates during erection so as to stack the same to form the ICAL Detector and subsequently to withdraw the steel plates from the ICAL detector during regular functioning of laboratory activities The capacity of the Auxiliary hook is fixed at 5 tons to handle smaller equipments/ components.

Lifting facility in Cavern-2:

5T crane is proposed at NDBD - I.

The technical details of crane, hook and other related aspects are given below:

(i) Class of crane

As per IS 807:2006 the class of utilization is considered as 'Class A' taking into account the application as "General and Assembly shop". The BIS to be adopted for mechanical and electrical portions is IS 3177 and for structural design is IS 807.

(ii) Speed

The speed of long travel, cross travel and hoisting/lowering motions of crane are shown in the technical data. 10% creep speed for all motions of the crane will be provided.

(iii) Hook lift

The height of the lift of the crane will be governed by the lifting requirement of detector stacks. The total lift of crane works out to 23m.

Sl.No	Technical Data	Cavern-1	Cavern-2
1.	Effective span	25m	10m
2.	Length of bridge travel (Longitudinal travel)	147m	9.6m
3.	Main hoist capacity	25 tons	5 tons
4.	Auxiliary hoist capacity	5 tons	-

5.	Vertical lift of Main hoist & Auxiliary hoist	23m (15m+8m)	12m
6.	Hook approach Main hoist U/s D/s Auxiliary hoist U/s D/s	 1500mm 2500mm 2500mm 1500mm	 1000mm 2000mm -
7.	Runway rail	120lbs or as per design	90lbs
8.	Type of hook MH AH	 Conventional Shank or 'C' type	 Conventional Shank or C type
9.	Mode of operation	Remote /Pendent	Remote /Pendent
10.	Standard	Conforming to IS3177/807	Conforming to IS3177/807
11.	Speed i) Long travel ii) Cross Travel iii) Lift speed (main hook) iv) Lift for auxiliary hook	 25 m/min creep speed … 2.5 m/min 5m/min creep speed … 0.5 m/min 2m/min creep speed … 0.2 m/min 3m/min creep speed … 0.3 m/min	 25 m/min creep speed … 2.5 m/min 5m/min creep speed 0.5 m/min 2m/min creep speed 0.2 m/min 3m/min creep speed 0.3 m/min
12.	Down shop lead	Shrouded	___

All drives such as long travel, cross travel, main hook and auxiliary hook shall be provided with at least 1 No EMB and 1 No. EHT.

16.1.2 Surface structures - Detector assembly building, Administrative building with workshop

In Detector assembly building and Repair bay/ workshop (Administrative building) one number 10 tone capacity pendant operated EOT crane each will be provided so as to facilitate the lifting operations. Steel store shed will have 1 Number 10 Tonne EOT crane.

Technical Data of EOT Crane

Sl. No.	Description	Detector Assembly building	Administrative Building with workshop	Steel Store shed
1	capacity of crane	10 tons	10 tons	10 tons
2	Class	EOT	EOT	EOT
3	Effective span	20m	14m	24m
4	Length of bridge travel (Longitudinal)	125m	20m	38m
5	Vertical height	5m	5m	5m
6	Type of hook	'C' or shank type	'C' or shank type	'C' or shank type
7	Mode of operation	Pendent	Pendent	Pendent
8	Running rail	45 lbs as per design	45 lbs as per design	45 lbs as per design

16.2 Passenger Elevator/Lift

16.2.1 Cavern –1 & 2

Two numbers Passengers lifts proposed in Cavern-1 are to be located one at the exit of interconnecting tunnel and another in the opposite phase at Floor Level 0. These elevators/lifts are proposed to facilitate movement of personnel from floor Level of operating bay level - 0 to Level +1, Level –1, Level –2, Level –3 (i.e.) Bottom level.

Technical data	Cavern -1	Cavern -2
Number of Elevator	1	1
Type & Capacity	Passenger (5 persons, 340 kgs)	Passenger (5 persons, 340 kgs)
Speed	0.63 Meter/Second	0.63 meter/second
Drive	Single speed (+/- 40mm leveling accuracy)	Single speed (+/- 40mm leveling)
Travel	16.3 Meters serving Ground to 4th Floor. 6 Stops, 6 Levels & 6 Openings	6 Meters 2 Stops 2 Floors
Required Well Size	1550 mm Wide x 1400 mm Deep	1550 mm wide x 1400 mm deep
Power Supply	415 v Three-PHASE & 230 v Single Phase AC	415 v Three-phase & 230 v Single phase AC
Car Size (Clear Inside)	1100 mm Wide x 850 mm Deep	1100 mm wide x 850 mm deep
Fan	300 mm Sweep	300 mm sweep
No. of Entrance	One location front	One location front

Car enclosure	Steel car; Pre-factory painted with metallic finish in triangular embossed pattern. Ceiling–Eureka false ceiling with a black matt finish. Tubular handrail also provided	Steel car; Pre-factory painted with metallic finish in triangular embossed pattern. Ceiling–Eureka false ceiling with a black matt finish. Tubular handrail also provided
Car entrance	Side opening automatic door	Two sides opening automatic door
Landing entrance	Side opening door along with provision for emergency key opening at all landings	Two sides door opening
Clear opening	750mm wide x 2000 mm high	750mm wide x 2000 mm high
Control	Micro computer based – down collective logic system with/without attendant mode	Micro computer based – down collective logic system with/without attendant mode
Car indicator	Digital 7 segment 1.5mm height direction l & position indicator with high intensity indication.	Digital 7 segment 1.5mm height direction l & position indicator with high intensity indication.
Landing indicators	Direction & position indicator at all landings	Direction & position indicator at all landings

CHAPTER - 17

RPC GAS MIXTURE AND DUCT SYSTEM

17.1 Specification of ICAL and RPC

The Resistive Plate Chamber (RPC) has been proposed as the active ICAL detector. The specification of ICAL and RPC are as below:

ICAL	
No. of modules	3
Module dimension	16 m x 16 m x 14.4 m
Detector dimension	48 m x 16 m x 14.4 m
No. of layers	150
Iron plate thickness	5.6 cm
Gap for RPC trays	4.0 cm
Magnetic field	1.3 Tesla
RPC	
RPC unit dimension	2 m x 2 m
Readout strip width	3 cm
No. of RPC units/ row/ layer	8
No. of rows/ layer/ module	8
No. of RPC units/ layer	192
Total no. of RPC units	28800
No. of electronic readout channels	3.6×10^6

For the operation of RPC, a gas mixture of about 95.5% Freon (R134a), 4.2% Isobutane & 0.3% SF6 is required.

