1. INTRODUCTION

Physics is one of the important branches of basic sciences in which revolutionary developments are frequent. It is one of the important fields of human pursuit since it is very fundamental and critical for both intellectual and material development of the mankind. In broad terms, breakthroughs in physics have been corner stones of quantum jumps in human knowledge about the nature of the whole world in general and the revolutionary leaps in technology. Of the various fields in physics, an important one is neutrino physics, in which Indian scientists are pioneers, and were the first to detect neutrinos produced by cosmic ray interactions in the earth's atmosphere.

Neutrinos are tiny, neutral, elementary particles which interact with matter via the weak force. The weakness of this force gives neutrinos the property that matter is almost transparent to them. The Sun, and all other stars, produces 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 (supernovae), relic neutrinos (from the birth of the universe), natural radioactivity, and cosmic ray interactions in the atmosphere of the Earth. For example, the Sun produces over two hundred trillion trillion trillion neutrinos every second, and a supernova blast can unleash 1000 times more neutrinos than our Sun will produce in its 10-billion year lifetime. Billions of neutrinos stream through human body every second, yet only one or two of the higher energy neutrinos will scatter from an individual lifetime.

From recent experiments it is known that the mass of the neutrino is non-vanishing, but researchers are unsure how large the masses of the three individual neutrino types are 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) and so even a tiny mass for the neutrinos can enable them to have an effect 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 stars. Researchers are confident that non-zero neutrino masses have profound implications on various fields such as nuclear physics, geophysics, astrophysics and cosmology apart from being of fundamental interest to particle physics.

Neutrinos, elusive oscillating particles of very small mass that are most numerous of all the other particles excluding photons, are of very wide energy spectra, depending on their sources thus, making them very challenging to be detected. Neutrinos 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. Hence, most neutrino observatories are located deep inside the Earth's surface. The overburden provided by the Earth matter is transparent to neutrinos, whereas most background from cosmic rays is substantially reduced depending on the depth at which the detector is located.

As noted above detection of neutrinos is quite challenging and demands highly sophisticated laboratory set-up. Perhaps, filtering-off the cosmic rays and background radioactivity can make detection of the neutrinos possible, and may help answering many a question that challenge scientists. 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 kilometer or more. There are two types of underground laboratories: either located in a mine or in a road tunnel. There are now four major laboratories around the world: in Sudbury in Canada, in Kamioka in Japan, under the Gran Sasso Mountains in Italy and in Soudanmines in the USA. Several others are planned including INO as an attempt to recapture the pioneering studies on neutrinos at KGF.

Due to closure of the KGF by the Bharat Goldmines and Ministry of Mines, the study had to be terminated in 1992. Realizing the significance of such study in a global framework and knowledge generating potential of such studies, the possibility of establishing a neutrino observatory was being explored since 1989 itself. Later after a series of meetings and discussions at Institute of Mathematical Sciences (IMSc), Chennai, Tata Institute of Fundamental Research (TIFR), and at the instance of Department of Atomic Energy (DAE), a Neutrino Collaboration Group (NCG) was formed to study the possibility of building an India-based Neutrino Observatory (INO). "Creation of an underground neutrino laboratory with the long term goal of conducting decisive experiments in neutrino physics" and "also other experiments which require such a unique underground facility" was the purpose of the NCG. Open multi-institutional neutrino collaboration was also formed to create the INO. Consequently, two potential sites were identified to establish the INO and to construct an underground laboratory in India. It is stated that "an underground laboratory for doing neutrino physics at an internationally competitive level requires a depth in excess of 1000 meters {3000 meters water equivalent (mwe)}" (Anonymous, 2005).

The proposed INO site is at Singara, Masinagudi, Nilgiris district in Tamil Nadu. With respect to the proposed establishment to establish the world class laboratory, the Institute of Mathematical Sciences (IMSc), Chennai, requested Sálim Ali Centre for Ornithology and Natural History (SACON) to undertake a rapid environmental assessment with emphasize on ecological components.

1.1. THE INDIA-BASED NEUTRINO OBSERVATORY (INO)

1.1.1 Creation of the INO

As noted earlier world over currently four major laboratories are working. These laboratories are located either in mines or in road tunnels, for the express need of having thick overburden to curtail background radiations. India being one of the pioneer countries researching neutrino physics, the idea of establishing a neutrino observatory in the country was actively pursued since 1989. The Workshop on High Energy Physics

Phenomenology (WHEPP-6) held at Chennai during early 2000, the "Neutrino 2001" meeting at IMSc, Chennai and several other meetings elsewhere to bring in and interactions with experimentalists and theorists in the field of neutrino physics was one of the important deliberations further in this line. The proposal to establish an India-based Neutrino Observatory (INO) was presented by the Neutrino Physicists before the Department of Atomic Energy (DAE), Government of India, which followed the formation of a Neutrino Collaboration Group (NCG) for studying the feasibility of creating the INO. Nearly 20 scientific and academic institutions are involved in this endeavour. A Site Selection Committee (SSC) was authorised to identify an area where the observatory can be established.

1.1.2 The Site

The SSC studied the site survey reports on two locations; one in Tamil Nadu and the other in West Bengal. The criteria set for the suitability of the sites are given in Appendix 1. The site (Latitude = 27.4° N, Longitude = 88.1° E) in the Eastern Himalayas is located adjacent to the Rammam Hydel project in the district of Darjeeling. The proposed portals of access tunnel and adit are located adjacent to the metalled road leading to the powerhouses of the hydel projects. The SSC after carefully studying aspects such as stability, safety, access and minimal damage to the environment, recommended the site at Singara, Nilgiri district, Tamil Nadu for locating INO (details of the proposed site is furnished in Appendix 2). The site in Tamil Nadu is located at Singara, Masinagudi, Nilgiris district (Figure 1) adjacent to the Pykara Ultimate Stage Hydro Electric Project (PUSHEP; Latitude = 11.5° N, Longitude = 76.6° E). An engineering task force is entrusted to prepare the Detailed Project Report (DPR) for the site.

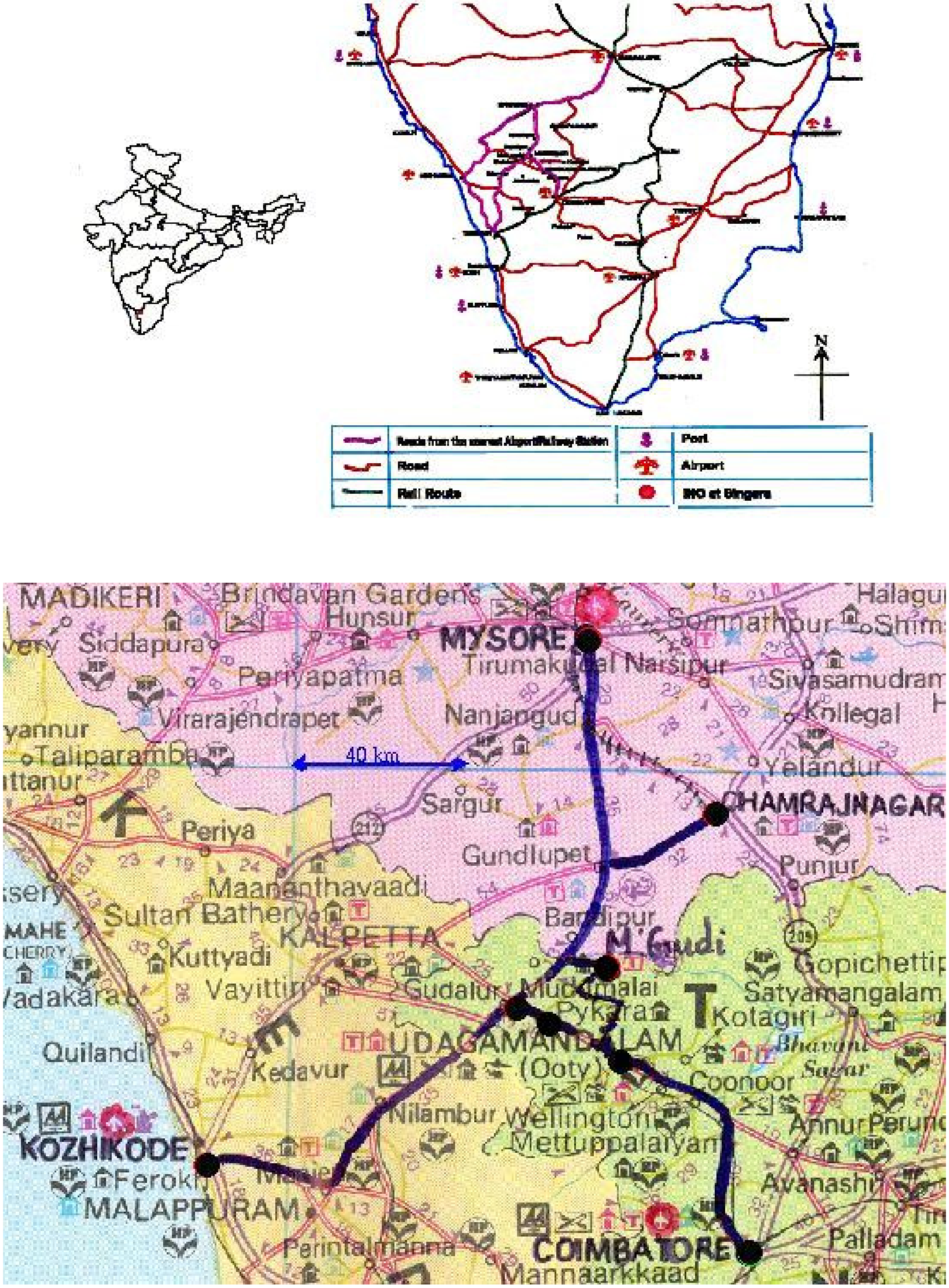

Figure 1. Location of the project site INO-Masinagudi

1.1.3 The project

The INO site at Singara is close to the PUSHEP tunnels and generator cavern (Figure 2). The tunnel portal of the proposed INO is to be located near the south portal of the PUSHEP access tunnel. It is about 50 m from the PUSHEP main gate located nearby Singara Coffee Estate in the Pykara camp of the Tamil Nadu Electricity Board (TNEB). The observatory will be located deep underground at about 1300 m below the 2207 m peak in the Nilgiris. The tunnel to the laboratory cavern will be nearly 2370 m long and 7.5 m wide in diameter (Table 1). To detect the neutrinos and to get the neutrinos scattering pattern, which otherwise are difficult to locate, an Iron Calorimeter (ICAL) of about 50000 tonnes will be located in the cavern.

1.1.4 Components of the project

The proposed Observatory comprises of two caverns with about 132 x 26 x 28.5 m and 55 x 12.5 x 8.5 m in dimensions (Figure 3) for the control and utility equipment and four inter-connecting adits for accessibility and safety. The observatory will house the neutrino experimental set-up. The set-up for the detection of neutrinos (Appendix 3) will have Resistive Plate Chamber (RPC) detectors sandwiched between stacks of magnetised steel plates. The detector will have a coating of metal with thin glass chamber, filled with Argon, Freon (R 134a) and nearly 8% Isobutane. The detector can hold 1000 cubic meter of the gas. The magnets will be water cooled. The gas and the water cooling system will be in a closed cycle. It is also suggested that the gas will be diluted with fresh air before release of the same into the atmosphere, if required. Nearly 3000 kVA of power will be required for the project, which would be availed from the nearby TNEB substation.

Table 1**.** INO Main access tunnel alignment and cavern details

Location	Adjacent to PUSHEP - Access Tunnel (200m East)
Length	2370 m
Gradient	1 in 13.5
Inlet sill level	+863.67
Sill level at Cavern	+852.67
Cavern Height	29.5 ms

Cavern crown level	+881.17
Vertical cover from Sill level	1340 m
Sill level of INO access tunnel at PUSHEP TRT crossing	+958.4 m
Crown RL of PUSHEP TRT at crossing	929.93 m
Cover between INO access and TRT	28.52 mtrs. PUSHEP
(Source: INO)	

The main components of the experiments facility at Singara are given in Table 2.

Table 2. Facilities proposed for INO at Singara				
No	Facilities		Location	Dimensions
1	Laboratory	Hall 1	Underground	132m x 26m x 29.5m
		Hall 2		40m x 12.5m x 8.5 m
2	Access tunnel		Underground	2370m long x 7.5m diameter
3	Utility building (substation, chilling plant, etc.)		Surface (Over ground) in the TNEB land at Masinagudi.	42m x 22m x 5m

Apart from the above items several residential, offices and administrative facilities (Table 3) are also proposed in the INO project.

Table 3. Surface Facilities (Over ground) proposed for INO at Masinagudi	
Items	Dimensions
Surface laboratory	250 m^2
Administrative building	400 m^2
Assembly shop	500 m^2
Workshop	50 m^2
Substation for power distribution	240 m^2
Residence for	20 families
Hostel / guest house for	40 members
Source: Sreenivasan (2007), First four items will be in one building	

1.1.5 Land and other resources requirement

Most of the project components are placed underground in tunnel and caverns. Therefore, no forest land is required for the project. The tunnel portal is located in the TNEB land nearby. The labour camp, staff quarters and administrative buildings will be located in the TNEB land opposite to the PUSHEP guest house in Masinagudi.

The total land area required for the project is around 15.1 Ha including notional land required of about 5 Ha for fully underground facilities. The other major resource required is about 101 KT of various grades. The power requirement will be about 1MW during construction stages and about 3MW during operational phase. The demand on other resources like water etc. is minimal. (Appendix 4 for details of land and other resources requirements).

1.1.6 Construction technology and execution

The following are the important construction activities of the INO project

- Excavation of the access tunnel, adits and the cavern for laboratory
- Concrete lining of the tunnel and caverns
- Mobilizing materials and equipments for the laboratory
- Establishment of underground laboratory and related facilities
- Formation of residential quarters and administrative facilities

All the above project components except the last one are to be established underground. The construction activities for the access tunnel are proposed by forming portal at the entry. Once the portal is formed, the tunnelling will be carried out by core drilling and blasting. All other associated shafts and underground caverns will be excavated in proper sequence one after another through access tunnel. Concreting works in the tunnel will be carried out when excavation is completed.

According to the project proponent, tunnel would be excavated by conventional drilling technology. Blasting pattern requiring minimum charge and yielding maximum pull will be designed based on the nature and quality of rock mass and size of excavation. All the tunnels, except construction adits, will be excavated first followed by benching. The sequence of tunnelling operation is as given below

- Surveying and marking of the area to be excavated
- Drilling of holes as per blasting pattern design
- Loading of explosives
- Blasting
- Defuming
- Scaling
- Row supporting (Shotcreting, Rock bolting, etc.)
- Drilling drainage holes wherever seepage of water encountered, and
- Concrete lining and Grouting

In all, 110 men (contractor workers and departmental staff will be working at the site on daily basis during construction of the laboratory facilities (Table 4) (Sreenivasan, 2007). The personnels expected to be involved in operation phase are given in Table 5. It is expected that the construction would be completed in four years. The installation of the ICAL experimental set up will take another one (1) year (Sreenivasan, 2007).

Table 4. Personnel involved in INO project and resident population during Construction Phase

Year	Contract Labour			Departmental Staff			
	Skilled	Semi Skilled	Unskilled	Engineers	Scientists	Total family members	Total residents
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	05	-	5	10	50	90

Source: INO

Table 5. Resident population during Operation phase.

Scientist	6
Auxilary staff	14
Family members	60
Total	80

Source: INO

A few of the various construction equipments proposed to be used are listed below.

- Drill jumbos
- Air compressors
- Mobile cranes
- Tippers
- Tip trucks
- Jack hammers
- Road rollers
- Gas welding units
- Dewatering pumps with motors
- Lorries
- Hand winches
- Rock bolters
- Raise climbers and
- Excavators/ Loaders

2. THE PRESENT STUDY

Study of the ecological community would be useful in assessing the influence of varying operational and environmental conditions on the ecosystem. The recent thrust on biodiversity conservation necessitates documentation of flora and fauna and identification of threats to the local biodiversity. Establishing the INO at the PUSHEP site may have impact on its surroundings, both in short and long-term time scale. In broad terms, the present study is undertaken to examine and document the impacts, if any, due to the construction and operation of the project. The duration of study was three months from December 2006.