The total volume of the active detector elements of ICAL will be approximately $216 m^3$. The gas distribution system for such a big detector will be approximately one volume change per day. The whole detector will be divided into several zones. Each zone will have a gas supply from a separate gas mixing system. The three gases (Argon, isobutene and R134a) will be sent to mass flow controllers for mixing in appropriate ratios. The gas distribution system will be designed to provide

independent gas supply to each row (8 RPC modules). Mixed gas will be distributed to 24x140 rows through a series of manifolds. Uniform distribution in each row will be maintained by flow resisters. Active control of the exhaust pressure and relief bubblers will be introduced to avoid an over pressure situation.

The return gas from the connected chambers is collected in a common manifold before it is finally vented out into the atmosphere.

Gas flow at every stage of the system is achieved through the use of electrically or pneumatically operated switches or valves. The system is equipped with a host of sensors and monitoring devices and appropriate displays of various crucial operating and quality control parameters.

The gas mixture that settles down at the floor level is proposed to be collected through branch return air ducts run down up to (-) 10 m at intervals of 3m from the main return air duct of air handling units. Suitable terminal filters will be provided in the branch return air ducts to absorb isobutene.

17.2 Neutrinoless Double Beta Decay Experiment

For Double Beta Decay experiment liquid Nitrogen gas @ 2 bar under various pressures is required which is proposed to be stored in the storage tank to be provided near the utility building in an uncovered space.

Liquid Nitrogen storage Tank

The consumption rate of Liquid Nitrogen will be about 200 liters per day. The total inventory planned would be about 5000 liters at 2 bar. The liquid nitrogen has been proposed to be outsourced and stored in the Tank-I and will be transported to the cavern in liquid storage containers having capacity of 200-300 liters.

Technical data

i) Capacity	: $5m^3$
ii) Material	: SS 314
iii) Construction	: Fabricated out of SS 314 plates with double shell
iv) Diameter of the tank	: 1.5 m
v) Height of the tank	: 3 m
vi) Thickness of shell	: 8mm
vii) Quantity of Material required	: 1.6 tons

CHAPTER - 18

COOLING WATER SYSTEM

The cooling water is required for the laboratory activities in Cavern-1 & Cavern-2.

18.1 Cavern- 1

The ICAL detector has two fold purposes of providing (i) target nucleons for neutrino interactions and (ii) a medium in which secondary charged particles can be separated on the basis of their magnetic rigidity so that their momentum can be estimated.

A stack of steel plates interlaced with position sensitive gas detectors make up ICAL calorimeter.

The mechanical and electrical specifications of the magnet and the coil are given in the table:-

MAGNET CORE	
Length	16 m
Width	16 m
Height	16.9 m
Plate thickness	6.3 cm
No. of plates	135
Steel specification	ASE 1010 or C10
Carbon content	0.1%
Weight of steel	51,000 ton
MAGNET COIL	
Coil dimension	20 cm x 100 cm
Coil height	15 m
Coil weight	100 to 250 ton
Amp-turns	40,000
No. of turns	20x100x2
Conductor size	1 cm x 1 cm
Current	9 A

Resistance	15.6
Voltage	156 Volt
Power dissipation	250 KW for 50 kton
Coil inductance	1710 Henry
Rise in temperature of coil	$\leq 10^0$ C (with cooling)
Rise in temperature of iron surface	$\leq 2^0$ C
Stored magnetic energy	5.3 MJ
Characteristic magnetization time (L/R)	10 min
Current stability	2% long term

The magnets will generate heat to the equivalent of 250 KW in phase 1 and 250 KW in phase 2. The primary cooling of the magnet is proposed to be done by De-mineralised water (DM water) in closed circulation system. The DM water plant will be provided near the Utility Building.

The secondary cooling of the magnet is proposed by circulating raw water around the ICAL through Heat exchangers. The heat from the primary cooling system will be transferred to the heat exchangers proposed in the secondary raw water cooling system.

A closed loop re-circulation cooling water system is proposed. A surface level tank, the floor level of which will be kept above the sill level of Access tunnel at the entry, will be constructed so that the water will be taken to all the caverns through cooling water pipe by gravity flow.

The cooling water source has been identified as the water from Mullai Periyar river. The main underground sump of 1200 KLD capacity (thrice the design capacity) is proposed to be provided at the lowest point so as to draw the maximum water. The water from this main sump will be pumped into the surface tank meant for cooling purpose at the tunnel portal entry.

From the common header of the cooling water pipe, branch pipes with necessary booster pumps will be provided for taking cooling water to the Cavern-1 for magnet cooling.

The cooling water outflow after circulation from both Caverns 1 & 2 will be pumped back to the surface tank by means of booster pumps of suitable capacity, passing through the cooling water return pipelines after passing through cooling towers.

Technical Data

(i) From surface tank to common header inside the tunnel

a) Size of Surface tank at portal : 20m x 10m x 6m

b) Length of pipe : 2250 m

c) Dia of pipe : 250 mm size.

(ii) Cooling water line to Cavern- 1

a) Length of pipe : 100 m

b) Dia of pipe : 65 mm

(iii) Cooling water line to Cavern-2

a) Length of pipe : 40 m

b) Dia of pipe : 40 mm

(iv) Return line to the surface tank

a) Head to be pumped : 150 m

b) Length of the pipe : 2500 m

c) Diameter of the pipe : 250 mm

d) Capacity of the pump : 3 x 75 m^3/hr (2 W +1 S)

e) Capacity of the motor : 3 x 25 KW

18.2 Cooling water for NDBD in cavern - 2

Chilled water from the branch piping from the respective AHUs will be tapped to meet the process cooling water requirement of NDBD-I and NDBD-II (Total 25 TR).

CHAPTER - 19

SECURITY SYSTEM AND MISCELLANEOUS SERVICES

The security system proposed for the various areas of the underground and surface facilities are as following:

a) Surveillance system

b) Access control system

19.1 Surveillance system

(i) Caverns 1, 2, 3 and 4 (Intermediate):

It is proposed to install Closed Circuit Television (CCTV) which is one of the fastest growing segments in the security industry.

For monitoring the activities in the Caverns 1, 2, 3 & 4 (Intermediate), PTZ Speed colour cameras are proposed. These cameras will be having the special features like built in Pan, Tilt and zoom functions to view the system effectively and Electronic day/night function which automatically converts images from colour to monochrome in low light situation.

The camera will have the feature of rotating 360º horizontally and 90º vertically and subsequently can zoom in/ zoom out so as to provide a clear picture to the user.

A Digital Video Recorder (DVR) is also proposed in the control room which should be capable of taking input of cameras and provide video outputs and with features such as high IPS performance excellent record quality fast/ slow, forward/ reverse searching and other user friendly operations. This DVR has a network facility and can be linked with local area network (LAN) or to internet for remote monitoring.

(ii) Access tunnel, Auxiliary tunnel and Intermediate tunnel:

It is proposed to install weatherproof IR cameras at the entrances of the Access tunnel, Auxiliary tunnel and Intermediate tunnel.

19.2 Access control system

It is proposed to introduce access control system at the entry of Access tunnel portal leading to all the Caverns (1, 2, 3 & 4) so as to restrict the entry of unauthorized person into the premises. This access control system will be by means of Biometric access control system and this control unit supports the thermal sweep type hand geometry reader. It also performs the main operation of storing the information, verifying and providing the authorization to the access.

Further it is proposed to introduce automatic electrically operated boom barrier at entry portal for monitoring the vehicles moving in and out of the laboratories.

19.3 Audio-visual equipment

It is proposed to provide high quality audio and video systems at the lecture hall, Common meeting room and audiovisual room as detailed below:

(i) Lecture hall in Administrative building:

- Loud Speaker
- Microphone
- Amplifiers to support loud speaker
- System digital controller to actively equalise speakers and drive them with suitable power
- Digital feedback exterminator to remove unwanted feedback from system and balance the acoustic environment
- Mixer to integrate all the microphones & audio source with the system.
- Processor with display panel to control all switching operations of the system
- Control system for the audio video components with touch panel
- Ceiling mounted projector
- Motorised sliding screen for projection

(ii) Common meeting room in Guest House:

- Loud Speakers system with suitable amplifier
- Ceiling mounted projector
- Video conferencing facility

- Processor for switching facility
- Digital controller for loud speakers
- Digital feed back exterminator to remove unwanted feed back and to balance the acoustic environment
- Mixer to integrate all the microphones & audio source with the system.

(iii) Audio and video room in Guest house:

- Loudspeakers system with suitable amplifier
- Ceiling mounted projector
- Digital controller for loud speakers

19.4 Workshop machineries, Material handling equipments and vehicles

It is proposed to provide the following machineries, material handling equipments and vehicles to facilitate for the smooth functioning of the laboratory activities both in caverns and in surface.

(i) Workshop Equipment:

- Medium size Lathe
- Radial drilling machine
- Small milling machine
- Welding generator
- Set of portable tools and hand tools

(ii) Material Handling Equipment:

- Fork lift
- Truck (10 Ton)
- Hydromac crane (3 ton)
- Mobile trolley for detector repair in large cavern (Lift 2 m to 15 m and load 500 kg)

(iii) Vehicles:

- Jeep - 1 No
- 16 seater van - 1 No
- Two wheelers (Battery operated) – 3 Nos.

CHAPTER - 20

DRINKING/ SERVICE WATER SUPPLY AND SANITARY DISPOSAL SYSTEM

20.1 During the construction phase

5 Lorry loads of water through Water tanks of each 8000litres capacity will be arranged during construction phase for drinking and construction purpose.

20.2 During the operation phase

The requirement of Drinking and service water supply has been computed taking the per capita consumption at 170 litres per day.

(i) For Surface facilities

Personnel	Number
Scientists	6
Auxiliary staff	14
Family members	60
Total	80

Requirement of water per day for the staff and their family is 13,600 litres

(ii) For Cavern facilities

Sl. No.	Under ground facilities	Requirement of water per day in litres
1	Caverns 1,2,3 and 4	1,500
2	Cooling water system $125m^3$ per hour-make up water-1.5%	60,000
3	Cooling water for AC units-750TR make up water @1.5%	2,14,600
Total		2,76,100

Total = 13,600 + 2,76,100 = 2,89,700 litres or 290 KLD

Considering the future requirements, the total requirement of water for drinking & service facilities is projected as 400 KLD

The above requirement of water will be arranged to be supplied by Tamil Nadu Water supply & drainage Board through a dedicated water pipe line for a length of 15km

from the Mullai Periyar river. The water need to be pumped over 100m head. This will be a Deposit Contribution Work by TWAD Board for INO Project.

20.3 Main underground sump and overhead tanks

Requirement of water during INO operation phase is 400 KLD. Hence a main underground sump, thrice the design requirement of 400 KLD (viz.) of dimensions 20 m x 10 m x 6 m (storage capacity 12 lakhs litres) will be constructed, in order to store 3 days supply. From this main underground sump, apart from surface level tank at the portal entry for cooling purpose (para 18.1) water will be pumped to main overhead tank of 3 lakhs liters from which water will be fed into the following four overhead tanks at

i) Residential quarters
ii) Administrative building cum workshop
iii) Guest house cum hostel
iv) Utility building for the caverns