2.1. SCOPE AND OBJECTIVES

The broad scope of the present study is to conduct a rapid survey and examine the impacts of the proposed INO project on the biological and ecological environment. The major objectives of the study are

i) Assessment of the flora in the project location and its environs,

ii) Assessment of the fauna in the project location and its environs,

iii) Identification of probable impacts arising from the execution of the project on the biological and ecological environs,

iv) Propose mitigation for minimal impacts, if any

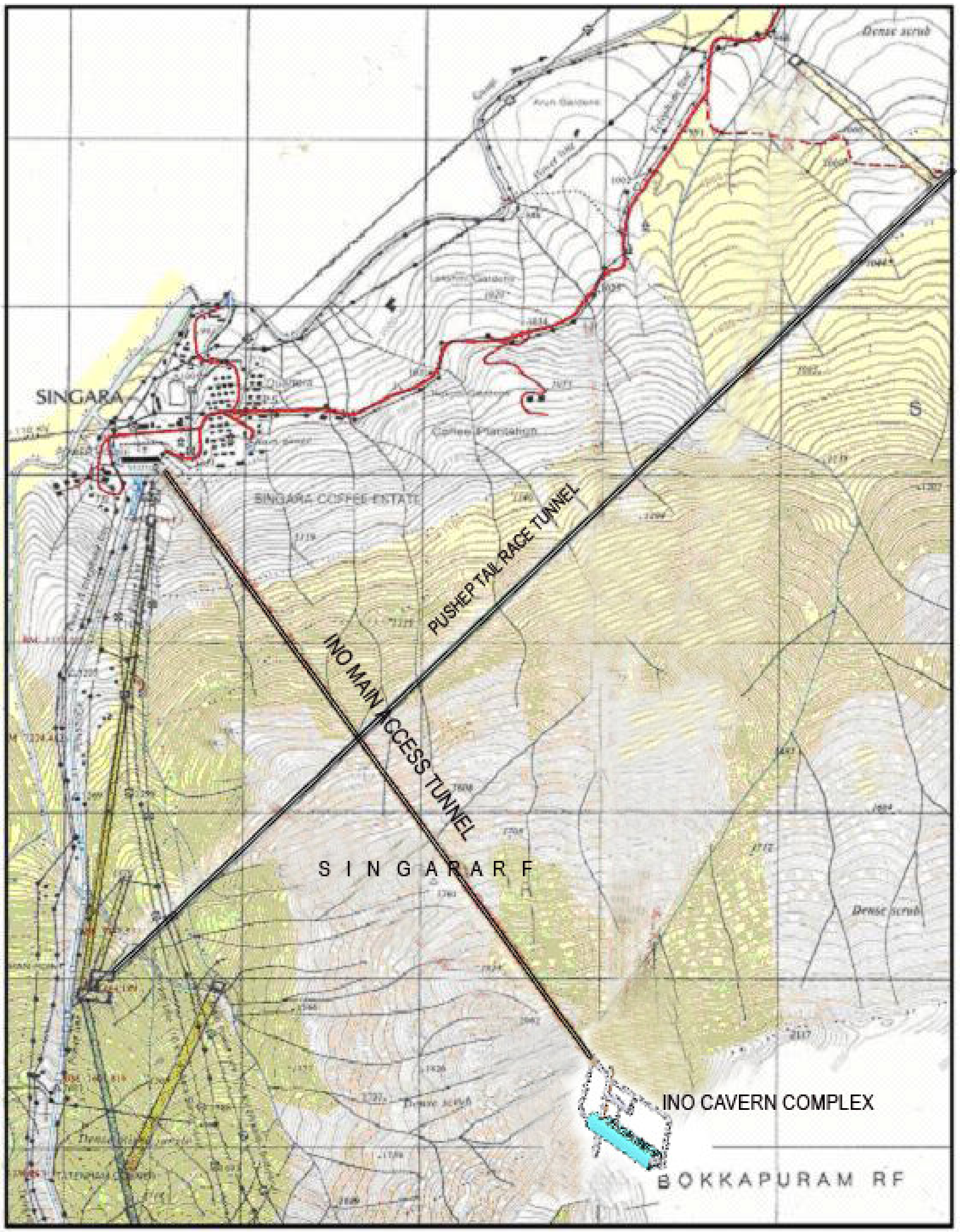

Figure 2. INO main access tunnel alignment

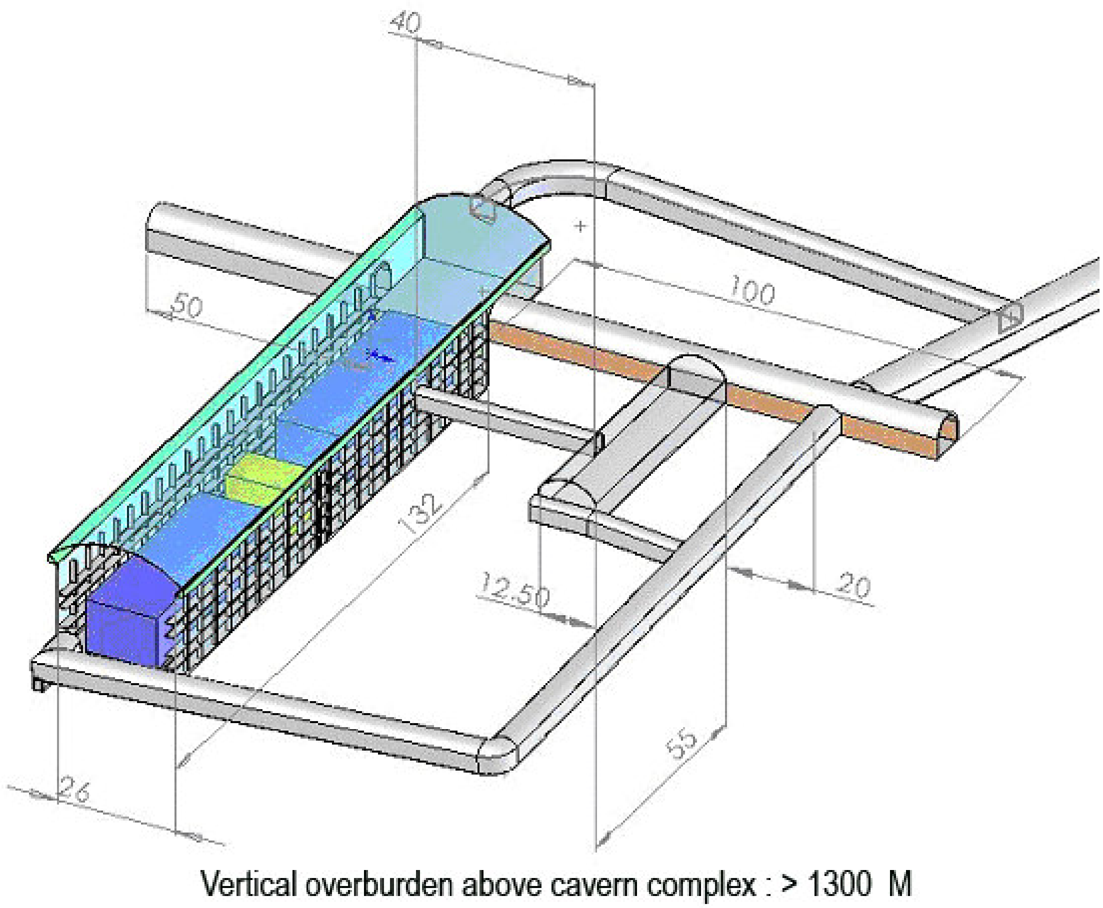

Figure 3. The proposed model of tunnel

2.2. STUDY AREA

The study primarily concentrates on the project location, namely i) the proposed Singara portal of the INO, near the PUSHEP, and ii) its environs. The area within 5-10 km radial distance from the site of proposed project (referred to hereafter as the environs of the project) was also examined. The total study period was three months: December 2006 to February 2007. However, information from secondary sources and published and unpublished reports were consulted to satisfactorily document the environmental scenario of the project area and its environs.

2.3. METHODOLOGY

Detailed scientific information on the ecological makeup of a natural system, specifically with respect to flora and fauna is a prerequisite for its long term and strategic management, and also to weigh any possible impacts of activities proposed to be undertaken in the area. This is also essential to develop a general perception about the project and its impacts. In the present study, the first exercise was focussed on collecting and collating this basic information. To collect data and information on specific components of the ecological system and pertinent issues widely used standard scientific methods were adopted. Generally, the guidelines of the Ministry of Environment and Forests, Government of India (Anonymous, 1985; World Bank, 1991a & b) were followed with respect to the scope and objectives.

The present investigation focussed on the project area and its environs. Area falling within 5-10 km radial distance from the INO location was included for the field study. Taking note of the ecological and special proximity of the project site to Protected Areas (PAs) and the Mudumalai Wildlife Sanctuary, which is well known for its wildlife heritage, attempt was made to incorporate available information about these protected areas and their ecological significance. The Mudumalai Wildlife Sanctuary is one of the most popular and oldest wildlife sanctuaries in India. The project was examined keeping in view of the long-term survival of the wildlife habitats and the increasing threats to it arising from the drastic anthropogenic activities and commercial activities in the Masinagudi area and the natural resources around.

2.3.1 *Methodology for the study of flora*

The flora of the project areas, in Singara, Masinagudi, which lies in continuity with the Mudumalai Wildlife Sanctuary (Figure 4), was examined following standard methods (Greig-Smith, 1983; Caustan, 1988). Similarly, the flora in the environs of the project location was also documented. Species encountered during the surveys were recorded. As noted earlier, information was drawn extensively from previous works. Taxonomic identification of the species encountered in the field was done consulting the flora of Hooker (1872-97), Gamble (1957) and Jain and Rao (1983). Sources referred for the preparation of plant list include Sharma *et a l*. (1977), Sukumar *et al*. (1992), Azeez *et al*. (1997a, b and 2006) and Suresh *et al*. (2006).

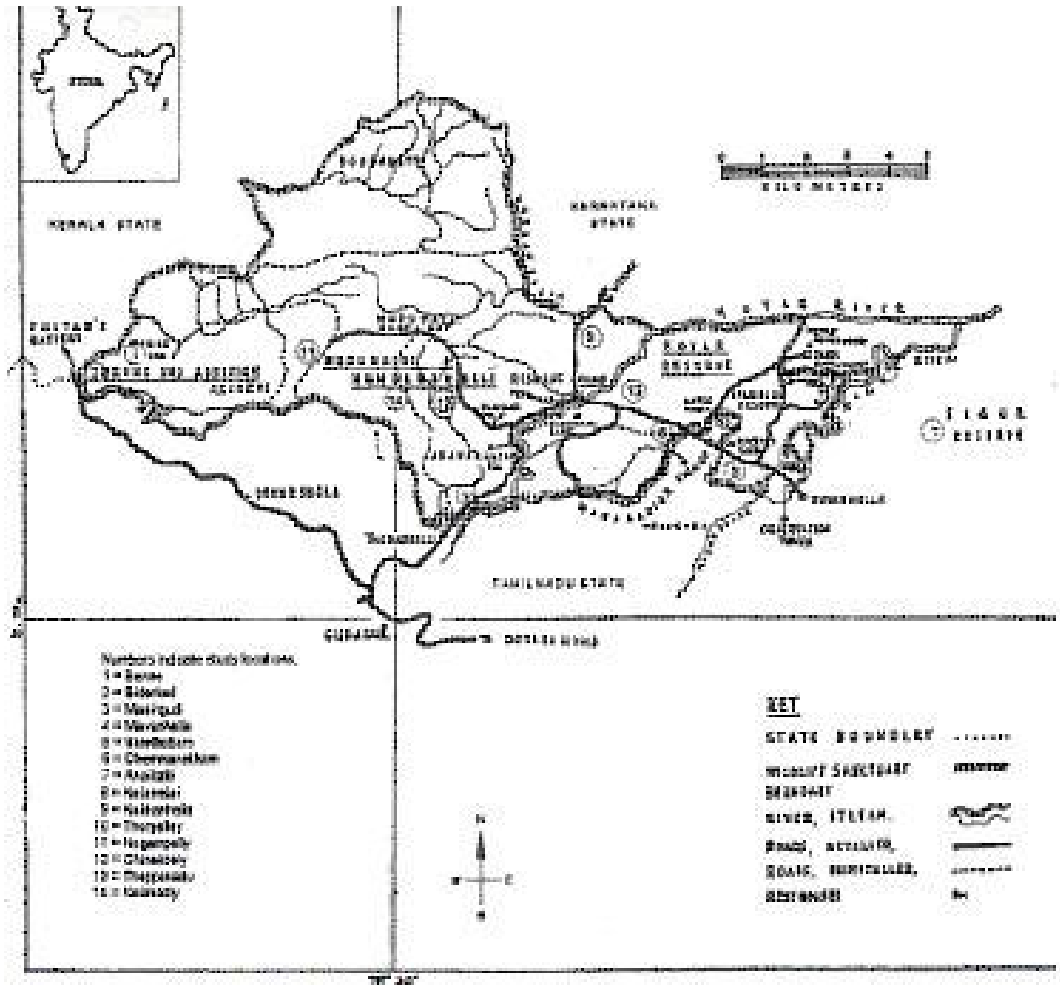

Figure 4. Mudumalai Wildlife Sanctuary, proposed INO location and immediate surroundings

2.3.2 Methodology for the study of fauna

The survey for the study of fauna of the environs of the proposed project site was conducted following methods given in Table 6. Visual encounter survey was conducted for listing amphibians and reptiles, whereas opportunistic observations and random walk was used for birds. For the survey of mammals, tracks and signs, and visual encounter survey was followed. The species were also identified with indirect evidences such as pug marks, calls, signs and scats (Bang *et al*., 1972; Heyer *et al*., 1994). The reports by Azeez *et al*. (1997a, 1997b and 2006) were referred for the preparation of the check list as this study was a rapid one lasting only three months.

Table 6. Techniques used for sampling fauna

Taxa	Sampling Methods
Amphibians	Visual encounter survey (search)
Reptiles	Visual encounter survey (search)
Birds	Random walk, opportunistic observations
Mammals	Tracks and signs, and visual encounter survey

3. OBSERVATIONS

The present observations are made based on field work specifically conducted for the study on INO project, as well as studies conducted earlier in the area. Extensive use of research conducted in the area by various agencies, including the Tamil Nadu Forest Department (TNFD), Indian Institute of Sciences (IISc), Bangalore, Bombay Natural History Society (BNHS), Mumbai, Wildlife Institute of India (WII), Dehra Dun and others were included. The project site is located just outside the Mudumalai Wildlife Sanctuary. An important portion of the area lying within 10 km radial distance from the project site is within the sanctuary boundaries, while the rest comes under Reserve Forests, revenue lands and private lands. Revenue land contiguous with the Sigur Revenue Forest lies towards the east. Since, the Mudumalai Wildlife Sanctuary is an important wildlife habitat of India lying close to the INO project site, the information available on the flora and vegetation of the sanctuary elsewhere is described in detail in the report.

3.1. TOPOGRAPHY

The Nilgiris, extending to about 56 km in length and 32 km in width in the Western Ghats, show considerable variation in vegetation types that can be attributed to the varied topographic, climatic and physiographic features. The proposed INO project's laboratory component is situated at Singara, about 6.5 km from the Masinagudi village, which is expanding fast in view of its tourism potentials and closeness to the Mudumalai Wildlife Sanctuary. The administrative and over ground facilities are to be located close to the PUSHEP guest house owned by TNEB on the Masinagudi – Moyar road.

The terrain of the general area is undulating with hillocks, plains and deep gorges. The average altitude of the study area is around 1000 m above sea level varying from 450 m at the Moyar gorge / valley to 2500 m. The most remarkable geo-morphological feature of the area is the 450 m deep and 20 km long Moyar gorge / valley known in the past as "Mysore ditch" that runs towards the east. The river Moyar meanders through the gorge for about 20 km and joins the river Bhavani at Bhavanisagar reservoir. Several smaller rivers and rivulets also traverse the area of which the major one is river Sigur. The Moyar and Sigur rivers make a natural boundary of the Mudumalai sanctuary on the north and east respectively. The major stream traversing the immediate environs of the project, nearby Masinagudi is Avari halla, joining the Maravakandy reservoir at Masinagudi. Further to the Maravakandy dam the Avari halla carries only the trickling water from the reservoir or the overflow from it. The sanctuary is drained by Benne halla, Bider halla, Doddagatti halla and Kakkan halla. However, the flow in almost all the streams gets considerably decimated during summer. The major sources of water in the area during the dry season are the Maravakandy reservoir, the flume channels and the Moyar fore-bay maintained by the Tamil Nadu Electricity Board.

The rock type in the area is peninsular gneiss with black sandy loam and red heavy loam soil types (Suresh *et al*., 1996). The basic rock formation of the Nilgiri - Wynad plateau differ sharply from the Nilgiri plateau being typical Archean biotite and hornblendic gneiss with intensive bunts of charnokite and much younger biotite-granite pegmatite and basic doleric dykes. Two kinds of soils may be recognized in the area; black sandy loam, which contains over 50% sand and gravel, and the red heavy loam (Jeyadev, 1957). The red soil is generally confined to the southern part of the range where the rainfall is higher. Black soil is seen in environs such as Manradiar Avenue in the Mudumalai Wildlife Sanctuary.

3.2. CLIMATE

The area experiences three distinct seasons; summer starting from (February / March - May), monsoon (mid May – October) and winter (November – February). The temperature in the environs of the project location varies from place to place due to varied rainfall and vegetation. Temperature is comparatively lower in the project location than in the Masinagudi area. Temperature decreases with the onset of south-west monsoon in June. The hottest months are April-May and the coldest December-January (Figure 5).

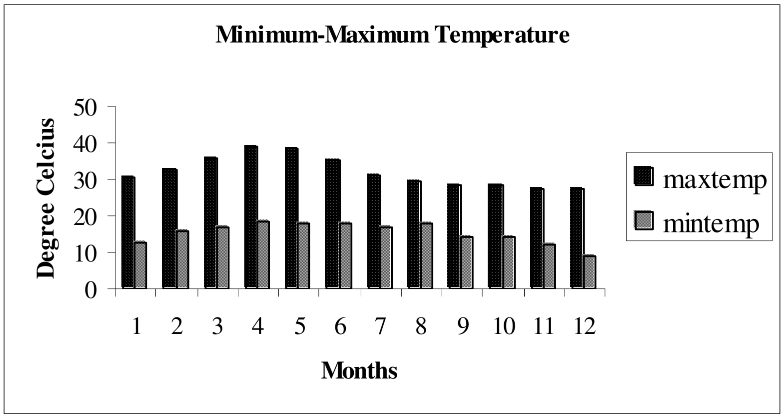

Figure 5. Mean monthly average temperature -Masinagudi Area (1993-96)

The study area receives rain from both the southwest (June – September) and the northeast (October- November) monsoons. The rainfall in the environs of the study area varies widely. In general, June and October months receive high rainfall (Figure 6). The rainfall ranges from 400 mm to 2500 mm in the eastern and western parts of the study area respectively. The average annual rainfall during 1992-1996 at Maravakandy and Moyar, which are not far away from each other, was 532.3 mm and 652.5 mm respectively (Azeez *et al*., 1999).

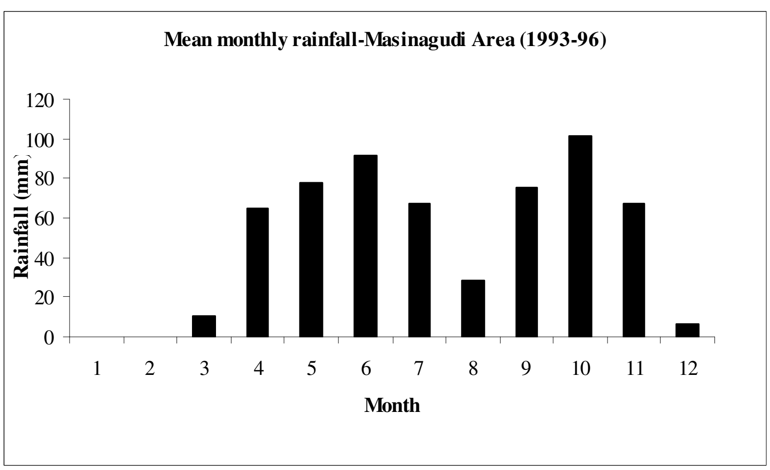

Figure 6. Mean monthly rainfall-Masinagudi Area (1993-96)

3.3. BIODIVERSITY

Prioritisation of the conservation issues, in terms of flora and fauna, in addition to other base-line parameters is necessary for inferring the impact of a proposed project. The survey on the flora and fauna in and around the project site was made both directly by conducting field surveys and by collating from other sources as mentioned earlier. Western Ghats, one of the two biodiversity hot-spots in India, is unique in holding various endemic and endangered species. The area around the Masinagudi apparently is significant for it falling adjacent to the Mudumalai Wildlife Sanctuary practically skirting two wildlife corridors (Singara - Mavanhalla and Moyar - Avarihalla Corridors). In the following section an attempt is made to elaborate vegetation, and floral and faunal biodiversity in various locations in the study area.