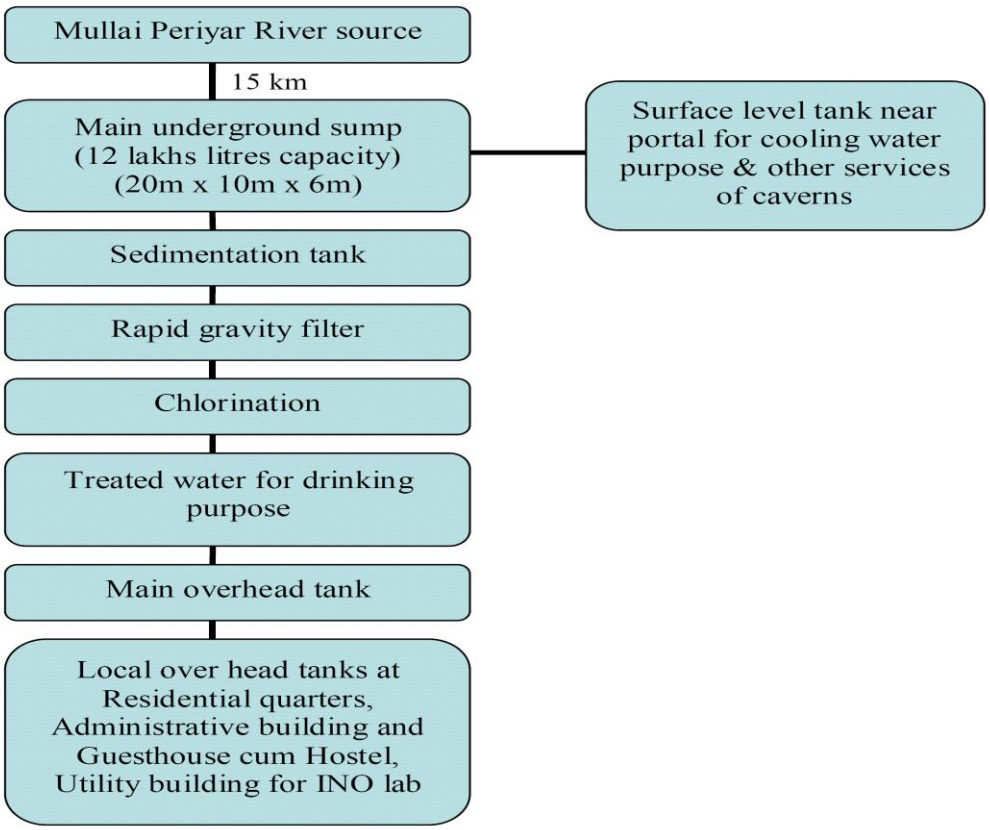


Figure 20.1 Water supply network

20.4 Sanitary disposal from Cavern, Tunnel and Surface facilities

- Cavern-2 : 2 Toilets *(Gents - 1 and Ladies - 1)*
- Cavern-4 : 1 Toilet
- Last vehicle pocket of the Access tunnel : 1 Toilet(Drivers + Security staff)
- Utility building : 1 Toilet
- 20 Residential quarters, Guest house cum hostel, Administrative building cum Work shop : Toilets as per the norms

A single main Septic tank of size 9.5m x 3.3m x 2.3m (Refer *Figure 20.2*) which will serve for 250persons will be located at the lowest level of the landscape.
While the sanitary load from the Caverns and Tunnels will be pumped into the main septic tank, the Sanitary load from the surface facilities will flow into.

The effluent from this septic tank on passing through Sewage water treatment process (*Refer Figure 20.3)* will be disposed through dispersion trenches far off for good vegetable growth, well away from water bodies. The sewage sledge from Septic tank will be arranged to be cleared periodically by the municipal vehicles of Theni/ Bodinaickanur.

The sullage water from kitchen/ wash rooms/ bathrooms will not be sent in to septic tank which will unnecessarily load the tank but it will be put into use for gardening purpose beneficially.

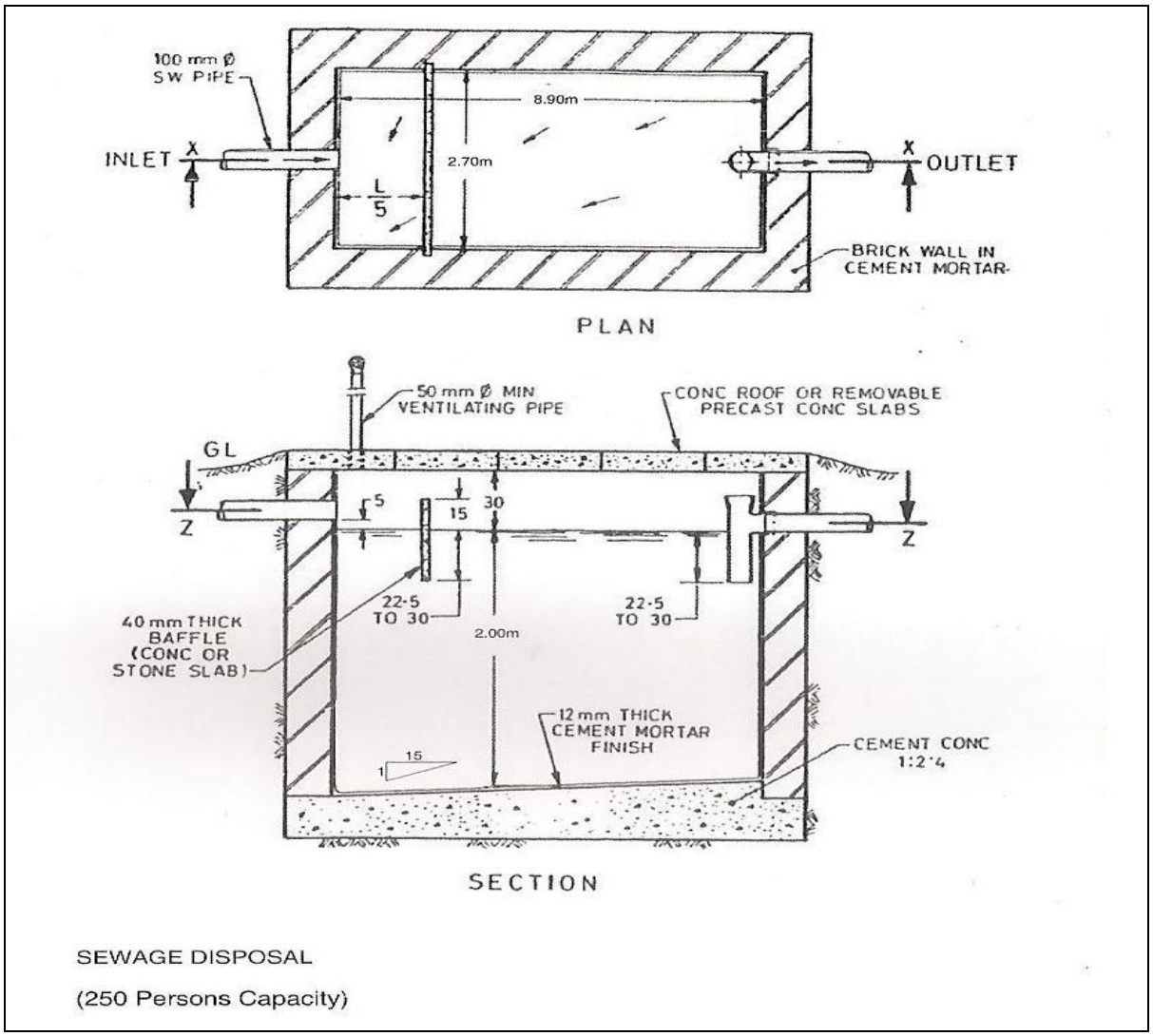


Figure 20.2 Septic tank

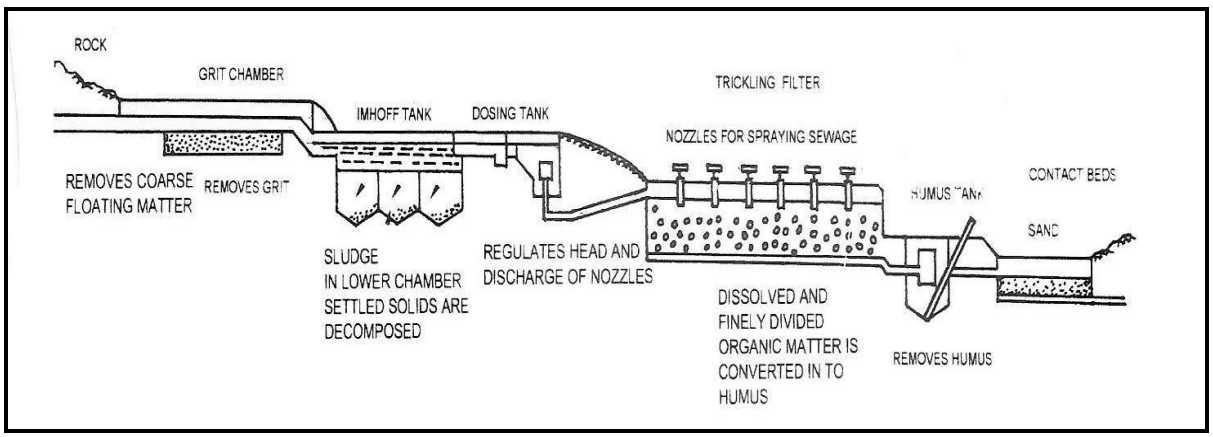


Figure 20.3 Sewage water treatment process

Part V Risk, Safety, Health and Environment Management

CHAPTER - 21

RISK ASSESSMENT, SAFETY AND HEALTH MANAGEMENT PLAN

21.1 Risk assessment

Risk assessment is the pro-active identification of hazards. An action plan to control the hazards in order of priority as assessed will be documented. The action plan will be monitored on a regular basis.

Identified risks are to be managed to ensure their reduction to a level "As Low As Reasonably Practicable" (ALARP)

Eliminate	- Through design options
Reduce	- Through choices of materials for construction and operating method
Protect	- Through emergency and organizational control
Mitigate	-Through effective controls
Monitor	-Inspection, Audit, Review

Construction and operating risk that cannot be designed out, should be uniquely identified and tracked through each Project phase, using a "Hazard register" process.

Safety plan requirements

- Risk assessments
- Organisation for safety.
- Safety responsibilities.
- Method of statements
- Procedures & Instructions
- Compliance monitoring
- Inspection, Investigation & Audit
- Corrective actions

Areas of safety requirement

- Excavation & ground support
- Permanent support
- Compressed air working
- Fire and smoke
- Firefighting and rescue
- Ventilation
- Dust
- Underground and surface illumination
- Operating communications
- Noise & vibration
- Lifting equipment
- Access
- Transport & loading
- Tunnel plant
- Electrical failure
- Maintenance & Repair

21.2 Safety measures

This project does not use any source of radiation and natural background radiation from the rock is very low and well within limits. All electrical equipment will be suitably designed to prevent fire/spread of fire and fast acting interlock and protection system will be provided to isolate the faulty section quickly. Besides, all risks will be assessed on a regular basis with the intention of either reduction or removal. The three most effective measures involve safety audits, staff training and evacuation drills.

21.3 Safety audits

Safety audits involve checking, as a regular routine, all electrical equipment, wiring, fire extinguishers, hose maintenance, roof leaks, pest infestations, damaged flooring or steps, clearways through fire exits, and more generally ongoing daily OH&S issues. Particular attention will be paid at times of capital works.

21.4 Evacuation drills

The aim of controlled evacuation drills is to improve performance should a real evacuation occur. Shortcomings in the drills can be addressed during the evacuation stage following the drill leading to increased efficiency and safety during emergency. The knowledge and confidence gained during drills will help in speedier and thorough evacuation. The timing of evacuation drills will be so chosen to avoid potential distruption during critical periods.

21.5 Staff training

Training the staff dramatically helps to prevent minor or major disasters. If staff are knowledgeable about safety issues, evacuation procedures, fire prevention methods and OH&S practices, the probability of sustaining damage, loss and injury is significantly reduced.

21.6 Emergency management plan

The Emergency management plans will be updated as required so to accommodate unexpected eventualities.

The posters containing building plan, exit, location of fire extinguisher and evacuation steps will have to be prominently displayed within the caverns and surface buildings for the benefit of both the staff and security.

For management of safety at workplace, four distinct developments can be identified.

a) Engineering and technical consideration for management of job hazards.
b) Developing statutory measures and strengthening of suitable enforcing agencies for improvement in the workplace safety.
c) Incorporating safety as a basic function in the organization and setting up of safety department as an integral part of the work organisation.
d) Understanding behavioral base of accident potential and evolving of appropriate strategies based on such appreciation.

It is of no doubt that engineering control of hazards and working conditions will constitute the top priority for safety management.