3.3.1 Vegetation in Bokkapuram

The area in Bokkapuram is highly degraded and in a rapid state of change compared to situation reported in previous studies (Azeez *et al.*, 1997a). Several tourist resorts have come up in the area and most of them just border the reserve forests and practically are the only entry points to the reserve forest flanking the hillock. The stretch of forest patch between the privately owned lands, resorts and the steep hills are increasingly with high gradients, limiting the movements of larger mammals to the adjacent forest patches. Of the 32 tourist resorts in Masinagudi and its surroundings, almost 50% falls in Bokkapuram, which indicates the severity of the situation.

The common species of trees seen at Bokkapuram are *Acacia pennata, Buchanania lanzan* and *Pterocarpus marsupium*. Common shrub species of the area includes *Argyreia cuneata, Gmelina asiatica* and *Toddalia asiatica*. The exotic weeds such as *Lantana camara, Chromolaena odorata* and *Opuntia dilleni* have extensively invaded the area, causing hindrance to the movement of wild animals. It seems the local villagers largely depend on the forests for fuel-wood.

3.3.2 Vegetation in Mavana halla and Masinagudi

Common tree species found in this area are *Acacia leucophloea*, *Cassia fistula and Ziziphus mauritiana* etc. The common herbs and shrubs are *Acalypha fruticosa*, *Achyranthes aspera*, *Argemone mexicana*, *Argyreia cuneata*, *Boerhavia diffusa*, *Croton bonplandianum*, *Lantana camara*, *Malvastrum coromandelianum*, *Sida acuta and Tephrosia purpurea*. The plantations in the Masinagudi and Mavana halla are dominated by *Eucalyptus globulus*, an exotic species. The major herb and shrub species recorded in the area are *Acanthospermum hispidum*, *Argyreia cuneata*, *Barleria mysorensis*, *Flacourtia indica*, *Gmelina asiatica*, *Solanum indicum*, *Tephrosia purpurea and Toddalia asiatica*.

3.3.3 Vegetation towards south of Moyar village

The vegetation type in this region is scrub forest dominated by species such as *Albizia odoratissima*, *Diospyros montana* and *Elaeodendron glaucum*. The ground cover comprised of *Aristida adscencionis*, *Bothriochloa pertusa*, *Cassia mimosoides*, *Chrysopogon fulvus*, *Lantana camara*, *Opuntia dillenii*, *Oxalis corniculata* and *Sida cordata*.

3.3.4 Vegetation of Mudumalai Wildlife Sanctuary

The Mudumalai Wildlife Sanctuary (11º 32' - 11º 43' N and 76º 22' - 76º 45 E) located in the Nilgiri District extends over an area of about 321 km^2 and forms a part of the Nilgiri Biosphere Reserve (Suresh *et al.*, 1996). The sanctuary is bounded by Wynad Wildlife Sanctuary of Kerala in west, Bandipur Tiger Reserve of Karnataka in north and by private lands with coffee and tea plantations of Tamil Nadu in south and east (Azeez *et al.*, 1997a). Mudumalai Wildlife Sanctuary is endowed with various vegetation types and holds a rich biodiversity which purely depends on the rainfall gradient (Sharma *et al.*, 1977). Four major vegetation types, based on the classification by Champion and Seth (1968), are found in the sanctuary and are described below.

3.3.4.1 Tropical semi-evergreen forests

Tropical semi-evergreen forests are seen in western parts of the sanctuary with a rainfall of nearly 1800 mm per annum. The dominant tree species were *Acronychia pedunculata*, *Ficus hispida*, *Glochidion velutinum*, *Mangifera indica*, *Meliosma simplicifolia*, *Michelia* sp., *Olea dioica*, *Toona ciliata*, *Vernonia arborea* and *Viburnum punctatum*. Herbaceaous vegetation is predominated by *Ardisia solanacea, Cyathula prostrata*, *Justicia wynaadensis* and *Rungia parviflora*.

3.3.4.2 Tropical Moist Deciduous Forests

Tropical moist deciduous forests are seen in the western parts of the Mudumalai block as well as Benne block. This forest type receives rainfall of 1500 mm per annum. Tree species seen here includes *Bambusa arundinacea*, *Careya arborea*, *Dalbergia latifolia*, *Elaeocarpus tuberculatus*, *Glochidion velutinum*, *Lagerstroemia microcarpa Launea coromandelica*, *Syzygium cumini*, *Tectona grandis, Terminalia bellirica, T. crenulata*, and *Trema orientalis*. The undergrowth comprises of *Abutilon indicum*, *Cippadessa bacciferra*, *Leea asiatica*, *Oxalis corniculata*, *Triumfetta annua* and *Urena lobata*. The dominant grasses are *Cymbopogon flexuosus*, *Imperata cylindrica*, *Themeda cymbaria* and *Setaria intermedia*.

3.3.4.3 Tropical Dry Deciduous Forests

Major portion of the sanctuary receiving an intermediate rainfall of 900-1500 mm per annum falls in the category of Tropical dry deciduous forest. The dominant tree species are *Anogeissus latifolia*, *Butea monosperma*, *Diospyros montana*, *Gmelina arborea*, *Grewia tiliifolia*, *Kydia calycina*, *Tectona grandis*, *Terminalia crenulata*, *Schleichera oleosa* and *Ziziphus xylopyrus*. Species such as *Antidesma diandrum*, *Cassia* sp., *Hibiscus* sp., *Lantana indica*, *Physalis minima*, *Sida acuta*, *Vernonia cinerea*, *Waltheria indica*, *Zornia diphylla* and *Tarenna asiatica* are dominant among the herbs and shrubs.

3.3.4.4 Tropical thorn Forests

Tropical dry thorn forest is seen in the eastern part of the sanctuary along the border with the Sigur plateau lying in the rain shadow of the Nilgiri massif. The area experiences an annual rainfall of 600-900 mm and is dominated by xerophytic tree species such as *Acacia chundra*, *A. leucocephloea, A. polyantha*, *A. ferruginea*, *Capparis sepiaria*, *Dalbergia lanceolaria*, *Opuntia dillenii*, *Premna tomentosa, Sapindus emarginatus* and *Ziziphus* sp. The common herbs and shrubs include *Acalypha indica*, *Blumea mollis*, *Indigofera* sp., *Lantana wightiana*, *Tribulus terrestris* and *Trichodesma indicum*.

3.3.5 Flora at the INO entry portal and nearby areas

The vegetation at the proposed entry portal tunnel and on the surface locations of the underground INO tunnel and laboratory were surveyed. Species recorded were *Artocarpus* sp., *Bothriochloa pertusa*, *Centella asiatica*, *Conyza* sp., *Desmodium* sp., *Eragrostis* sp., *Ficus racemosa*, *F.religiosa*, *Ipomoea sepiaria*, *Leucas aspera*, *Mangifera indica*, *Oxalis corniculata*, *Panicum* sp., *Rhynchosia* sp., *Rubia cordifolia*, *Setaria* sp., *Sida* sp., *Solanum* sp., *Syzygium cumini*, *Anogeissus latifolia*, *Aristida* sp., *Arundinella* sp., *Bambusa arundinacea*, *Blumea* sp., *Butea monosperma*, *Calotropis gigantea*, *Cardiospermum* sp., *Cassia fistula*, *Chloris* sp., *Commelina benghalensis*, *C.ensifolia*, *Cyperus* sp., *Dalbergia* sp., *Dactyloctenium aegyptium*, *Dolichos* sp., *Erythrina indica*, *Euphorbia geniculata*, *E.hirta*, *Ficus tsjakela*, *F. virens*, *Gnaphalium* sp., *Heteropogon contortus*, *Indigofera* sp., *Kydia calycina* and *Themeda triandra.*

Species recorded in the vicinity also included many exotic elements; *Lantana camara*, *Trema orientalis*, *Parthenium hysterophorous, Vinca rosea, Eupatorium repandum, Cassia siamea, C. tora* and *Grevillea robusta*. The exotic species would have been brought here by the TNEB staff that had stayed here for operating the power plant in the area for several decades.

3.3.6 Floral enumeration

The project site is covered mainly with dry deciduous vegetation. A total of 676 plant species belonging to 100 families are occurring in the study area, covering major part of the Mudumalai Wildlife Sanctuary. Among the 676 species, 189 species are trees (Appendix 5), 197 are shrubs (Appendix 6), 222 are herbs (Appendix 7) and 68 are grasses (Appendix 8). Of the 100 families reported from the study area, Fabaceae is the dominant family with 78 species.

3.3.7 Endemic plants

A total of 62 endemic plant species (marked in Appendices 2, 3, 4, 5, 6) are occurring in the study area. Among the 62 endemic species 13 are trees, 16 are shrubs, 26 herbs and seven are grasses. These species are endemic to the peninsular Indian region.

3.4. FAUNAL ANALYSIS

In all, 173 species of vertebrates were recorded in and around the proposed site. As the study was rapid, information on the faunal elements was largely collated from published literatures and reports. Twelve species of amphibians (Table 7), 46 reptiles (Table 8), 87 avian (Appendix 9) and 28 mammalian (Table 9) species were reported to occur in the vicinity of the project area. In the area near the entry portal only a few species could be recorded during the survey, due to the existing disturbance and short survey period. Species number and abundance was higher in locations away from the project site, especially in the Mudumalai Wildlife Sanctuary and thorn forests of Moyar.

3.4.1 Amphibians

Twelve species of amphibians could be observed in and around the project site. Of the 12 amphibian species, three taxa are endemic to Western Ghats.

3.4.2 Reptiles

Forty six species of reptiles were recorded around the project site. Five species of reptiles are endemic to the Western Ghats (Table 8) and five are aquatic fauna.

3.4.3 Birds

Eighty six bird species were recorded in the study site. Of these, nine are aquatic and the remaining terrestrial in habit (Appendix 9). Records of a fewer of water dependent species (11 out of 86) could be mainly due to dry nature of the area and lack of larger water bodies in the environs.

Table 7. Amphibians observed in the vicinity of INO project area

No	Common Name	Scientific Name
1	Common Indian Toad	*Bufo melanostictus*
2	Ornate Microhylid	*Microhyla ornata*
3	Leaping Frog	*Indirana* sp.*
4	Skittering Frog	*Euphlyctis cyanophlyctis*
5	Indian Pond Frog	*Euphlyctis hexadactylus*
6	Indian Burrowing Frog	*Sphaerotheca breviceps*
7	Indian Cricket frog	*Limnonectes limnocharis*
8	Indian Bull frog	*Hoplobatrachus tigerinus*
9	Jerdon's Bull Frog	*Hoplobatrachus crassus*
10	Wrinkled Frog	*Nyctibatrachus* sp.*
11	Common Tree Frog	*Polypedates maculates*
12	Bush Frog	*Philautus* spp.*

* Endemic to the Western Ghats. Nomenclature followed, Dutta (1992)

Table 8. Reptiles recorded in the vicnity of INO projcet location

No	Common Name	Scientific Name
1	Mugger#	*Crocodylus palustris*
2	Indian Flapshell Turtle#	*Lissemys punctata*
3	Indian Black Turtle#	*Melanochelys trijuga*
4	Leith's Softshell Turtle#	*Aspideretes leithii*
5	Indian Star Tortoise	*Geochelone elegans*
6	Brook's Gecko	*Hemidactylus brookii*
7	Bark Gecko	*Hemidactylus leschenaultia*
8	Termite Hill Gecko	*Hemidactylus triedrus*

9	House Gecko	*Hemidactylus frenatus*
10	Indian Day gecko*	*Cnemaspis* sp.
11	Elliot's Forest Lizard*	*Calotes elliotí*
12	Large Scaled Forest Lizard*	*Calotes grandisquamis*
13	Garden Lizard	*Calotes versicolor*
14	Nilgiri Forest Calotes*	*Calotes nemoricola*
15	Green Forest Calotes	*Calotes calotes*
16	Roux's Forest Calotes	*Calotes rouxii*
17	Western Ghats Flying Lizard	*Draco dussumeiri*
18	South Indian Rock Agama	*Psammophilus dorsalis*
19	Fan Throated Lizard	*Sitana ponticeriana*
20	Spotted Supple Skink	*Lygosoma punctata*
21	Keeled Grass Skink	*Mabuya carinata*
22	Indian Chamaeleon	*Chaemaeleo zeylanicus*
23	Common Monitor	*Varanus bengalensis*
24	Blind Snake	*Ramphotyphlops braminus*
25	Common Sand Boa	*Eryx conicus*
26	Red Sand Boa	*Eryx johnii*
27	Indian Rock Python	*Python molurus*
28	Common Rat Snake	*Ptyas mucosa*
29	Banded Kukri Snake	*Oligodon arnensis*
30	Indian Cat Snake	*Boiga trigonata*
31	Wolf Snake	*Lycodon aulicus*
32	Green Whip Snake	*Ahaetulla nasuta*
33	Brown Vine Snake	*Ahaetulla pulverulenta*
34	Ornate Flying Snake	*Chrysopelea ornate*
35	Bronzbacked Tree Snake	*Dendrelaphis tristis*
36	Striped Keelback	*Amphiesma stolatum*
37	Green Keelback	*Macropisthodon plumbicolor*
38	Checkered Keelback#	*Xenochrophis piscator*
39	Indian Cobra	*Naja naja*
40	King Cobra	*Ophiophagus hannah*
41	Indian Krait	*Bungarus caeruleus*
42	Bamboo Pit Viper	*Trimeresurus gramineus*
43	Malabar Pit Viper*	*Trimeresurus malabaricus*
44	Russell's Viper	*Daboia russelii*
45	Saw Scaled Viper	*Echis carinatus*
46	Hump-nosed Pit Viper	*Hypnale hypnale*
*species endemic to the Western Ghats, , #Aquatic, Nomenclature following Das (2003)		

3.4.4 Mammals

Twenty eight mammalian species (Table 9) is reported from in and around the proposed site and its environs.

Table 9. Mammals observed in the study area		
No	Common Name	Scientific Name
1	Bonnet Macaque	*Macaca radiata*
2	Common Langur	*Presbytis entellus*
3	Nilgiri Langur.	*Presbytis* sp.
4	Leopard	*Panthera pardus*
5	Tiger	*Panthera tigris*
6	Jungle Cat	*Felis chaus*
7	Civets	*Viverricula* sp.
8	Common Palm Civet	*Paradoxurus hermaphroditus*
9	Mongoose	*Herpestes* sp.
10	Striped Hyena	*Hyaena hyaena*
11	Jackal	*Canis aureus*
12	Wild Dog	*Cuon alpinus*
13	Sloth Bear	*Melursus ursinus*
14	Otter	*Lutra* sp.
15	Indian Flying Fox	*Pteropus giganteus*
16	Giant Squirrel	*Ratufa indica*
17	Fivestriped Palm Squirrel	*Funambulus palmaram*
18	Porcupine	*Hystrix indica*
19	Indian Hare	*Lepus nigricollis*
20	Elephant	*Elephas maximus*
21	Gaur	*Bos gaurus*
22	Black Buck	*Antilope cervicapra*
23	Four-horned Antelope	*Tetracerus quadricornis*
24	Sambar	*Cervus unicolor*
25	Chital	*Axis axis*
26	Mouse Deer	*Muntiacus muntjak*
27	Wild Pig	*Sus scrofa*
28	Pangolin	*Manis crassicaudatus*
Nomenclature after Prater 1993		

The Mudmalai Wildlife Sanctuary and its environs provide habitats to a large number of wild species such as elephants. The area also offers shelter to a huge population of domestic cattle, competing with the wild species for the limited natural resources. The sanctuary has a wild mammalian biomass of about 364 kg/km^2 which comprises of Chital

(*Axis axis*), Sambar (*Cervus unicolor*), Elephant (*Elephas maximus*) and Gaur (*Bos gaurus*) (Varman and Sukumar, 1993; Suresh *et al*., 1996). The Mudumalai Wildlife Sanctuary harbours large number of Elephants, which seasonally migrate from Wayanad, Bandipur and Nagarahole through this sanctuary and Nilgiri North division before reaching Thalamalai Reserve Forest of Sathyamangalam Forest Division, Eastern Ghats. Studies conducted by Desai and Baskaran (1996), Sivaganesan (1991) and Silori and Mishra (2001) highlight the importance of such corridors for the long term sustenance of the wild species.

3.4.5 Threatened Species

Species listed in Schedule I and II of the Indian Wildlife Protection Act 1972 and those proposed by the Zoological Survey of India (Gosh, 1994) are considered as threatened species.

Table 10. Endangered mammals occurring in the environs of the proposed project

No	Species	WPA Schedule	Red data book[@]
1	Tiger	I	Vulnerable
2	Panther	I	Vulnerable
3	Jungle Cat	II	No mention
4	Dhole or Indian Wild Dog	II	No mention
5	Jackal	II	No mention
6	Civet	II	No mention
7	Otter	II	No mention
8	Indian Elephant	I	Vulnerable
9	Gaur	I	Vulnerable
10	Four-horned antelope	I	Vulnerable
11	Mouse Deer	I	Vulnerable
12	Sloth Bear	II	No mention
13	Pangolin	I	Vulnerable
14	Giant Squirrel	I	No mention
15	Bonnet Macaque	II	No mention

Note: Based on sightings and literature (Daniel and Datye, 1995; Sivaganesan, 1991; WPA= Wildlife Protection Act, 1972 and [@]Gosh, 1994

Table 11. Endangered birds occurring in the environs of the proposed project			
No	Species	WPA Schedule	Red data book@
1	Indian Shikra	I	No mention
2	Spoonbill	I	Endangered
3	Peafowl	I	Vulnerable
Note: Based on sightings and literature, WPA= Wildlife Protection Act (1972), @Gosh (1994).			

Table 12.Endangered reptiles occurring in the environs of the proposed project			
No	Species	WPA Schedule	Red data book@
1	Python	I	Endangered
2	Indian Flapshell turtle	I	Vulnerable
3	Chameleon	I	No mention
4	Bengal Lizard	II	Endangered
5	Checkered-keelback Water Snake	II	No mention
6	Rat Snake	II	No mention
7	Russell's Viper	II	No mention
8	Indian Cobra	II	No mention
9	Mugger	I	No mention
Note: Based on sightings and literature, Bhupathy and Kannan, 1997; WPA= Wildlife Protection Act (1972) and @Gosh, 1994			

3.5. PROTECTED AREAS AND WILDLIFE CORRIDORS

Even though the project (both laboratory and other) facilities are to be located in the TNEB land, the Mudumalai Wildlife Sanctuary, Bokkapuram Reserve Forest and Singara-Mavanhalla Corridor are located bordering the project site. There are at least two wildlife corridors present nearby the project site. They are Singara-Mavanhalla and Moyar-Avarihalla Corridor (Figure 7) (Menon *et al*., 2005). Both these corridors play a vital role in movement of wildlife and exchange of genetic materials as they connect Mudumalai Wildlife Sanctuary with Sigur Plateau and Eastern Ghats, which are vital for the long-term conservation of these species (Figure 8). These corridors are already highly threatened by various anthropogenic activities in the area.

The Singara-Mavanhala corridor is adjacent to the proposed project site. Animals intensively use this corridor for movement from the Mudumalai Sanctuary to Sigur Plateau and vice-versa on seasonal basis. High density of cattle and increasing hotel/tourist industry affect these corridors as resources of the area are over exploited.

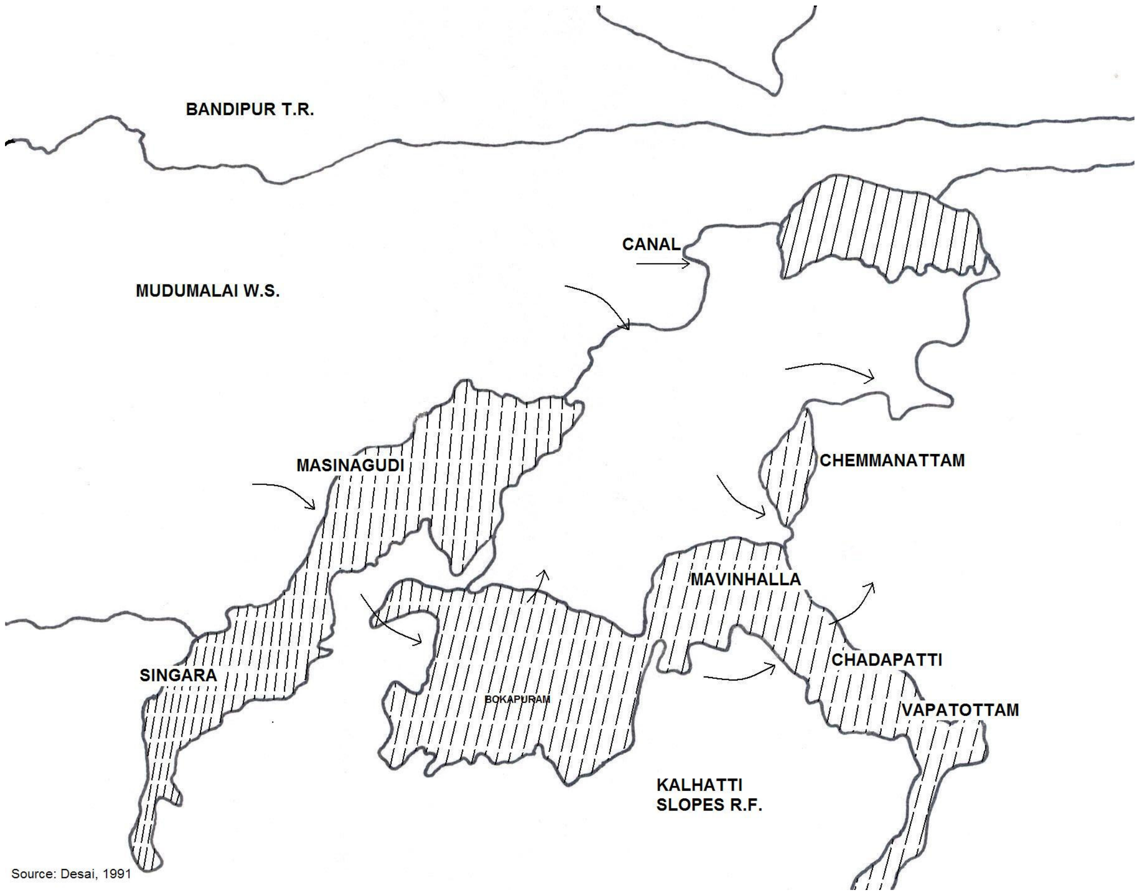

Figure 7. Forest corridors in the environs of the project; Arrow marks indicate direction of elephant movement (Source: Desai and Bhaskaran, 1996)

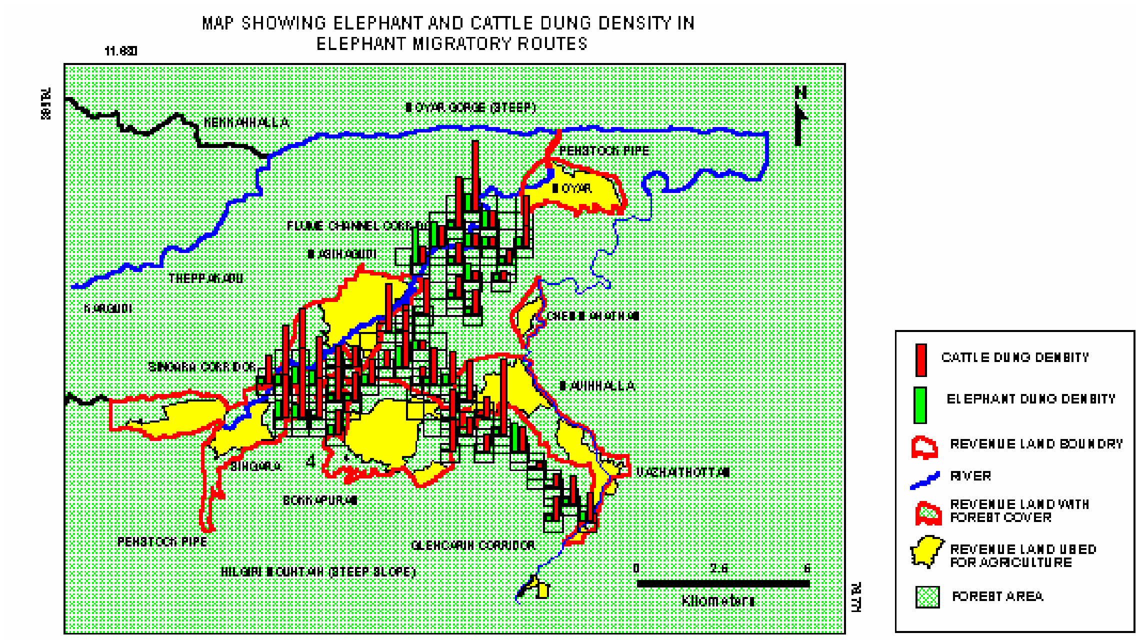

Figure 8. Elephant and cattle dung density in elephant migratory route (Source: Arumugam and Ramkumar, Undated)

4. POTENTIAL ENVIRONMENTAL THREATS AND PERTURBATIONS

Changes in the natural environment are likely to affect functioning of the natural system in various ways either temporarily or permanently. The effect may lead to destruction or changes in the biodiversity of the area affected. It may also affect the long-term survival of wildlife species. In the present case, the INO project was examined regarding the potential environmental threats and perturbations arising from the execution of the project (both construction and operation phases).

4.1. KEY CONCERNS

The key environmental concerns emphasising the biological environment were identified. The impacts of such a project with extensive construction activities call for examination from the perspective of the phases of the project, namely:

- construction phase, and
- operation phase

These two phases have distinctively dissimilar impacts on the environment. As noted earlier the major construction activity in the case of the present project happens under ground. The range in depth of the various activities reaches around 1300 m below ground level. The overlying geological strata over the caverns and tunnels are reportedly stable. Hence, the major zones of direct affect lies nearby the roads, opening of the access tunnel the muck dumping locations and the quarries or crusher locations.

4.2. IMPACTS DURING CONSTRUCTION PHASE

The major facilities associated with the INO are the underground laboratory, access tunnels and residences for the personnel staffing the observatory (Table 2 and Table 3). The construction phase in general involves activities such as clearing of the vegetation, excavation, transportation, labourer activities, etc. During the construction phase various activities may affect the environment which can be broadly categorised into the following heads

- Erecting structures required for the project,
- Sourcing of materials,
- Vehicular and labourer movement,
- Vibrations, smoke, noise during the operation,
- Blasting during excavation and clearing routes,
- Temporary human inhabitation during the construction phase,
- Transport and disposal of excavated overburden, debris and muck, and
- Disposal spills of wastes such as fuels and lubricants.

4.2.1 Impacts due to erecting structures required for the project

The construction of various temporary or permanent structures required for carrying out project works are likely to affect the movement pattern of the wild species, if placed along the route of their movement; close by to the Singara estate. However, it is expected that since the INO entry portal is close to the PUSHEP portal, no separate structures for water and electric supply are required. This area is frequently visited by the wild animals and hence, their likelihood of getting affected is high. Major part of the construction activity will be carried out under ground in the tunnel and cavern. Only minor construction activities may be carried on the surface. However, a large quantity of muck (approximately 2.25 lakh m^3, including the tunnels and caverns – Sreenivasan 2007) need to be transported to its storage and disposal site. As the disposal site is opposite to the entry portal location it is expected that the pressure on the road connecting Masinagudi to Singara will be low. The disposal of the massive quantity of muck involves several issues, some of which are listed below

- The muck storage occupies a large area,
- It leads to high suspended load in the run off during monsoon,

- If exposed to sun and wind or other activities muck adds on to the suspended particulate matter (SPM) in the ambient atmosphere,
- The dumping yards are aesthetically unpleasant in the overall environmental set up of the area, and
- It leads to increase in vehicle movement to transport the muck from the point of generation to that of disposal or storage

It is planned that INO is proposing to store the muck in a PUSHEP dumping yard site. It appears that PUSHEP could successfully utilise a major portion of the muck, although a significant quantity in the form of a mount is still remaining in the site. Proper schedule of transport has to be sorted out to avoid undue pressure on the roads and disturbance to the wild animals crossing the roads. If approximately 50% of the debris is used for construction activities such as lining of the tunnel and laying roads, the transport and other activities related to the use involve labour and vehicle movement. To make the debris uniform of size utilisable for proposed use, crushers need to be installed.

Crushers are likely to add further noise and dust to the Singara area, if located there. This is not advisable. Measures should be taken to limit the possible environmental effect of labour forces and vehicle movement in and around the dumping yards.

4.2.2 Impacts arising from the sourcing of materials

Various types of materials will be required during the construction phase such as stones, steel, cement, etc. The transport of these materials is expected to be small in the case of INO project, since they propose to utilise the quantity excavated for own construction activities. The debris generated from the blasting can be utilized for the construction of tunnel, laying roads and other structures. This will reduce the amount of material required during construction leading to reduction in the project cost as well as pressure on the environment.

4.2.3 Impacts arising from the vehicular and labourer movement

Large number of vehicule movement such as that of bull dozers, dumpers, loaders, excavators (Table 13) will be required during the construction.

Table 13. List and number of machinery

No	Machinery	Quantity
1	Bull dozer/tipper	4
2	Jack Hammer	20
3	Road Rollers	02
4	Jeeps/trucks/vans	15

The loading and unloading of the material, the removal of debris and muck all these activities require a high number of workmen/labourer. The involvement of skilled, semi-skilled workers will be persistent during the construction phase and during transportation of the materials. The total number of workers proposed to be engaged is skilled 20, semiskilled 20 and unskilled 50 during the first year (Table 4). The number will remain more or less the same during the other years of construction. Large number of the vehicles as well as the men power will interfere with the routine movement of the wild animals across the Masinagudi - Singara road. At the portal site, as per seen the visit of the wild animals is low. But the unfamiliar sounds such as that during transportation and construction activities are likely to add pressure to the wildlife.

4.2.4 Blasting to excavate and clear routes of the tunnels and caverns

The experimental caverns, audits, and major part of the main access tunnel are to be constructed in hard rock area. Blasting hard rock produces tremendous sound, flash and vibrations. Many species living in dens are seen to desert the dens and even infants / cubs due to vibrations from blasting. The sound and vibrations from the blast may cause mild disruption to the normal activities, such as routine local movements, of wildlife frequenting the area. Blasting is also known to cause vibrations and serious damage to close by landscape and may have impact on the geological make-up / formation in the surroundings, an issue not under the scope of the present report. Nevertheless, avoiding or minimizing blasting by resorting to other methods, may be better to reduce the impacts. It is stated by the project proponent that delayed detonation will be adopted during blasting.

Presently blastings are expected to be conducted deep inside the tunnel with delayed detonation, the thick overburden of hard charnokites (hard rocks) and soil above the blasting sites considerably dampen the sound and the vibrations. The sound will be loud at the mouth of the tunnel, but appears largely muffled to that of rifle shots at a distance outside the tunnel. Briefly perceptible vibrations or disturbances are not to be experienced in the surroundings out side the tunnel at surface level during the blasting operation conducted inside the tunnels.

4.2.5 Ground vibration

All the major components of the project are located underground, 1300 m deep the earth surface. Blasting to be carried out for excavation of caverns and associated components, deep underground is likely to cause low vibrations. The ground vibration levels are commonly assessed using the following square root scaling formula

$$V = k \times \left[\frac{D}{\sqrt{Q}} \right]^b$$

Where,

V = Ground vibration as Peak particle velocity (mm/s),

D = Distance from blast (m),

Q = Maximum charge per delay (Kg),

K= Site constant,

b =Site exponent.

Based on the blast vibration study carried out recently for an underground Hydro Electric Project located nearby the proposed INO, the above expression has reduced to

$$V = 1361.87 \times \left[\frac{D}{\sqrt{Q}}\right]^{-1.17}$$

With this back ground attempt to estimate vibration level from INO project blasting shows the following. The excavation of experimental caverns is proposed to be carried out with the following assumptions

Distance from blast	=	1000 (alround rock cover)
		(Vertical rock cover is 1300 Mts)
Size of exaction per cycle	=	3.0 x 2.5 m
Pull likely to be obtained	=	1.5m
Maximum charge per delay	=	2.25 kg (PF: 1 Kg/m3)

Substituting these values, the peak particle velocity

$$V = 1361.87 \times \left[\frac{1000}{\sqrt{2.25}}\right]^{-1.17}$$

The estimated maximum ground vibration level may be in the order of 0.68 mm/s. It is proposed to carry out ground vibration monitoring study during actual execution of the project along with other rock mechanics and instrumentation studies as done in similar underground project already commissioned nearby. The ground vibration will be measured continuously during blasting operations for all the major components of the project. Appropriate blasting pattern and modern blasting techniques based on the actual site geology, will be adopted such that the blasting causes vibration to the minimum possible. All efforts will be taken to restrict the ground vibration in such a way that it does not endanger the wild animals, micro habitants and the existing eco-system.

In addition, wherever the earth cover is less than 300 m; the blasting will be restricted to daytime and will not be carried out during night (dusk to dawn) and the periods when the animals are active, mostly dawn, dusk and afternoon hours.

The INO project during the construction may cause a variety of impacts on the local environmental set up that are briefed in the Table 14. The Impacts could be distinguished into i) impacts on ambient abiotic environmental characteristics, ii) impacts on biological environment and iii) impacts on human social and economic environment.

Table 14. Key concerns and perturbations from the INO

No	Activities	Effects	Extend
1	Clearing of the sites	Damage to the flora and fauna	Small
2	Excavation	Noise, dust	High
3	Movement of men and materials	Noise, dust	High
4	Blasting	Noise, dust	High
5	Operation of earthmoving machinery	Noise, dust	High
6	Transport of muck	Noise, dust, disturbance to elephant corridor	High
7	Storage and dumping of the muck	Noise, dust, downstream siltation	High

Several workers, including engineers, technicians, skilled labour, semi-skilled and unskilled labour will be involved in the construction work. About 25 numbers of earthmovers, dumpers, trucks, road rollers, jeeps and other vehicles will be required for the job. These all are likely to produce notable changes in the ambient noise levels and ambient atmospheric suspended matter level.

Explosives used in rock excavation are another major source of dust, noise and vibrations. The noise in such situations can be grouped as i) continuous wide band noise, ii) continuous narrow band noise, iii) impact noise, iv) repetitive impact noise and v) intermittent noise each having wide ranging impacts on animals and environment. It may be possible to reduce the noise levels in many in-house activities such as in workshops related with the project execution. Nevertheless, it is less practical to reduce noise levels in the construction and excavation sites.

High level of noise can cause disturbance to birds and other animals frequenting the sites. Animals can perceive frequencies that are out of range for human auditory system. They are known to be highly sensitive to certain frequency ranges. They undergo stress, metabolic and behavioural changes. Many of them leave the site of high noise level. They are also seen to discard nests, eggs and even fledglings in response to certain noise levels. The sound and vibrations may cause disruption to the normal activities such as local and seasonal migration. Since the major part of the construction involved in the INO is underground tunnel, the entry portal is the location of intensive activities. Intensive activity at the portal can also cause in fragmentation of natural habitats / areas frequently used by elephants and other mammals. As the entry portal is located in TNEB residential area, the impact of construction activity on the natural habitat is expected to be low.

4.2.6 Impacts due to the vibrations, smoke, noise during the construction

The transportation of materials during the construction phase involves men and earth-moving machinery. The smoke from the automobiles is an important source of air pollutants including particulates. They are also the source of fugitive emissions mainly of Suspended Particulate Matter (SPM), SO^2, NO_x, CO and partially burnt hydrocarbons. Thus, the change in the ambient air quality is likely in the area, but depending on the vehicle activities.