21.7 Health management plan

- An ambulance will have to be made available by the EPC Contractor at the project site to take the injured persons to the nearby hospital.
- A medical attendant with first aid medical kit will have to be available at the Project site to attend the injured.
- A clause shall be added in the agreement so that the EPC (Engineering, Procurement & Construction) Contractor will have a tie up with the local hospital at Kambam/Theni towns to give medical treatment expeditiously and to provide periodical health check up to the workers.
- All the health protection appliances (viz.) Helmet, Gum boots, etc. will be given to the workers to protect them from dust, noise, rough surface and falling stones.
- All necessary precautions and safety measures will be taken to ensure good health condition of employees.
- The main focus of health management is to ensure 'Zero' Casualty during the Project construction period.
- During the operation period, all safety and health codes prescribed by the BIS will be strictly implemented in the Caverns & Tunnels.

21.8 Fire fighting

This covers a description of salient features of the different fire protection systems proposed for the caverns.

The fire protection systems proposed comprise the following sub-systems, each one of which will serve as an effective protection against the particular nature of fire risk involved. The fire risks in terms of equipment and facilities locations have been identified and suitable firefighting system have been proposed.

21.8.1 FM 200 system

Control room in the cavern-2 being a manned area, it is proposed to provide clean agent system (FM 200) to avoid suffocation at the time of fire.

The technical requirements/material requirements for this system are as given below:

a) FM 200 cylinders filled with FM 200 gas
b) Solenoid valve
c) Gauge assembly
d) Hoses
e) Check valves, nozzles
f) Pressure switch
g) Seamless schedule 40 pipe with fittings
h) NRV

21.8.3 Inert Gas Argon IG-01 system

Since the activity in Cavern-1 is sensitive to moisture, inert gas fire protection system is proposed. Two sets of cylinder bank arrangement (one set main and one set standby) using directional valve is proposed. Gas discharge is proposed to be done manually after verifying the real fire condition and by operating the respective manual gas discharge station.

The technical requirements/material requirements for this system are as shown below:

a) Argon cylinder with valve and filled with Argon gas at 200 bar pressure.
b) Flexible Hoses, Non Return Valves, Frame Assembly & Header
c) Pressure reducer
d) Argon IG-01 Nozzle
e) Pressure switch
f) Directional valve of suitable size.

21.8.4 Portable Fire Extinguishers

Portable fire extinguishers Class-A, B & C have been proposed in utility building, Assembly shop, surface facilities etc., so as to fight fire in such areas.

The technical requirements/material requirements for this system are as shown below:

a) 4.5 kg CO_2 type fire extinguisher(Class B).
b) 5 kg DCP type fire extinguisher(Class B/C)
c) 9 litre capacity Mechanical foam type fire extinguishers(Class A).

21.8.5 Fire detection and Alarm system

Fire detection

Despite the many precautions taken, fires do break out. Hence all caverns will have established measures to detect a fire and to attack it immediately. Automatic fire detection has been proposed as this has many advantages such as speed and reliability and is recommended for control rooms/ computer rooms and unoccupied areas with high fire hazard. They will be activated by one of the effects of fire such as temperature rise, smoke, flame or heat and will be coupled to an alarm system which will provide visual/audible alarms at designed manned locations. The selection/installation of the detection system will conform to the applicable national standards.

Alarm system

On receiving the message of emergency from the site, the control room will sound siren "wailing type for 5 minutes". On receiving the message of emergency over, the alarm will be sounded for 2 minutes. The features of alarm system shall be explained to all during trainings to avoid any confusion. Manual call points with associated alarm panels will be provided at suitable location and the following communication system also plays a major role during emergency.

a) Telephone system-Intercom and public.
b) Public address system with communication bus.
c) Radio paging and walkie-talkie systems.

(i) In caverns, following fire alarm systems are proposed:

a) Addressable fire alarm panel
b) Addressable photo detectors
c) UV Flame detectors
d) Smoke detectors

(ii) In Utility building and Assembly shop the following fire alarm systems are proposed:

a) Conventional modular type fire alarm panel
b) Photo Electric type smoke detector
c) Thermal detector

(iii) In gas storage tanks Quartzite Bulb detector is proposed.

21.9 Prevention of spread of fire

Building and Services

The building design will also facilitate safe evacuation of occupants and should conform to the various fire safety recommendations of the National Building Code as well as the Factories Act.

The building services such as electrical distribution, air handling and conditioning systems, other services will be so laid out as to prevent fire spread. Some of the specific measures include use of noncombustible linings with provision of adequate fire protection stops in cable ducts.

Fire dampers in A/C and ventilation ducts shall be provided at suitable locations to prevent spread of fire from the functional area to the other areas.

Lay-Out spacing

The project components design will be laid out in such a way as to provide unimpeded access for fire brigade equipment to every part of the underground laboratory.

Control of combustible/ flammable/ waste materials

Safe procedures for the collection and disposal of waste materials particularly combustible wastes will be established and all employees educated in such procedures.

Fire Protection Management Plan

A fire protection Manual should be prepared, preferably in 3-parts.

The first part will outline the fire risks in terms of laboratory locations, equipment and facilities and indicate the ways in which risks have been minimized.

The **second part** will set out operating procedures, standards of fire protection established, maintenances of these standards action to be taken in the event of fire by every level of management responsibility for inspection and repair. It will also include instructions for staff responsible for building services.

The **third part will** outline the training required for existing and new staff, the inspection schedules and check lists, sources of additional information and help.

21.10 Safety equipments

In addition to Fire Extinguishing network, the equipments detailed below are also to be provided for safety against fire.

a) Canister gas mask
b) Chemical cartridge type gas mask
c) Self rescue type gas filters
d) Mechanical filters for dust nuisance
e) Resuscitators
f) Fire proximity suits
g) Safety Helmets
h) Face Shields
I) Gas tight rubber goggles
j) Torches
k) Axes/Hand Saw
l) Fire Blankets
m) Gloves
n) Ropes
o) Ladders
p) Safety belt

CHAPTER - 22

ENVIRONMENTAL MANAGEMENT PLAN

The INO tunnels and caverns are to be located in Bodi West Hills, near Pottipuram village and the surface facilities in the Government promboke land in the village.