The activities of large earth-moving machinery may increase the ambient noise level. The machinery will produce sound, vibrations, noise which will be a cacophony for the wild species. Many of the wild species are sensitive to the unfamiliar sounds and are much affected due to them. The shy birds may also leave their nesting site and even discard their fledglings in response to increase in noise levels. Many of the species such as bats and elephants can hear sounds, which are not audible to human ears. This may affect their local and seasonal migration. However, the reduction in noise level is quite impractical in sites such as that of construction and excavation but the usage of well maintained machinery may help in the reduction of the same to a great extent. After the tunnel work has progressed considerably the noise reaching outside the tunnel is likely to be considerably muffled. Further, as the tunnel work progresses the vibration effective at the surface will also be reduced considerably reaching to a more or less negligible level of 0.68 mm/s, because of the large overburden (>1000 m) lying over the work site (see section 4.2.5).

4.2.7 Impacts due to blasting during excavation and clearing routes

The proposed work deals with the construction of tunnel underground. During this process blasting activity has to be carried out which is likely to cause considerable sound and vibrations. The blasting may also cause damage to the landscape and has impact on the geological make-up of the environment. There are many wild species that live or calf in sub-surface den and are likely to be affected due to the blasting and sounds and vibrations travelling through the sub-strata. Some of the species are very sensitive and can not survive in habitats with mild changes. The blasting is likely to meddle with their movement in and out of their dens. However, as the work progresses the vibrations are less perceptible because of hard rock layers interspersed with soft ones, the overburden of charnokites and soil above the blasting sites, dampen the sound and the vibrations produced during the blasting (4.2.5). Mudumalai Wildlife Sanctuary is a well known corridor for large mammals such as elephants. Exposed blasting may have an adverse affect on the behavioural and movement pattern as they are prone to changes in the noise level.

All the major components of the project are located underground. The Laboratory complex, a major component of this project is located at more than 1250 m below the earth surface. Blasting to be carried out for excavation of the cavern and associated components, underground is likely to cause low vibrations.

4.2.8 Impacts due to the workmen inhabitation during the construction phase

The construction work for the project involves a workforce of about 100 labourers (Table

4). The labourers are likely to depend on trees for fuel-wood and if left uncontrolled will cause tremendous damage to the ecosystem. Though temporary residents they are likely to bring livestock and poultry thus, causing more pressure on the environment.

4.2.9 Impacts due to the over burden, debris and muck during their disposal

The waste produced during the processes of excavation will be in the form of muck, boulders and other debris, about 2.25 lakh m^3 the disposal of which will require a large area. Carelessly disposed debris is likely to add on to siltation downstream along with the run off in the monsoon. The debris may directly affect the local environment if it is carried down as silt load and may cause loss to the aquatic life. The silt may also lead to the release of trace metals to the environment gradually. Measures should be taken in order to utilise maximum quantity of debris for construction at the earliest.

4.2.10 Impacts due to the spills of wastes such as fuels and lubricants

The possibility of spilling fuel, oils and lubricants from the field machinery during operation and maintenance cannot be neglected. The oily effluents are mostly expected from workshop and during breakdown of the machinery during their operation. Oil spillage though in minor levels will affect the aquatic species especially birds and fishes. Reduction in oxygen exchange between air and water due to oil film will lead to the deficiency of dissolved oxygen (DO). Oil film may also directly affect fish gills and can hamper respiration and other physiological activities. The oil spillage will also make exposed birds incapable of flying and affect their behaviour and thermoregulation.

4.3. IMPACTS DURING THE OPERATION PHASE

During the operation phase the impacts of the underground laboratory is limited, except in the case of release of gas, although the gas used in the laboratory, on its own, is not very toxic for short-term exposures. The major issues during the operational phase are those related to transport and residences. The increased human activity along the Masinagudi - Singara and Masinagudi - Ooty roads is likely to hamper animal movements. The impact of INO during the operation phase can be categorised into movement of i) staff involved in the day-to-day operation of the facility, ii) waste generated during operation and maintenance of the facility and iii) scholars and researchers visiting the facility in single, small or large numbers.

The project would have less impact during operation compared to the construction phase as its operation is mostly in underground set-up. The underground process will not cause much noise, perceptible from the outside of the plant. Comparatively negligible quantity of waste would be generated from the maintenance of the equipments. The technical personnel are not likely to cause notable ecological impacts, as their work will be confined to the underground caverns.

Taking note of the various aspects during the construction and operation phase, an attempt was made to develop an impact evaluation matrix (Appendix 10 & Appendix 11) in the case of the proposed project. The evaluation matrix is more or less a subjective guesstimate based on the observations and experiences of the investigators and could not be construed as a quantitative measurement. However, it provides a broad graded view suggestive of the gravity of the impacts. According to the pattern of grading the least impact is given a score 0. The grades increase with the seriousness of the impact up to 10, which indicates very severe impact. Although in developing the matrices worst-case scenarios were assumed, the exercise shows that during construction the possible impacts are high (Appendix 10 & Appendix 11) while during the operation phase the impacts can be limited. However, appropriate means have to be adopted to reduce the impacts.

5. MITIGATION MEASURES AND ENVIRONMENTAL MANAGEMENT PLAN

A varity of ecological impacts is probable from the proposed INO project. It is hoped that the following measures would help reducing the impact on the ecological set-up and the environs. Mitigation measures with respect to major aspects are given below.

Noise control

- Care should be taken to reduce noise generated during construction. Use of well maintained machinery and vehicles could considerably help in this matter. Workshops and such other facilities, which are also source of noise, may be located away from Masinagudi–Singara road.

- Blasting may be limited to the bare minimum, especially at the exposed areas such as entry portal and should be avoided if possible. Resorting to other methods may help avoiding the disturbances likely from blasting. Blasting work close to the surface may affect den dwelling species and cause stress to them. However, blasting deep inside the tunnel with delayed detonation and overburden of charnokites and soil above is expected to considerably dampen the sound and the vibrations. Our study on PUSHEP blasting did not show any instance of deserting dens, because of the blasting deep underneath, by common denning of species of animals seen in the area (Azeez *et al*., 1996). However, the number of blasts should be minimised and temporally spaced out to reduce the reverberations. Also, sophisticated drilling and blasting techniques may be adopted which would save time, resources and protect environment as well. Blasting and such activities may be avoided near by the open area during dawn, dusk and night. Well planned faster execution of construction phase would reduce the impact on environment very much.

Vibrations

- Blasting to be carried out for excavation of the cavern and associated components, underground is likely to cause low vibrations. However, it is likely to be much low because of the overburden of hard rocks and soils, except in the case of the initial sections of the tunnels. Nevertheless, INO may undertake ground vibration monitoring study during actual execution of the project along with other rock mechanics and instrumentation studies as done in similar underground project already commissioned nearby. The ground vibration may be measured continuously during blasting operations for all the major components of the project. Appropriate blasting pattern and modern blasting techniques based on the actual site geology, may be adopted such that vibration due to the blasting is the minimum.

- INO may ensure that the protocol of tunnel and cavern making to be fine-tuned to restrict the ground vibration in such a way that it do not endanger the wild animals, micro habitats and the existing eco-system. In addition, the blasting may be restricted to daytime and not at all during night (dusk to dawn) and the periods when the animals are active, mostly dawn, dusk and afternoon hours.

Muck disposal

- Disposal of the muck and other debris is a serious challenge in the case of INO construction. The debris should be taken care of and should be used to the maximum in construction purpose such as for lining the tunnel and laying the road. This will reduce the movement of transport vehicles along the wildlife corridor as well. The balance quantity of the muck and debris should be properly stored so that it does not become an eyesore and do not pose threat to the downstream areas causing siltation and high suspended particulate matter in the air and water. The storage should be with proper retention wall preventing the fine particulate matter from getting washed down during monsoon.

- In house utilisation of the muck and debris need to be strongly promoted to avoid various issues, including transportation and vehicular traffic density.

Sourcing materials

- Stone crushers would result in air and noise pollution, which will be highly disturbing to the wildlife. It is suggested that the stone crushers should erected away from forest.

Wastes

- Recycling and proper disposal of waste generated will help reducing the impact on environment to a large extent. The workers and staff members involved in construction and operation needs to be well aware of environmental problems and related issues.

- Non decomposable wastes such as plastic, rubber, metal, lubricants and oils should be either reused or managed appropriately.

Transportation

- As noted earlier another major impact of the INO is the disturbance to the very critical wildlife corridor across the Masinagudi–Singara road. The disturbance is likely to be serious in view of the large number of transport vehicles that are likely to ply over the stretch. It is expected that with the execution of such a project the vehicle movement will increase many multiples of the present traffic density. This should be avoided and it is an issue the managers executing the INO project need to seriously ponder over. However, the construction machinery movement like earthmovers, dumpers etc., will be between the tunnel and the nearby dumpyard only, and not along the sensitive road. The vehicle movement along the road have to be limited, properly scheduled and should be avoided during the period of the day when animal movement is likely to be high, namely morning, evening and night hours.

- Posting wildlife watchers along the road to warn about the animal movement also may help further in reducing encounters with the moving animals.

- Currently, check-posts are operated by the TNEB at the entry point of their installation at Singara. Additional check-posts near the INO portal as required by the project proponent may be erected. However, check-post at the entry point of

Masinagudi-Singara road (closer to Masinagudi) may help to record and monitor the people and vehicle movement.

- The INO also needs to ensure that no parallel fencing is made on the side of the Singara road connecting to Masinagudi, as that will seriously hamper the wild animal movements and increased man-animal conflicts.

Work force

- Number of labourers involved for the construction may be limited to the minimum. They should be made sensitive to the ecological importance of their area of work, nature conservation and be aware of the conservation strategies to avoid untoward effects. Movement of the workforce should be under strict control of the management responsible for environmental protection. Travel and transport should be curtailed strictly during the hours of the days when animal movements are high; morning, evening and night hours. Watchers to warn about animal movement along the corridor will help in accidental confrontation with the animals.

- Strict measures should be taken to avoid use of wood, collected locally. The labourers should be provided with LPG instead of fuel wood. Proper facilities for their temporary residences should be given. They should be educated about nature conservation.

- It is likely to happen that the workforce involved in construction would settle in the area, and may refuse to vacate even after completion of the work. Sufficient provisions should be made to evade this problem. Enough provisions should be given in the contracts with executing companies, regarding this aspect.

- The staff members involved in construction and during the operation phase needs to be well aware of environmental and wildlife problems and related issues. They should be educated about nature conservation.

Residential and infrastructure facilities

- Regarding the residential and other infra-structural facilities it is stated that "the

TNEB campus has residential houses as well as offices with recreational facilities like sports complex, children's park, and three well equipped Inspection Bungalows (IB) at different locations. The housing accommodation is in surplus in the area and may be used to accommodate people from other projects. Therefore, further new constructions are limited so that no natural vegetation loss is made. Placing the residences and other infrastructural facilities away from the INO laboratories reduce the pressure on the wildlife corridor along the Masinagudi-Singara road. The INO management may plant local plant species around the infrastructure facilities such as residences.

Disaster and fire management

- INO staff should be equipped/ trained to face any accidents such as fire or leakage of gases in the underground laboratory or elsewhere in their work area and or its environs. Sufficient provisions should be made to acquire fire fighting, communication equipments. Importance may be given to develop hospital facilities in the residential area. Suitable training for the staff with frequent refresher programmes should be arranged for them to remain well equipped both mentally and equipment wise to handle disasters such as fires.

Felling of Trees and plantation

- As mentioned earlier, the proposed project is not expected to fell trees. Felling of trees and clearing vegetation would lead to loss of feeding and breeding habitats to several species inhabiting the environs of the project and should be avoided. The large trees adjacent to the portal entry, in the TNEB quarters area, can be saved by realigning the approach road.

- No forest land is required to be diverted for executing this project; hence no Compensatory Afforestation Programme is mandatory. However, as a commitment for nature conservation and environmental protection, the INO may arrange plantation programme near the portal, along the Singara-Masinagudi road and residential complex in Masinagudi. The Tamil Nadu Forest Department may be consulted in this regard and native vegetations/flora should be considered for planting. Budgetary provisions should be made for such conservation measures.

- Some species suggested for planting are given below (Table 15). These species are native to the Nilgiris, commonly seen and grows faster. Saplings of these species are easily procurable from the local nurseries.

Table 15. Some of the tree species suggested for planting

No	Name of the tree species	Family
1	*Ailanthes excelsa*	Simaroubaceae
2	*Alstonia scholaris*	Apocynaceae
3	*Anacardium occidentale*	Anacardiaceae
4	*Artocarpus heterophyllus*	Moraceae
5	*Azadirachta indica*	Meliaceae
6	*Bischofia javanica*	Euphorbiaceae
7	*Bombax malabaricum*	Bombacaceae
8	*Butea monosperma*	Fabaceae
9	*Cassine glauca*	Celastraceae
10	*Cinnamomum malabatrum*	Lauraceae
11	*Elaeocarpus tuberculatus*	Elaeocarpaceae
12	*Feronia elephantum*	Rutaceae
13	*Ficus benghalensis*	Moraceae
14	*Filicium decipiens*	Moraceae
15	*Gyrocarpus americanus*	Hernandiaceae
16	*Phyllanthus emblica*	Euphorbiaceae
17	*Sapindus emarginatus*	Sapindaceae
18	*Syzygium cumini*	Myrtaceae
19	*Terminalia bellirica*	Combretaceae
20	*Terminalia chebula*	Combretaceae

Environmental monitoring

- The INO should organise a 'Local Ecological Monitoring Group' that can monitor the construction phase closely to safeguard the environment in general and forest and wildlife in particular. Such a body can help rationalizing the INO's environmental management strategy properly. The Local Ecological Monitoring Group needs to include experts in the field along with officials responsible for wildlife protection.

- An 'Environmental Monitoring Cell' overseen by an 'Environmental Monitoring Panel' may be also constituted.

- The Environment Monitoring Panel may be constituted drawing members from agencies such as the Tamil Nadu Forest Department, Pollution Control Board, Academic / Research institutions and TNEB. The broad mandate of this panel may be to oversee the environmental monitoring cell and advise INO management on environment related matter as and when required.

- The Environmental Monitoring Cell may over see and ensure that the measures to be taken under the Environmental Management Plan is implemented strictly and to ensure the pollution parameters are within the prescribed limits. For the purpose, a monitoring group and a pollution control equipment maintenance group will be placed in the Environmental Management Cell. The EM cell should be started in the initial stage of construction itself and its service should continue during the operation phase.

    a. The EM Cell will be responsible for proper maintenance and operation of the programme and it will over see the following aspects:

    b. Conduct environmental awareness program to the workers, supervisory staff and contract labourers during the construction period.

    c. Organize Environmental Audits and report to TNPCB or any such authorities.

    d. Regularly monitor the environmental parameters and prepare reports as required by the TNPCB and other statutory authorities.

    e. Recommend necessary measures to improve Environmental conditions.

    f. Advise on any negligence or derelictions on the part of concerned staff or workers in observing EMP or Environmental code of conduct and to advice on the necessary steps to be adopted.

g. Conduct safety programmes to create safety awareness among workers/staff.

h. Train the staff and other workers on safety measures and conduct safety drills to educate them.

Looking at the need for science and technology development of the country, the proposed project assumes global importance. Nevertheless, the project construction and operation is likely to have notable impact in the area, especially on wildlife. However, it may be possible to lower the impact on the environment, with proper planning and implementing appropriate measures.

6. SUMMARY AND CONCLUSIONS

- A rapid Environmental Impact Assessment (REIA) of the proposed India-based Neutrinos Observatory (INO) project at Singara, Nilgiris district on the biological environment was done by Sálim Ali Centre for Ornithology and Natural History (SACON). The study was undertaken on request from the Institute of Mathematical Sciences (IMSc), Chennai.

- In all, 676 species of plants and 173 species of vertebrates (12 species of amphibians, 46 reptiles, 87 birds and 28 mammals) were recorded in the study area. Several endemic and endangered flora and fauna are found to occur in the area.

- The proposed project location falls near the Mudumalai Wildlife Sanctuary which is rich in wild biodiversity. Immense care is needed during the construction as well as operation phase as the area is a corridor for the movement of large mammals such as Elephants. Unplanned human activities would affect their activity adversely.

- Most of the construction work of the proposed project work will be carried out deep inside the earth surface. However, the construction activities are likely to have impacts on the local environment especially wildlife. Proper work plan, debris and waste disposal, blasting activities to the bare minimum, controlled vehicular activity and limiting the number of workers may help to reduce the impacts. A number of probable impacts and mitigation methods of the same are suggested.

- Looking at the need for technology development of the country, the proposed project assumes global importance. Nevertheless, the project construction and operation is likely to have notable impact in the area, especially on wildlife. It may be possible to lower the impact on the environment, with proper planning and implementing appropriate measures.

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Ms. Dhanya R, EIA, SACON, Coimbtaore
Dr. Krishnamani, Project Officer, Ooty, WWF – India
Mr. Mohanraj, Project Officer, Ooty, WWF – India
Mr. Mohd Iqbal Basha, IFS, Divisional Forest Officer, Nilgiri North, Ooty.
Mr. Mukherjee D, EIA Division, SACON, Coimbatore
Mr. Prusty Anjan Kumar, EIA, SACON, Coimbatore
Mr Rajamamannan, SACON, COimbatore
Ms. Ranjini J, EIA, SACON, Coimbtaore
Mr. Rakesh Kr Dogra IFS, Wildlife Warden, Mudumalai Wildlife Sanctuary
Mr. Raslin Rose, Assistant Executive Engineer, TNEB
Mr. Selva Kumar, EIA, SACON, Coimbatore
Ms. Shanti, Avian Ecology Division, SACON, Coimbatore
Mr. Srinivas G, EIA Division, SACON, Coimbatore
Mr. Sreenivas NS, Project Leader (WG), INO, C/o IMSc, Chennai
Dr. Sukumar R, CES, Indian Institute of Science, Bangalore
Mr. Tyagi PC, IFS, Conservator of Forests, Coimbatore.

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APPENDICES

Appendix 1. The recommended site evaluation criteria for INO	
History of the site	This mainly translates to the issue of availability of the site on a long-term basis. It should be noted that the underground facility will be used for decades in future to conduct many experiments in physics and other sciences.
Cost factors	This includes both construction costs and operating costs. Existing underground projects like hydro-electric plants are better since many of the facilities such as access roads and housing would already be present and save costs.
Risk Factors and Safety issues	
Rock conditions risk	This risk factor includes multiple considerations relative to the risk of capital and operating cost overruns due to unexpected rock conditions. Forecasting based on known stress conditions may help in anticipating such a risk.
Environmental Risk	The time and expense required at various sites to determine what is safe and environmentally sound.
Seismic Risk	Although engineering can control seismic risk, there is an additional cost involved in installing detectors in a seismically active region. In addition, there is a risk of a more intense than expected earthquake or an engineering or installation mistake that leads to failure in an earthquake of expected magnitude.
Mechanical Systems Risk	Sites with heavy equipment, hoisting or other machinery have an operating cost risk due to the possibility of failure of significant mechanical systems.
Depth	Apart from a reasonable overburden in all directions, a complete 3D topo map of the region must be prepared for evaluating backgrounds. Rock density, suitability for low radioactivity experiments, is other considerations.
Neutrino Beam	Though this is still some way into the future, distances to various neutrino factories and any particular advantage that may be there due to physics reasons is an important factor.
Time to Install First Detectors	This is perhaps the most important factor for ICAL to be competitive.
Accessibility	Access to the laboratory by air/train/road throughout the year is an important factor. The perceived ease of personnel access to the laboratory is important both as a substantive factor and as a quality-of-life factor. Ideally, the laboratory should be available 24 hours a day, seven days a week.

Appendix 2. Salient features of Proposed INO site	
Location	11.5° N and 76.6° E
Cavern orientation	46° N and 6° E
Accessibility	Three airports
Site History	Singara project operating since 1930s; PUSHEP built to last 100 yrs
Geo-technical Data:	
▪ Rock type:	▪ Charnockite (Monolith)
▪ Specific gravity:	▪ 2.62-2.9
▪ Q-factor of tunnel Medium:	▪ 4-45: Good to very good
▪ Horizontal/vertical stress ratio:	▪ Approximately 1.6 (1-2 is desirable)
▪ Seepage:	▪ Moist to Dry
▪ Geological adversities:	▪ No known adversities.
▪ Geological mapping:	▪ Shears, dykes, joints are mapped from both surface projections and underground tunnels
▪ Stand up time:	▪ 90 days to infinity
▪ Support measures:	▪ PCC lining, shotcreting, rock bolting
▪ Rock radio-activity:	▪ Low : Appendix 12
Neutrino beam base-line: CERN (Magic base line): JHF Fermi Lab	7,100 km 6,600 km 11,300 km (with 3,700 km of core)
▪ Laboratory Location: ▪ Laboratory Access:	Below 2207 m peak at ≈ 900 m above MSL Horizontal two way heavy equipment transport
Tunnel details:	AccessTunnel Length (m); Vertical Cover above caverns (m); All-round cover (m) 2370, 1300, $\geq$ 1000
Risk Factors: Seismic Risk: Environmental Risk: Civil Unrest/Terrorism:	Zone-2 No discernible faults Reserve Forest Portals are inside TNEB/private land None so far
Cost Saving Factors: Facilities already available:	Housing, guest-house, access road, security guest-house at Ooty
Academic Institutions: Educational Inst:	Bangalore, Mysore, Coimbatore, Calicut Bangalore, Mysore, Coimbatore, Ooty (TIFR RAC/CRL)
Nearest Rail Heads	Coimbatore (south) 121 km Mysore (North) 111 km Calicut (West) 120 km

Nearest Airports	Coimbatore (Domestic) 121 km Calicut (Domestic) 120 km Bangalore (international) 270 km
Road distances from i) Masinagudi ii) Ooty iii) Mysore iv) Coimbatore v) Calicut vi) Bangalore	 6 km 35 km 111 km 121 km 120 km 250 km
Environmental Factors Weather: Rainfall/year: Access:	 Moderate (12-25° C) Low (100-150 cm) 24 hrs/365 days from Ooty or Mysore (through Mudumalai Wildlife sanctuary)

Appendix 3. ICAL detector – Brief description – Source INO

Charged particles produced in neutrino interactions can be detected by means of an iron calorimeter (ICAL) detector which will be constructed in layers at INO. These layers will be sandwiched with the detector material that will trigger whenever a charged particle passes through it.

The direction and the energy of the original incoming neutrino that caused the interaction can be determined from the tracks in the detector. By winding copper coils around the iron plates, and passing current through them, a uniform magnetic field can be created inside the detector. The charged particles bend in this magnetic field, with oppositely charged particles bending in opposite directions. This will not only allow an identification of the charge of the emitted particle, but also provides a separate measurement of its momentum and hence energy.

Basic parameters: The proposed detector will have a modular structure of total lateral size 48 m × 16 m and will consist of a stack of 140 horizontal layers of ∼ 6 cm thick magnetised iron plates interleaved with 2.5 cm gaps to house the active detector layers. The ICAL detector will be subdivided into three modules of size 16 m × 16 m. This modular structure will allow early operation with the completed modules while constructing others. The height of the detector will be 12 m. Considering the overall size of the apparatus and the large active detector area of ∼ 108,000 m^2, it is desirable that such a detector should be of low cost, modular in construction.

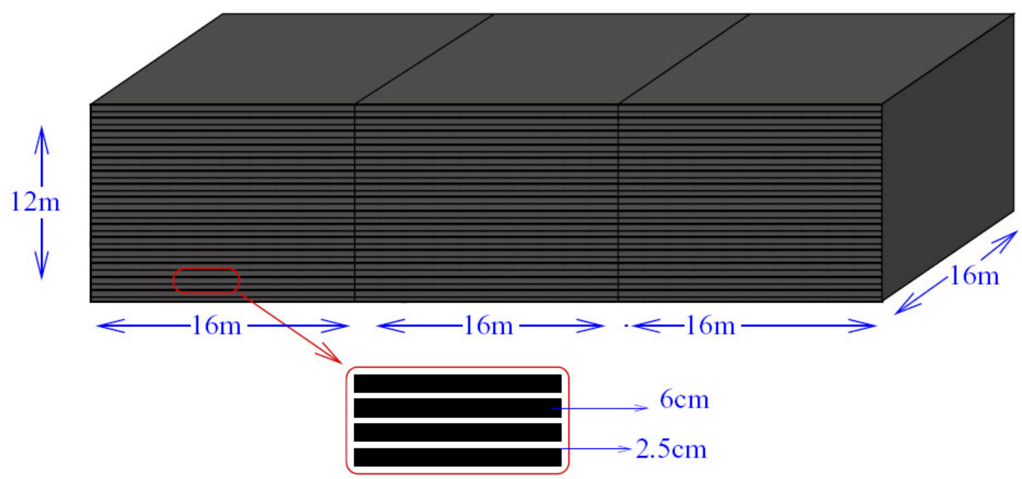


Figure 1: Schematic view of the 50 kton iron calorimeter detector consisting of 3 modules each having 140 layers of iron plates.

The active detector elements are reactive plate chambers or RPC's. The Resistive Plate Chamber is a type of spark chamber with resistive electrodes. Since such a detector has very good timing ($\sigma \sim 1$ ns) and spatial resolution, it is well suited for a fast calorimeter. A considerable portion of the feasibility study was in the construction RPC's and a study of their characteristics, especially timing and efficiency of d Proof-of-principle of RPC design and construction has already been achieved by tl which is now concentrating on improving the efficiency and stability of the RPC's. V RPC can be constructed using Bakelite or glass we have at present chosen glass ma to availability and cost. Fig. 1 shows the overall layout of the detector. Table 1 sur the specifications of the ICAL detector and the RPC elements.

The iron structure for this detector will be self supporting with the layer abov on the layer immediately below using iron spacers located every 2 m along the X-d The details are shown in Fig. 2. This will create 2 m wide roads along the Y-dire the insertion of RPC trays. There will be a total of 8 roads per module in a layer. plates will be magnetised with a field of about ∼1.3 Tesla. The total mass of the will be around 50 kton. The whole detector, as described above, will be surrou

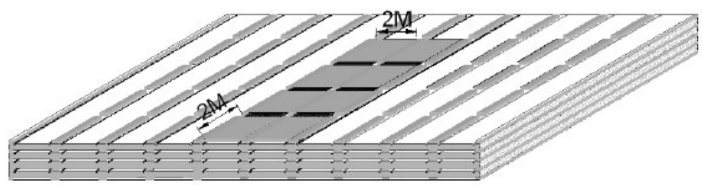


Figure 2: Structural detail of mounting active detector elements.

an external layer of scintillation or gas proportional counters. This will act as a v and will be used to identify muons entering the detector from outside as well as to partially confined events with the vertex inside the detector.

ICAL	
No. of modules	3
Module dimension	16 m × 16 m × 12 m
Detector dimension	48 m × 16 m × 12 m
No. of layers	140
Iron plate thickness	∼ 6 cm
Gap for RPC trays	2.5 cm
Magnetic field	1.3 Tesla
RPC	
RPC unit dimension	2 m × 2 m
Readout strip width	3 cm
No. of RPC units/Road/Layer	8
No. of Roads/Layer/Module	8
No. of RPC units/Layer	192
Total no. of RPC units	∼ 27000
No. of electronic readout channels	3.6×10^6

Table 1: Specifications of the ICAL detector

Appendix 4. Land & other resources required

1	Land	
a)	Over ground facilities at Singara and Masinagud i(including Housing)	*10.1 Ha
b)	Underground facilities in Forest land (including 5 m extra cover on all sides)	4.71 Ha
c)	Underground facilities in private land (including 5m extra cover on all sides)	0.29 Ha
	Total Land required	15.10 Ha
*Includes land proposed to be procured for future growth and land required for labour quarters during construction phase (which will be dismantled after completion of the project).		

			Construction Phase	Operation Phase
2.		Electrical Power:1MW	3MW	
3.		Water	5000 l/day	30000 l/day
4.		Materials		
	a)	Steel	52000 T (phase 1) 50000 T (phase 2)	
	b)	Cement	7500 T	
	c)	Aluminium/Copper	110/60 T	
	d)	Refrigerant gas	1700 kg	
	e)	Nitrogen	5000 l/ day	200 l/day
	f).	Helium	1000 m^3	100 m^3/year
	g)	Fuel (Petrol/Diesel/LPG gas)	45 T	5kg/day
	h)	PVC	40 T	
	i)	Blasting Geletine	450 T	
	j)	Detonator	360000 Nos	

Appendix 5. Tree species occurring in the study area		
No	Name of the species	Family
1	*Acacia auriculiformis*	Mimosaceae
2	*A. chundra*	Mimosaceae
3	*A. ferruginea*	Mimosaceae
4	*A. intsia*	Mimosaceae
5	*A. leucophloea*	Mimosaceae
6	*A. polyantha*	Mimosaceae
7	*Acacia sundra*	Mimosaceae
8	*Actinodaphne angustifolia**	Lauraceae
9	*Aglaia elaeagnoidea*	Meliaceae
10	*Ailanthus excelsa*	Simaroubaceae
11	*Albizia amara*	Mimosaceae
12	*A. lebbeck*	Mimosaceae
13	*A. odoratissima*	Mimosaceae
14	*Allophylus serratus**	Sapindaceae
15	*Alstonia scholaris*	Apocynaceae
16	*Anacardium occidentale*	Anacardiaceae
17	*Anogeissus latifolia*	Combretaceae
18	*Anthocephalus chinensis*	Rubiaceae
19	*Antidesma acidum*	Euphorbiaceae
20	*A. diandrum*	Euphorbiaceae
21	*A. menasu*	Euphorbiaceae
22	*A. Montana*	Euphorbiaceae
23	*Aphanamixis polystachya*	Meliaceae
24	*Ardisia solanacea*	Myrsinaceae
25	*Artocarpus gomezianus*	Moraceae
26	*A. heterophyllus*	Moraceae
27	*Atlantia monophylla*	Rutaceae
28	*Atlantia racemosa*	Rutaceae
29	*Azadirachta indica*	Meliaceae
30	*Bauhinia malabarica*	Fabaceae
31	*Bauhinia racemosa*	Fabaceae
32	*Bischofia javanica*	Euphorbiaceae
33	*Bombax malabaricum*	Bombacaceae
34	*Boswellia serrata*	Burseraceae
35	*Bridelia retusa**	Euphorbiaceae
36	*Buchanania lanzan*	Anacardiaceae
37	*Butea monosperma*	Fabaceae
38	*Callicarpa tomentosa*	Verbenaceae
39	*Canthium dicoccum*	Rubiaceae
40	*Careya arborea*	Lecythidaceae
41	*Casearia esculenta*	Flacourtiaceae

42	*Cassia fistula*	Fabaceae
43	*C. siamea*	Fabaceae
44	*Cassine glauca*	Celastraceae
45	*C. paniculata*	Celastraceae
46	*Casuarina equisetifolia*	Casuarinaceae
47	*C. litorea*	Casuarinaceae
48	*Catunaregam candolleana*	Rubiaceae
49	*C. spinosa*	Rubiaceae
50	*Ceiba pentandra*	Bombacaceae
51	*Celtis tetrandra*	Ulmaceae
52	*C. timorensis*	Ulmaceae
53	*Chionanthus mala-elengi**	Oleaceae
54	*Chloroxylon swietenia*	Rutaceae
55	*Chonemorpha fragrans*	Apocynaceae
56	*Chukrasia tabularis*	Meliaceae
57	*Cinnamomum malabatrum*	Lauraceae
58	*Clausena indica*	Rutaceae
59	*Commiphora berryi*	Burseraceae
60	*C. caudate*	Burseraceae
61	*Cordia oblique*	Boraginaceae
62	*C. wallichii*	Boraginaceae
63	*Croton oblongifolius*	Euphorbiaceae
64	*Dalbergia lanceolaria*	Fabaceae
65	*D. latifolia*	Fabaceae
66	*D. laxiflorum*	Fabaceae
67	*D. paniculata*	Fabaceae
68	*Delonix regia*	Fabaceae
69	*Dichrostachys cinerea*	Mimosaceae
70	*Diospyros assimilis*	Ebenaceae
71	*D. ebenum*	Ebenaceae
72	*D. malabarica**	Ebenaceae
73	*D. Montana*	Ebenaceae
74	*D. peregrine*	Ebenaceae
75	*Dolichandrone falcate*	Bignoniaceae
76	*Drypetes roxburghii*	Euphorbiaceae
77	*Elaeocarpus tuberculatus*	Elaeocarpaceae
78	*Eriolaena quinquelocularis*	Sterculiaceae
79	*Erythrina indica*	Fabaceae
80	*E. suberosa*	Fabaceae
81	*E. variegate*	Fabaceae
82	*Erythroxylum monogynum*	Erythroxylaceae
83	*Eucalyptus globules*	Myrtaceae
84	*Euphorbia nivulia*	Euphorbiaceae
85	*Euodia lunu-ankenda*	Rutacaeae
86	*Feronia elephantum*	Rutacaeae

87	*Ficus benghalensis*	Moraceae
88	*F. drupacea*	Moraceae
89	*F. hispida*	Moraceae
90	*F. microcarpa*	Moraceae
91	*F. mollis*	Moraceae
92	*F. racemosa*	Moraceae
93	*F. religiosa*	Moraceae
94	*F. tsjakela*	Moraceae
95	*F. virens*	Moraceae
96	*Filicium decipiens*	Sapindaceae
97	*Flacourtia indica*	Flacourtiaceae
98	*Garcinia gummi-gutta*	Clusiaceae
99	*Gardenia gummifera*	Rubiaceae
100	*Garuga pinnata*	Burseraceae
101	*Givotia rottleriformis*	Euphorbiaceae
102	*Glochidion velutinum**	Euphorbiaceae
103	*G. zeylanicum*	Euphorbiaceae
104	*Gmelina arborea*	Verbenaceae
105	*Grevillea robusta*	Proteaceae
106	*Grewia orbiculata*	Tiliaceae
107	*G. tiliifolia*	Tiliaceae
108	*Gyrocarpus americanus*	Hernandiaceae
109	*Hedyotis corymbosa*	Rubiaceae
110	*Holoptelea integrifolia*	Ulmaceae
111	*Hymenodictyon orixense**	Rubiaceae
112	*Ilex malabarica**	Aquifoliaceae
113	*Ixora arborea*	Rubiaceae
114	*Jacaranda mimosifolia*	Bignoniaceae
115	*Kydia calycina*	Malvaceae
116	*Lagerstroemia microcarpa*	Lythraceae
117	*L. parviflora*	Lythraceae
118	*Launea coromandelica*	Anacardiaceae
119	*Ligustrum perrottetii**	Oleaceae
120	*Litsea deccanensis*	Lauraceae
121	*L. mysorensis*	Lauraceae
122	*Madhuca longifolia*	Sapotaceae
123	*Mallotus intermedius**	Euphorbiaceae
124	*M. philippensis*	Euphorbiaceae
125	*M. tetracoccus*	Euphorbiaceae
126	*Mangifera indica*	Anacardiaceae
127	*Manilkara roxburghiana*	Sapotaceae
128	*Marsdenia brunoniana**	Asclepiadaceae
129	*Maytenus heyneana*	Celastraceae
130	*Melia dubia*	Meliaceae
131	*Meliosma simplicifolia*	Sabiaceae

132	*Memecylon umbellatum*	Melastomataceae
133	*Mimusops elengi*	Sapotaceae
134	*Mitragyna parvifolia*	Rubiaceae
135	*Morinda coreia*	Rubiaceae
136	*Moringa concanensis*	Moringaceae
137	*M.oleifera*	Moringaceae
138	*Naringi crenulata*	Rutacaeae
139	*Nerium indicum*	Apocynaceae
140	*Olea dioica*	Oleaceae
141	*O. glandulifera*	Oleaceae
142	*Ougeinia oojeinensis*	Fabaceae
143	*Persea macrantha*	Lauraceae
144	*Phyllanthus emblica*	Euphorbiaceae
145	*Pittosporum floribundum*	Pittosporaceae
146	*Pleurostylia opposita**	Celastraceae
147	*Plumeria alba*	Apocynaceae
148	*P. rubra*	Apocynaceae
149	*Pongamia pinnata*	Fabaceae
150	*Premna tomentosa*	Verbenaceae
151	*Psidium guajava*	Myrtaceae
152	*Pterocarpus marsupium*	Fabaceae
153	*Radermachera xylocarpa*	Bignoniaceae
154	*Randia malabarica*	Rubiaceae
155	*Ricinus communis*	Euphorbiaceae
156	*Salix tetrasperma*	Salicaceae
157	*Santalum album*	Santalaceae
158	*Sapindus emarginatus*	Sapindaceae
159	*Sapindus laurifolius*	Sapindaceae
160	*Schleichera oleosa*	Sapindaceae
161	*Schrebera swietenioides*	Oleaceae
162	*Scolopia crenata*	Flacourtiaceae
163	*Shorea roxburghii**	Dipterocarpaceae
164	*Soymida febrifuga*	Meliaceae
165	*Spathodea campanulata*	Bignoniaceae
166	*Sterculia urens*	Sterculiaceae
167	*S. villosa*	Sterculiaceae
168	*Stereospermum angustifolium*	Bignoniaceae
169	*S. colais*	Bignoniaceae
170	*Strychnos potatorum*	Loganiaceae
171	*Syzygium cumini*	Myrtaceae
172	*Tamarindus indica*	Fabaceae
173	*Tecoma stans*	Bignoniaceae
174	*Tectona grandis*	Verbenaceae
175	*Terminalia arjuna*	Combretaceae
176	*T. bellirica*	Combretaceae