Any Eco-system will get disturbed due to any development. The impacts due to the developmental process cannot be completely eradicated, but the same can be controlled to the maximum extent possible. The Environmental management plan aims to mitigate the impacts due to the development.

Main Impacts of INO Project

The perceived main impacts of the INO project on the eco system are

(i) Cut & cover reach formation and tunnel in weathered rock

(ii) Muck disposal from tunnels and caverns – Muck transit yard.

(iii) Dust generation.

(iv) Impact of men and machineries over land, air and water

(v) Surface structures/ facilities

(i) Cut & cover reach formation and tunnel in weathered rock

As good rock is not available in the initial reaches of Access tunnel (ie.) Ch 0 to Ch 157, this portion will be a cut & cover reach. The earth, weathered rock/ soft rock are to be excavated with sufficient side slopes for RCC tunnel construction and after that construction, excavated earth/ weathered rock will be dumped over the tunnel. During this construction, there will be atmospheric pollution due to dust and also increased noise due to construction machineries.

The use of explosives in this reach for controlled blasting will be limited, as the major excavation will be by earth moving equipments.

As this open construction will be completed within 3 months, the impact will be temporary one. However water sprinkling system to suppress the dust and

carrying out the work during the day time will be ensured. The reach from chainage 157 to chainage 197 will be tunnel formation under weathered rock. In this reach, controlled blasting will be ensured and the construction phase will proceed cautiously as in the case of earthen tunnel. Beyond Ch 197 the tunnel will be a regular one under hard rock tunnel.

The vibration due to the control blasting in the initial reaches of Access tunnel will be negligible and it cannot be felt in the nearby habitat (ie.) T.Pudukottai village which is at 1.2 km from the Tunnel portal.

The calculation to prove the above aspect is as follows:

Assessment of ground particle velocity as per clause 4.1 of Bureau of Indian Standards: IS 6922-1973.

For safety of structures from threshold damage, the permissible peak particle velocity

(i) In soils, weathered or soft rock : 50mm/sec

(ii) Hard rock : 70mm/sec

Ground particle velocity calculated at the tunnel entry location when blasting is carried out at the following locations:

Table 22.1 Ground particle velocity

Blasting locations	Peak particle velocity
At the middle of cut & cover reach	16.94mm/sec<70mm/sec
At 200m inside the tunnel	7.12mm/sec<70mm/sec
At 1000m inside the tunnel	0.95mm/sec<70mm/sec
At 2000m inside the tunnel	0.40mm/sec<70mm/sec

Hence the nearby habitation (ie.) T.Pudukottai village will not be affected in anyway due to the tunnel blasting. Moreover the overground fauna if any will not be affected due to the cavern blasting, as the rock cover is above 1000 m.

(ii) Muck disposal from Tunnels and Caverns – Muck Transit yard.

About 2.3 lakh m^3 of excavated rock muck will be generated during the formation of caverns and tunnels. A portion of muck will be utilized for the project construction work. However, the disposal of such huge quantum is

considered as the main issue from environmental management point of view. The best solution will be disposing off the entire muck as it is generated daily. The assistance from District Revenue authorities may be availed. The residual stock of tunnel muck may be kept in the muck transit yard, for the gradual disposal in course of time. Tunnel muck transit area of 20,000 m² (2 ha)will be made into 2 segments of 10,000m² each, to facilitate simultaneous loading and lifting of tunnel muck by the dumpers/ tippers at any point of time. In order to retain the muck stack, retaining walls in random rubble masonry will be constructed upto 4 m height. GCI sheet will be provided over masonry for another 4 m height to prevent the flying of dust during the loading/ lifting operations.

(iii) Dust generation & prevention

Dust generated during blasting of tunnels & cavern formation, muck transport, loading/ lifting at muck transit yard and in the crusher unit for BG metal and crusher/'M'sand will be suppressed as follows:

Table 22.2 Dust Suppression Methods

Dust prevention	Methodology
Dust dilution in tunnels and caverns	Providing more air to dilute the dust.
Dust prevention when loading the excavated tunnel/ cavern muck in to the dumpers/ tippers.	Adequate wetting is extremely important for dust control. The vast majority of dust particles created during breakages are not released into the air, but, stays attached to the surface of broken material. Wetting this broken material ensures that dust particles stay attached. The broken material is to be wetted uniformly.
Dust prevention when muck is unloaded in the transit area.	By water spraying to capture airborne dust.

Dust prevention in crusher unit	Providing dust collectors to suck the dust.

(iv) Impact of Men and Machineries over Land, Air and Water

Environmental Impact of men at the project will be minimized by engaging local labourers to avoid migration. The personnel involved in INO Project and the resident population during construction phase are given in *Table 22.3*. The resident population during operation phase are given in *Table 22.4*.

Table 22.3 Details of people engaged during construction phase

Year	Contract labour			Department staff			Total
	Skilled	Semi skilled	Un-skilled	Engineers	Staff	Family members	
1	20	20	50	10	10	220	330
2	20	20	50	10	10	220	330
3	15	15	40	10	10	180	260
4	20	10	-	5	10	60	105
5	20	25	-	5	10	50	90

Table 22.4 Details of staff during operation phase

Personnel	Number
Scientists	6
Auxiliary staff	14
Family members	60
Total	80

The labourers will be educated on the need for environmental protection and they will not be permitted to venture into forest area for collection of firewood and other sundry works. The labourers will be provided LPG or Kerosene. They will not be permitted to raise cattle for milk at any cost. Instead, Govt. 'Aavin' milk will be arranged by the contractor.

New vehicle will be insisted for the muck disposal to reduce pollution. The loaded vehicles carrying excavated muck will be arranged to be covered with tarpaulins to prevent flying of dust particles from the tunnel muck while being discharged at the dumping yard. The raising dust will be suppressed by sprinkling of water. Compressed air will be utilized in the sprinkler system to economize the water consumption.

During construction period, the EPC Contractor will arrange supply of water through tanker (5 tankers a day) for all underground and surface activities. During operation period a dedicated water supply from Mullai Periyar river will be effected by Tamil Nadu Water Supply and Drainage Board (TWAD). Hence there will not be any ground water extraction. More over the project area is grey area and ground water availability is low.