177	*T. chebula*	Combretaceae
178	*T. crenulata*	Combretaceae
179	*Thevetia peruviana*	Apocynaceae
180	*Toona ciliate*	Meliaceae
181	*Trema orientalis*	Ulmaceae
182	*Trewia nudiflora*	Euphorbiaceae
183	*Viburnum punctatum*	Caprifoliaceae
184	*Vitex altissima*	Verbenaceae
185	*V. leucoxylon*	Verbenaceae
186	*V. peduncularis*	Verbenaceae
187	*Wrightia tinctoria*	Apocynaceae
188	*Ziziphus mauritiana*	Rhamnaceae
189	*Z. xylopyrus*	Rhamnaceae
*Endemic to the study area		

Appendix 6. Shrub species occurring in the study area		
No	Name of the plant species	Family
1	*Abutilon crispum*	Malvaceae
2	*Acacia pennata*	Mimosaceae
3	*Acalypha fruticosa*	Euphorbiaceae
4	*A. indica*	Euphorbiaceae
5	*A. paniculata*	Euphorbiaceae
6	*Allophylus cobbe**	Sapindaceae
7	*Ampelocissus araneosa**	Vitaceae
8	*Anisomeles indica*	Lamiaceae
9	*Argyreia cuneata*	Convolvulaceae
10	*A. elliptica*	Convolvulaceae
11	*A. pomacea*	Convolvulaceae
12	*A. strigosa*	Convolvulaceae
13	*Artanema longifolia*	Scrophulariaceae
14	*Artemisia vulgaris*	Asteraceae
15	*Asparagus racemosus*	Liliaceae
16	*Asystasia chelonoides* var. *quinquangularis*	Acanthaceae
17	*Barleria buxifolia*	Acanthaceae
18	*B. infundibuliformis*	Acanthaceae
19	*B. mysorensis**	Acanthaceae
20	*B. prionitis*	Acanthaceae
21	*Caesalpinia mimosoides*	Fabaceae
22	*Cansjera rheedii*	Opiliaceae
23	*Canthium parviflorum*	Rubiaceae
24	*Capparis grandiflora**	Capparaceae
25	*C. sepiaria*	Capparaceae
26	*C. zeylanica*	Capparaceae
27	*Carissa carandas*	Apocynaceae
28	*Celastrus paniculatus*	Celastraceae
29	*Chromolaena odorata*	Asteraceae
30	*Cipadessa baccifera*	Meliaceae
31	*Cissus discolour*	Vitaceae
32	*C. gigantean*	Vitaceae
33	*C. glauca*	Vitaceae
34	*C. pallida*	Vitaceae
35	*C. quadrangularis*	Vitaceae
36	*Clerodendrum serratum*	Verbenaceae
37	*C. viscosum*	Verbenaceae
38	*Coccinia grandis*	Cucurbitaceae
39	*Combretum albidum*	Combretaceae
40	*Costus speciosus*	Costaceae
41	*Crossandra infundibuliformis*	Acanthaceae

42	*Crotalaria verrucosa*	Fabaceae
43	*C. walkeri**	Fabaceae
44	*C. willdenowiana*	Fabaceae
45	*Croton bonplandianum*	Euphorbiaceae
46	*Cryptolepis buchananii*	Periplocaceae
47	*Datura metel*	Solanaceae
48	*D. stramonium*	Solanaceae
49	*Decaschistia crotonifolia**	Malvaceae
50	*Dendrophthoe falcate*	Loranthaceae
51	*D. trigona*	Loranthaceae
52	*Desmodium ferrugineum*	Fabaceae
53	*D. heterocarpon*	Fabaceae
54	*D. laxiflorum*	Fabaceae
55	*D. pulchellum*	Fabaceae
56	*D. triangulare*	Fabaceae
57	*D. velutinum*	Fabaceae
58	*Dioscorea bulbifera*	Dioscoreaceae
59	*D. oppositifolia*	Dioscoreaceae
60	*D. pentaphylla*	Dioscoreaceae
61	*D. tomentosa*	Dioscoreaceae
62	*Dracaena terniflora*	Liliaceae
63	*Ehretia ovalifolia*	Boraginaceae
64	*Embelia tsjeriam-cottam*	Myrsinaceae
65	*Flemingia macrophylla*	Fabaceae
66	*F. strobilifera*	Fabaceae
67	*Fluggea leucopyrus*	Euphorbiaceae
68	*Furcracea foetida*	Agavaceae
69	*Gardenia resinifera*	Rubiaceae
70	*Gliricidia sepium*	Fabaceae
71	*Gloriosa superba*	Liliaceae
72	*Gmelina asiatica*	Verbenaceae
73	*Gomphostemma heyneanum*	Lamiaceae
74	*Grewia abutilifolia*	Tiliaceae
75	*Grewia hirsute*	Tiliaceae
76	*G. rhamnifolia*	Tiliaceae
77	*G. villosa*	Tiliaceae
78	*Gymnema sylvestre*	Asclepiadaceae
79	*Gynura nitida**	Asteraceae
80	*Helicteres isora*	Sterculiaceae
81	*Hemidesmus indicus*	Periplocaceae
82	*Hibiscus lobatus*	Malvaceae
83	*Hiptage benghalensis*	Malpighiaceae
84	*Holostemma ada-kodien*	Asclepiadaceae
85	*Homonoia riparia*	Euphorbiaceae
86	*Indigofera cassioides*	Fabaceae

87	*I. mysorensis*	Fabaceae
88	*I. parviflora*	Fabaceae
89	*I. trita*	Fabaceae
90	*Ipomoea alba*	Convolvulaceae
91	*I. carnea*	Convolvulaceae
92	*I. hederifolia*	Convolvulaceae
93	*I. sepiaria*	Convolvulaceae
94	*I. staphylina*	Convolvulaceae
95	*I. turbinate*	Convolvulaceae
96	*Ixora nigricans**	Rubiaceae
97	*Jasminum auriculatum*	Oleaceae
98	*J. cuspidatum*	Oleaceae
99	*J. malabaricum**	Oleaceae
100	*Jasminum ritchiei*	Oleaceae
101	*Jatropha heynei*	Euphorbiaceae
102	*Justicia betonica*	Acanthaceae
103	*Kirganelia reticulate*	Euphorbiaceae
104	*Kyllinga melanosperma*	Cyperaceae
105	*Lantana camara*	Verbenaceae
106	*L. indica*	Verbenaceae
107	*L. wightiana*	Verbenaceae
108	*Leea asiatica*	Leeaceae
109	*Leucas aspera*	Lamiaceae
110	*L. hirta*	Lamiaceae
111	*L. martinicensis*	Lamiaceae
112	*Lobelia nicotianifolia*	Lobeliaceae
113	*Ludwigia hyssopifolia*	Onagraceae
114	*L. peruviana*	Onagraceae
115	*Macrosolen capitellatus*	Loranthaceae
116	*M. parasiticus*	Loranthaceae
117	*Malvastrum coromandelianum*	Malvaceae
118	*Maytenus emarginatus*	Celastraceae
119	*Memecylon gracile**	Melastomataceae
120	*Naravelia zeylanica*	Ranunculaceae
121	*Nerium oleander*	Apocynaceae
122	*Nilgirianthus heyneanus**	Acanthaceae
123	*Nilgirianthus perrottetianus**	Acanthaceae
124	*Ocimum gratissimum*	Lamiaceae
125	*Olax scandens*	Olacaceae
126	*Ophiorrhiza mungos*	Rubiaceae
127	*Opilia amentacea*	Opiliaceaa
128	*Opuntia dillenii*	Cactaceae
129	*Orthosiphon thymiflorus*	Lamiaceae
130	*O. wynaadensis**	Melastomataceae
131	*Parthenium hysterophorus*	Asteraceae

132	*Passiflora subpeltata*	Passifloraceae
133	*Pavetta indica*	Rubiaceae
134	*Pavonia zeylanica*	Malvaceae
135	*Pergularia daemia*	Asclepiadaceae
136	*Phyllanthus pinnatus*	Euphorbiaceae
137	*Plumbago zeylanica*	Plumbaginaceae
138	*Pogostemon paniculatus*	Lamiaceae
139	*Polygonum chinense*	Polygonaceae
140	*Pouzolzia auriculata*	Urticaceae
141	*Pterolobium hexapetalum*	Fabaceae
142	*Pupalia lappacea*	Amaranthaceae
143	*Rauvolfia serpentine*	Apocynaceae
144	*Rhus mysorensis*	Anacardiaceae
145	*Rhynchosia hirta*	Fabaceae
146	*Rivea hypocrateriformis*	Convolvulaceae
147	*Rubia cordifolia*	Rubiaceae
148	*Rungia plicata*	Acanthaceae
149	*Salvia coccinea*	Lamiaceae
150	*Sarcostemma brunonianum**	Asclepiadaceae
151	*Scirpus sp.*	Cyperaceae
152	*Scurrula cordifolia*	Loranthaceae
153	*S. parasitica*	Loranthaceae
154	*Scutia myrtina*	Rhamnaceae
155	*Secamone emetica*	Asclepiadaceae
156	*Senecio zeylanicus*	Asteraceae
157	*Senna auriculata*	Caesalpiniaceae
158	*Sida acuta*	Malvaceae
159	*Sida cordifolia*	Malvaceae
160	*S. glutinosa*	Malvaceae
161	*S. rhombifolia*	Malvaceae
162	*Smilax perfoliata*	Smilacaceae
163	*Solanum erianthum*	Solanaceae
164	*S. giganteum*	Solanaceae
165	*S. indicum*	Solanaceae
166	*S. melongena*	Solanaceae
167	*Solanum torvum*	Solanaceae
168	*S. viarum*	Solanaceae
169	*S. violaceum*	Solanaceae
170	*Sophora glauca*	Fabaceae
171	*Tarenna asiatica*	Rubiaceae
172	*Taxillus cuneatus**	Loranthaceae
173	*T. tomentosus*	Loranthaceae
174	*Tephrosia purpurea*	Fabaceae
175	*T. tinctoria*	Fabaceae
176	*Thespesia lampas*	Malvaceae

177	*Thunbergia alata*	Acanthaceae
178	*T. fragrans*	Acanthaceae
179	*Tinospora cordifolia*	Menispermaceae
180	*Toddalia asiatica*	Rutacaeae
181	*Tragia involucrate*	Euphorbiaceae
182	*Trichosanthes tricuspidata*	Cucurbitaceae
183	*Triumfetta rhomboidea*	Tiliaceae
184	*Tylophora indica*	Asclepiadaceae
185	*T. pauciflora**	Asclepiadaceae
186	*Uraria rufescens*	Fabaceae
187	*Urena lobata*	Malvaceae
188	*Vernonia cinerea*	Asteraceae
189	*Vernonia divergens*	Asteraceae
191	*Viscum angulatum*	Viscaceae
192	*V. articulatum*	Viscaceae
193	*V. capitellatum*	Viscaceae
194	*V. trilobatum*	Viscaceae
195	*Waltheria indica*	Sterculiaceae
196	*Wattakaka volubilis*	Asclepiadaceae
197	*Ziziphus oenoplia*	Rhamnaceae
198	*Z. rugosa*	Rhamnaceae
*Endemic to the study area		

Appendix 7. Herbs occurring in the study area		
No	Name of the plant species	Family
1	*Abelmoschus angulosus*	Malvaceae
2	*Abutilon indicum*	Malvaceae
3	*Acalypha malabarica**	Euphorbiaceae
4	*Acalypha racemosa*	Euphorbiaceae
5	*Acanthospermum hispidium*	Asteraceae
6	*Achyranthes aspera*	Amaranthaceae
7	*Achyranthes bidentata*	Amaranthaceae
8	*Acrocephalus hispidus*	Lamiaceae
9	*Aerva lanata*	Amaranthaceae
10	*Ageratum conyzoides*	Asteraceae
11	*Allmania nodiflora*	Amaranthaceae
12	*Alternanthera sessilis*	Amaranthaceae
13	*Amaranthus viridis*	Amaranthaceae
14	*Alysicarpus bupleurifolius*	Fabaceae
15	*A. monilifer*	Fabaceae
16	*Anaphalis aristata**	Asteraceae
17	*Andrographis serpyllifolia**	Acanthaceae
18	*Argemone mexicana*	Papaveraceae
19	*Arisaema tortuosum*	Araceae
20	*Asclepias curassavica*	Asclepiadaceae
21	*Barleria cristata*	Acanthaceae
22	*Bidens biternata*	Asteraceae
23	*B. pilosa*	Asteraceae
24	*Biophytum sensitivum*	Oxalidaceae
25	*Blainvillea acmella*	Asteraceae
26	*Blepharis boerhavifolia*	Acanthaceae
27	*Blepharispermum subsessile*	Asteraceae
28	*Blumea lacera*	Asteraceae
29	*B. mollis*	Asteraceae
30	*B. rhomboidea*	Asteraceae
31	*B. virens*	Asteraceae
32	*Boerhavia diffusa*	Nyctaginaceae
33	*B. verticellata*	Nyctaginaceae
34	*Borreria articularis*	Rubiaceae
35	*B. ocymoides*	Rubiaceae
36	*B. pusilla*	Rubiaceae
37	*Byttneria herbacea*	Sterculiaceae

38	*Calotropis gigantean*	Asclepiadaceae
39	*Canscora diffusa*	Gentianaceae
40	*Caralluma adscendens*	Asclepiadaceae
41	*C. umbellate*	Asclepiadaceae
42	*Cardiospermum canescens*	Sapindaceae
43	*C. halicacabum*	Sapindaceae
44	*Cassia mimosoides*	Fabaceae
45	*C. tora*	Fabaceae
46	*Centella asiatica*	Apiaceae
47	*Centratherum anthelminticum*	Asteraceae
48	*Ceropegia hirsuta**	Asclepiadaceae
49	*Chlorophytum tuberosum*	Liliaceae
50	*Cissampelos pareira*	Menispermaceae
51	*Cleome feline*	Capparidaceae
52	*C. monophylla*	Capparidaceae
53	*Coldenia procumbens*	Boraginaceae
54	*Colocasia esculenta*	Araceae
55	*Commelina benghalensis*	Commelinaceae
56	*C. ensifolia*	Commelinaceae
57	*Conyza leucantha*	Asteraceae
58	*Corchorus aestuans*	Tiliaceae
59	*Cosmos sulphurous*	Asteraceae
60	*Crotalaria calycina*	Fabaceae
61	*C. dubia*	Fabaceae
62	*C. evolvuloides*	Fabaceae
63	*C. juncea*	Fabaceae
64	*C. medicaginea*	Fabaceae
65	*C. mysorensis*	Fabaceae
66	*C. pallida*	Fabaceae
67	*C. prostate*	Fabaceae
68	*C. retusa*	Fabaceae
69	*C. spectabilis**	Fabaceae
70	*Cucumis melo*	Cucurbitaceae
71	*Curculigo orchioides*	Hypoxidaceae
72	*Curcuma longa*	Zingiberaceae
73	*Cyanotis cristata*	Commelinaceae
74	*C. fasciculate*	Commelinaceae
75	*Cyathula prostrate*	Amaranthaceae
76	*Cyclea peltata*	Menispermaceae
77	*Cynoglossum zeylanicum*	Boraginaceae
78	*Cyperus distans*	Cyperaceae

79	*C. iria*	Cyperaceae
80	*Desmodium alysicarpoides*	Fabaceae
81	*D. motorium*	Fabaceae
82	*D. triflorum*	Fabaceae
83	*D. triquetrum*	Fabaceae
84	*Dichrocephala integrifolia*	Asteraceae
85	*Dicliptera cuneata**	Acanthaceae
86	*Dioscorea hispida*	Dioscoreaceae
87	*Diplocyclos palmatus*	Cucurbitaceae
88	*Dunbaria ferruginea**	Fabaceae
89	*Echinops echinatus*	Asteraceae
90	*Ehretia canarensis*	Boraginaceae
91	*Elephantopus scaber*	Asteraceae
92	*Emilia scabra*	Asteraceae
93	*E. sonchifolia*	Asteraceae
94	*Erigeron karvinskianus*	Asteraceae
95	*Eriocaulon quinquangulare*	Eriocaulaceae
96	*Eupatorium repandum*	Asteraceae
97	*Euphorbia cristata*	Euphorbiaceae
98	*E. geniculata*	Euphorbiaceae
99	*E. hirta*	Euphorbiaceae
100	*E. indica*	Euphorbiaceae
101	*Evolvulus alsinoides*	Convolvulaceae
102	*Exacum tetragonum**	Gentianaceae
103	*Fimbristylis dichotoma*	Cyperaceae
104	*F. woodrowii**	Cyperaceae
105	*Floscopa scadens*	Commelinaceae
106	*Glycine wightii*	Fabaceae
107	*Gnaphalium* sp.	Asteraceae
108	*Habenaria planteginea*	Orchidaceae
109	*H. viridiflora**	Orchidaceae
110	*Hedychium coronarium*	Zingiberaceae
111	*Hedyotis affinis*	Rubiaceae
112	*H. auricularia*	Rubiaceae
113	*H. nitida*	Rubiaceae
114	*H. puberula*	Rubiaceae
115	*H. pumila*	Rubiaceae
116	*Hibiscus lunariifolius*	Malvaceae
117	*H. ovalifolius*	Malvaceae
118	*H. solandra*	Malvaceae
119	*Hybanthus enneaspermus*	Violaceae