(vi) Surface structures/facilities

The DG set to be provided at the utility building will be of 'Silent' type. Suitable Acoustics have to be provided in the building and also appropriate flora have to be planted to reduce the impact of noise emanating from machineries.

Since the tunnel portal & muck transit yard are located within the project site, and so the plying of vehicles is localized, the nearby village (viz.) T.Pudukottai will not be affected in any way.

The sullage/ sewage water from the wash rooms and toilets respectively of the caverns and surface structures will be suitably treated and dispersed at suitable locations, well away from the water bodies. The sludge from the septic tank or STP will be arranged to be cleared periodically by the municipal vehicles of Theni/ Kambam.

The Environmental Monitoring Cell (EMC) constituted by the project proponent will ensure implementation of the Environmental Management Plan (EMP) during the construction and operation phase.

M/s. Salim Ali Centre for Ornithology and Natural History, Coimbatore, Tamil Nadu, an Environmental research agency under the Ministry of Environmental and Forests/ Government of India, has taken up the EIA study for this INO Project. Their recommendations and conclusion will form the basis for EMP apart from the above aspects.

Suitable Environmental Management Plan covering all the mitigatory measures will be evolved for adoption during the construction and operation phases.

Part VI – Energy Conservation and Socio-economic Development of Neighborhood

CHAPTER - 23

ENERGY CONSERVATION AND SOCIO-ECONOMIC DEVELOPMENT OF NEIGHBOURHOOD

23.1 Energy conservation

Energy is the main input for the economic development of any country. Demand for energy is increasing day by day due to rapid growth of population, industrial and service sectors. To meet this increasing demand, pressure is mounting for increased power generation by taking the execution of new power generating stations.

Hydropower, Solar power, Bio-mass energy and Wind power are the renewable sources of energy, but not firm energy sources, as they are only seasonal.

Thermal power & Nuclear power are non-renewable source of energy, but are firm sources of energy.

The increasing power demand deplete the fossil reserves of our country as well as place pressure on Nuclear fuel. Also such non-renewable energy sources have their own environmental impacts.

Energy conservation plays an important role in the area of Energy development, as the new slogan is *"Conserve energy today for the prosperous future"*.

Hence conservation of energy is drawing more attention to bridge the gap between the supply and demand. Energy conservation is a more rational and scientific use of energy in order to reduce consumption of energy to accomplish a given task.

The following Energy conservation measures will be adopted during the INO Project Construction/ Operation phase:

- Compact Fluorescent Lamps (CFL) are the long-term solution to conserve power as well as bring comfort to every place.
- CFL & LED lamps will be used in access tunnel, street lighting, rest rooms, washrooms, toilets and corridor.

- By using correct sized (rated) energy efficient motors and employing variable frequency drives wherever possible, sufficient energy will be saved.
- Variable frequency drives will be used for chillers, blowers and Air handling units.
- Solar water heater will be used in Guest house and Solar powered CFL will be used for small roads.
- Natural lighting will be utilized wherever possible.
- Efforts will be made to minimize heat ingress into the Air-conditioned areas.
- In this project, all the systems will be designed with energy conservation as one of the main goals.

23.1.1 Energy efficiency

Energy efficiency measures not only helps to conserve the depleting fossil fuels and reduce the need to create new capacity addition requiring high investment, but also result in protecting the environment from the following impacts:

- Global warming.
- Green house effect.
- Ozone depletion.
- Acid rain.
- Pollution.

23.1.2 Towards energy and water efficient buildings (Residential/Office buildings)

- Painting the house roof top with light colour reflects off the light & heat and keep the house cool.
- Right orientation of the house.
- Protection of windows from the sun
- Houses should not have much glass area or otherwise should have the right orientation & adequate shade.
- Good curtains for winds made of cloth which have low conductivity
- Optimise use of natural ambient light.
- Cross ventilation
- Avoiding partition structures

- In offices, indoor set point temperature according to Indian weather conditions in usage of Air-conditioners
- Rainwater harvesting installations for all the buildings.
- Re-use of water from wash rooms for gardening works.
- Green house Design adoption.

23.1.3 Energy audit

Energy audit is to be undertaken during the INO operation phase to conserve energy as well as to identify the less energy efficient areas, so as to eliminate the same.

23.2 Socio-economic development of neighbourhood

By way of social responsibility and commitment, it has been proposed to uplift socio-economic condition of Pottipuram and adjoining villages by improving the existing infrastructure facilities, for which provision has been made in the estimate.

CHAPTER - 24

CIVIL WORKS

Analysis of Data

The INO Project is located in the Theni District of Tamil Nadu. The following are the three major methods of rate adoption for the Civil works in this estimate.

(i) Tunnel and Cavern excavation

As this is special type of works and as there is no standard schedule of rates, TNEB's awarded rates during the year 1995-96 for the Tunnels and cavern excavation for the Pykara Ultimate stage Hydro Electric Project, at 10% escalation in a year which is compounded has been taken out over 11 years and after that 5% escalation taken for 3 more years, this rate has been adopted. RCC lining for cavern, Shotcreting, rock bolting for tunnels, high/Low pressure grouting for cavern & Tunnels has been provided.

(ii) Regular construction works like concreting etc.

The CPWD schedule of rates for the year 2007 which is available only has been taken with escalation of 40 % for INO Project in Theni (DT) for the year 2010 as confirmed by BSNL office/Chennai.

(iii) Building cost estimation

The PWD plinth area rates for the year 2010-11 as published by Public Works Department/Tamil Nadu have been taken for all the buildings Viz. Utility Building, Administrative Building, Quarters numbering 20 and Guest House cum Hostel.

Suitable provisions as per the Schedule of rates have been added to the basic rates for the following as applicable to the type of buildings. When there is no approved schedule of rates for such works, reasonable provisions has been made.

a) Anti Termite treatment
b) Marbonite tiles
c) Aluminium Joiners
d) Cement paint internal & external
e) Internal water supply, Sanitary & Electrical
f) External water supply, Sanitary & Electrical

g) Extra for Deep foundation

h) Earthquake resistant structures

i) Finishing the elevation

j) Provision of Lawn

k) Non-Ductable AC rates

l) Furnishing of rooms

m) Extra for additional height

(iv) Electrical engineering services.

The rates are based on prevailing market rates.

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