120	*Hydrocotyle javanica*	Apiaceae
121	*Hygrophila salicifolia*	Acanthaceae
122	*Hyptis suaveolens*	Lamiaceae
123	*Impatiens chinensis*	Balasaminaceae
124	*Indigofera cordifolia*	Fabaceae
125	*I. linnaei*	Fabaceae
126	*I. spicata*	Fabaceae
127	*Indocourtoisia cyperoides*	Cyperaceae
128	*Justicia simplex*	Acanthaceae
129	*Knoxia sumatrensis*	Rubiaceae
130	*Lagascea mollis*	Asteraceae
131	*Laggera alata*	Asteraceae
132	*Laportea interrupta*	Urticaceae
133	*Lepidagathis incurve*	Acanthaceae
134	*Leucas lavandulaefolia**	Lamiaceae
135	*L. marrubioides*	Lamiaceae
136	*L. nutans*	Lamiaceae
137	*L. vestita**	Lamiaceae
138	*Lindernia antipoda*	Scrophulariaceae
139	*Liparis prazeri**	Orchidaceae
140	*Lipocarpha sphacelata*	Cyperaceae
141	*Lobelia heyneana*	Lobeliaceae
142	*Ludwigia perennis*	Onagraceae
143	*Melhania cannabina*	Tiliaceae
144	*Merremia hastate*	Convolvulaceae
145	*Mimosa pudica*	Mimosaceae
146	*Mollugo pentaphylla*	Molluginaceae
147	*Monochoria vaginalis*	Pontederiaceae
148	*Murdannia japonica*	Commelinaceae
149	*M. spirata*	Commelinaceae
150	*M. zeylanica*	Commelinaceae
151	*Neanotis indica**	Rubiaceae
152	*N. wightii**	Rubiaceae
153	*Notonia grandiflora*	Asteraceae
154	*Ocimum americanum*	Lamiaceae
155	*Orthosiphon rubicundus*	Lamiaceae
156	*O. viscosus*	Lamiaceae
157	*Oxalis corniculata*	Oxalidaceae
158	*Peperomia dindigulensis**	Piperaceae
159	*Peristrophe bicalyculata*	Acanthaceae
160	*Peristylus goodyeroides**	Orchidaceae

161	*Phyllanthus amarus*	Euphorbiaceae
162	*P. maderaspatensis*	Euphorbiaceae
163	*P. rheedii*	Euphorbiaceae
164	*P. virgatus*	Euphorbiaceae
165	*Pimpinella heyneana**	Apiaceae
166	*P. wallichiana**	Apiaceae
167	*Piper longum*	Piperaceae
168	*Plectranthus barbatus*	Lamiaceae
169	*P. mollis*	Lamiaceae
170	*P. wightii**	Lamiaceae
171	*Pogostemon auricularius*	Lamiaceae
172	*Polycarpaea corymbosa*	Caryophyllaceae
173	*Polygala elongate*	Polygalaceae
174	*Polygonum barbatum*	Polygonaceae
175	*P. glabrum*	Polygonaceae
176	*P. hydropiper*	Polygonaceae
177	*Polystachya flavescens**	Orchidaceae
178	*Priva cordifolia*	Verbenaceae
179	*Rhinacanthus nasutus*	Acanthaceae
180	*Rhynchosia minima*	Fabaceae
181	*R. rufescens*	Fabaceae
182	*Rostellularia diffusa*	Acanthaceae
183	*Rotala indica*	Lythraceae
184	*Rothia indica*	Fabaceae
185	*Scilla hyacinthine*	Liliaceae
186	*Scleria levis*	Cyperaceae
187	*Scoparia dulcis*	Scrophulariaceae
188	*Semecarpus anacardium*	Anacardiaceae
189	*Senna hirsute*	Fabaceae
190	*Sida cordata*	Malvaceae
191	*Sigesbeckia orientalis*	Asteraceae
192	*Smithia conferta**	Fabaceae
193	*Solanum nigrum*	Solanaceae
194	*Sonerila tenera**	Melastomataceae
195	*Sophubia delphinifolia*	Scrophulariaceae
196	*Spatholobus parviflorus*	Fabaceae
197	*Spermacoce hispida*	Rubiaceae
198	*Spilanthus acmella*	Asteraceae
199	*S. paniculata*	Asteraceae
200	*Stachytarpheta indica*	Verbenaceae
201	*Striga angustifolia*	Scrophulariaceae

202	*S. asiatica*	Scrophulariaceae
203	*Strobilanthes consanguineus**	Acanthaceae
204	*Swertia angustifolia**	Gentianaceae
205	*Synedrella nodiflora*	Asteraceae
206	*Tephrosia pumila*	Fabaceae
207	*Thesium wightianum**	Santalaceae
208	*Tribulus terrestris*	Zygophyllaceae
209	*Trichodesma indicum*	Boraginaceae
210	*T. sedgwickianum*	Boraginaceae
211	*Tridax procumbens*	Asteraceae
212	*Triumfetta pilosa*	Tiliaceae
213	*Uraria lagopodioides*	Fabaceae
214	*Vanda testacea*	Orchidaceae
215	*Vernonia albicans*	Asteraceae
216	*Vigna adenantha*	Fabaceae
217	*V. radiate*	Fabaceae
218	*V. trifoliate*	Fabaceae
219	*V. trilobata*	Fabaceae
220	*Xanthium strumarium*	Asteraceae
221	*Zingiber officinale*	Zingiberaceae
222	*Zornia diphylla*	Fabaceae
223	*Zornia diphylla*	Fabaceae
*Endemic to the study area		

Appendix 8. Grasses occurring in the study area		
No	Species	Family
1	*Alloteropsis cimicina*	Poaceae
2	*Apluda mutica*	Poaceae
3	*Aristida adscensionis*	Poaceae
4	*A. setacea*	Poaceae
5	*Arthraxon depressus**	Poaceae
6	*Arundinella purpurea**	Poaceae
7	*Axonopus compressus*	Poaceae
8	*Bambusa arundinacea*	Poaceae
9	*Bothriochloa pertusa*	Poaceae
10	*Brachiaria distachya*	Poaceae
11	*B. eruciformis*	Poaceae
12	*B. ramose*	Poaceae
13	*B. semiundulata**	Poaceae
14	*Cenchrus biflorus*	Poaceae
15	*Centotheca lappacea*	Poaceae
16	*Chloris barbata*	Poaceae
17	*C. dolichostachya*	Poaceae
18	*Chrysopogon aciculatus*	Poaceae
19	*C. fulvus*	Poaceae
20	*Cymbopogon coloratus*	Poaceae
21	*C. flexuosus*	Poaceae
22	*C. nardus*	Poaceae
23	*Cynodon dactylon*	Poaceae
24	*Cyrtococcum oxyphyllum*	Poaceae
25	*Dactyloctenium aegyptium*	Poaceae
26	*Digitaria abludens*	Poaceae
27	*D. bicornis*	Poaceae
28	*D. ciliaris*	Poaceae
29	*Eleusine indica*	Poaceae
30	*Eragrostis artrovirens*	Poaceae
31	*E. bifaria*	Poaceae
32	*E. ciliaris*	Poaceae
33	*E. minor*	Poaceae
34	*E. tenuifolia*	Poaceae
35	*E. unioloides*	Poaceae
36	*Hackelochloa granularis*	Poaceae
37	*Heteropogon contortus*	Poaceae
38	*Imperata cylindrical*	Poaceae
39	*Isachne globosa*	Poaceae
40	*I. lisboa**	Poaceae
41	*Ischaemum indicum*	Poaceae

42	*Oplismenus compositus*	Poaceae
43	*Panicum notatum*	Poaceae
44	*Paspalidium flavidum*	Poaceae
45	*Paspalum canarae**	Poaceae
47	*P. scrobiculatum*	Poaceae
48	*Pennisetum hohenackeri*	Poaceae
49	*P. polystachyon*	Poaceae
50	*Perotis indica*	Poaceae
51	*Pogonatherum paniceum*	Poaceae
52	*Pseudanthistiria hispida*	Poaceae
53	*Rottboellia cochinchinensis*	Poaceae
54	*Sacciolepis indica*	Poaceae
55	*Setaria intermedia*	Poaceae
56	*S. italica*	Poaceae
57	*S. palmifolia*	Poaceae
58	*S. pumila*	Poaceae
59	*S. verticillata*	Poaceae
60	*Sorghum halepense*	Poaceae
61	*Sporobolus indicus*	Poaceae
62	*S. wallichii*	Poaceae
63	*Themeda cymbaria*	Poaceae
64	*T. quadrivalvis**	Poaceae
65	*T. tremula*	Poaceae
66	*T. triandra*	Poaceae
67	*Triopogon bromoides**	Poaceae
68	*Urochloa panicoides*	Poaceae
*Endemic to the study area		

Appendix 9. Birds observed in the study area		
No	Common Name	Scientific Name
1	Little Grebe	*Podiceps ruficollis #*
2	Little Cormorant	*Phalacrocorax niger #*
3	Indian Pond Heron	*Ardeola grayii #*
4	Cattle Egret	*Bubulcus ibis #*
5	Night Heron	*Nycticorax nycticorax#*
6	Crested Honey Buzzard	*Pernis ptilorhynchus*
7	Pariah kite	*Milvus migrans*
8	Brahminy Kite	*Haliastur indus #*
9	Indian Shikra	*Accipiter badius*
10	Indian Crested-Hawk Eagle	*Spizaetus cirrhatus*
11	Indian Whitebacked Vulture	*Gyps bengalensis*
12	Short-toed Eagle	*Circaetus gallicus*
13	Crested Serpent Eagle	*Spilornis cheela*
14	Grey Patridge	*Francolinus pondicerianus*
15	Jungle Bush Quail	*Perdicula asiatica*
16	Grey Jungle Fowl	*Gallus sonneratii*
17	Indian Peafowl	*Pavo cristatus*
18	Whitebreasted Waterhen	*Amaurornis phoenicurus #*
19	Yellow-wattled Lapwing	*Vanellus malabaricus#*
20	Marsh Sandpiper	*Tringa stagnatilis #*
21	Yellow-footed Green Pigeon	*Treron phoenicoptera*
22	Indian Blue Rock Pigeon	*Columba livia*
23	Indian Ring Dove	*Streptopelia decaocto*
24	Spotted Dove	*Streptopelia chinensis*
25	Roseringed Parakeet	*Psittacula krameri*
26	Southern Blossomheaded Parakeet	*Psittacula cyanocephala*
27	Indian Lorikeet	*Loriculus venalis*
28	Pied Crested Cuckoo	*Clamator jacobinus*
29	Common Hawk-Cuckoo	*Cuculus varius*
30	Cuckoo	*Cuculus canorus*
31	Indian Koel	*Eudynamys scolopacea*
32	Common Crow-Pheasant	*Centropus sinensis*
33	Collard Scops-Owl	*Otus bakkamoena*
34	Spotted Owlet	*Athene brama*
35	House Swift	*Apus affinis*
36	Lesser Pied Kingfisher	*Ceryle rudis*
37	Small Blue Kingfisher	*Alcedo atthis #*

38	Whitebreasted Kingfisher	*Halcyon smyrnensis#*
39	Small Green Bee-eater	*Merops orientalis*
40	Indian Roller	*Coracias benghalensis*
41	Hoopoe	*Upupa epops*
42	Large Green Barbet	*Megalaima zeylanica*
43	Crimsonbreasted Barbet	*Megalaima haemacephala*
44	Lesser Golden-backed Woodpecker	*Dinopium benghalense*
45	Pigmy Woodpecker	*Picoides nanus*
46	Ashycrowned Finch lark	*Eremopterix grisea*
47	Wiretailed Swallow	*Hirundo smithii*
48	Baybacked Shrike	*Lanius vittatus*
49	Rufousbacked Shrike	*Lanius schach*
50	Golden Oriole	*Oriolus oriolus*
51	Black Drongo	*Dicrurus adsimilis*
52	White-bellied Drongo	*Dicrurus caerulescens*
53	Blackheaded Myna	*Sturnus pagodarum*
54	Common Myna	*Acridotheres tristis*
55	Jungle Myna	*Acridotheres fuscus*
56	Indian Tree Pie	*Dendrocitta vagabunda*
57	House Crow	*Corvus splendens*
58	Indian Jungle Crow	*Corvus macrorhynchos*
59	Scarlet Minivet	*Pericrocotus flammeus*
60	Common Wood Shirke	*Tephrodornis pondicerianus*
61	Common Iora	*Aegithina tiphia*
62	Redwhiskered Bulbul	*Pycnonotus jocosus*
63	Whitecheeked Bulbul	*Pycnonotus leucogenys*
64	Redvented Bulbul	*Pycnonotus cafer*
65	Yelloweyed Babbler	*Chrysomma sinense*
66	Common Babbler	*Turdoides caudatus*
67	Jungle Babbler	*Turdoides striatus*
68	Whiteheaded Babbler	*Turdoides affinis*
69	Whitebrowed Fantail Flycatcher	*Rhipidura aureola*
70	Paradise Flycatcher	*Terpsiphone paradise*
71	Ashy Wren-Warbler	*Prinia socialis*
72	Tailor Bird	*Orthotomus sutorius*
73	Indian Great Reed Warbler	*Acrocephalus stentoreus*
74	Lesser Whitethroat	*Sylvia curruca*
75	Magpie-Robin	*Copsychus saularis*
76	Pied Bush Chat	*Saxicola caprata*
77	Indian Robin	*Saxicoloides fulicata*
78	Grey Tit	*Parus major*

79	Grey Wagtail	*Motacilla cinerea*
80	White Wagtail	*Motacilla alba*
81	Purplerumped Sunbird	*Nectarinia zeylonica*
82	Purple Sunbird	*Nectarinia asiatica*
83	Oriental White-eye	*Zosterops palpebrosa*
84	House Sparrow	*Passer domesticus*
85	Yellowthroated Sparrow	*Petronia xanthocollis*
86	Whitethroated Munia	*Lonchura malabarica*
87	Whitebacked Munia	*Lonchura striata*
# Aquatic species, Nomenclature following Ali and Riply 1983		

Appendix 10. Environmental Impact evaluation matrix (Construction phase)						
Aspects		Impact on				
		Flora		Fauna		
		Trees	Others	Mammals	Birds	Herpetofauna
Laboratories	Clearing the land at the entry portal	3	3	4	2	4
	Machinery and materials mobilization	2	2	6	5	4
	Construction of Tunnel and caverns	2	2	4	3	3
	Transport of muck	1	1	5	3	4
	Storage and dumping of the muck	1	4	4	3	3
Residences	Site clearance and leveling	4	2	3	3	4
	Construction and erection	2	2	2	3	4
Workforce demands	Transportation	1	2	4	3	3
	Communication	0	0	0	0	0
	Power / Fuel	3	3	1	1	1
	Supportive infrastructure and other facilities such as medical and educational	4	2	3	2	4
Note: Graded from 0-10 based on the severity of the impact; 0 denotes no impact and 10 very severe impact. Maximum possible score is given in the brackets						

Appendix 11. Environmental Impact evaluation matrix (Operation phase)							
Aspects		Impact on					
		Flora		Fauna			
		Trees	Others	Mammals	Birds	Herpetofauna	
Laboratories	Transport of materials	0	0	4	3	3	
	Transport of men	1	1	4	4	4	
	Storage and dumping of the waste	1	1	3	1	1	
Residences	Travel	2	2	1	2	2	
Workforce demands	Transportation	0	0	0	0	0	
	Communication	0	0	0	0	0	
	Power / Fuel	0	0	0	0	0	
	Supportive infrastructure and other facilities such as medical and educational	4	2	0	0	3	

Note: Graded from 0-10 based on the severity of the impact; 0 denotes no impact and 10 very severe impact. Maximum possible score is given in the brackets

Appendix 12.Background measurements at PUSHEP

24th Feb 2007

Portable HpGe detector (45mm dia, 25mm long)

Summary:

1. Background was measured at TIFR (LINAC counting room), TIFR guest house at Ooty and PUSHEP tunnel. Inside the tunnel, background was also measured with ~ 45mm thick lead shield.
2. Overall background seems higher at Ooty (see Fig.1).
3. No new lines seen in the spectrum inside the tunnel. However yield of 1460 (40K) gamma ray is significantly higher (see Fig.2).
4. The yield of U-Th decay products, with detector at the centre of tunnel and detector close to wall on the ground shows significant differences, latter being larger (see Fig.3).

Background radiation measured at PUSHEP tunnel with overall rock cover of around 500 M in given at Fig: 4. The measurements will be repeated in the INO caverns (with a vertical rock of 1300 M, when built before moving the detectors). Based on the findings necessary safety measures will be adopted.

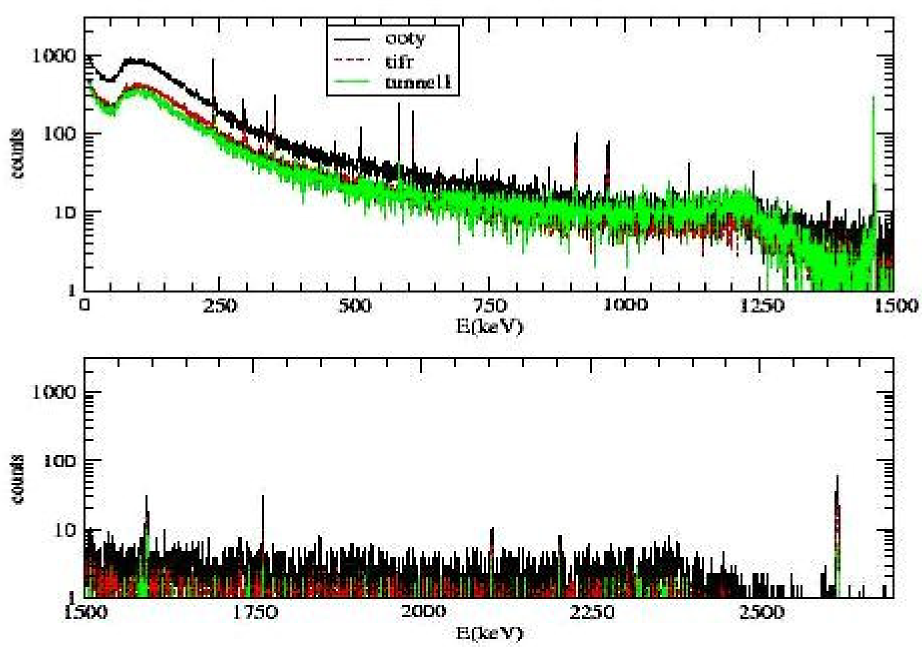


Fig: 1 Enhanced background at low energy (~500-1250 keV) inside the tunnel is due to higher yield of 40K (1460 keV).

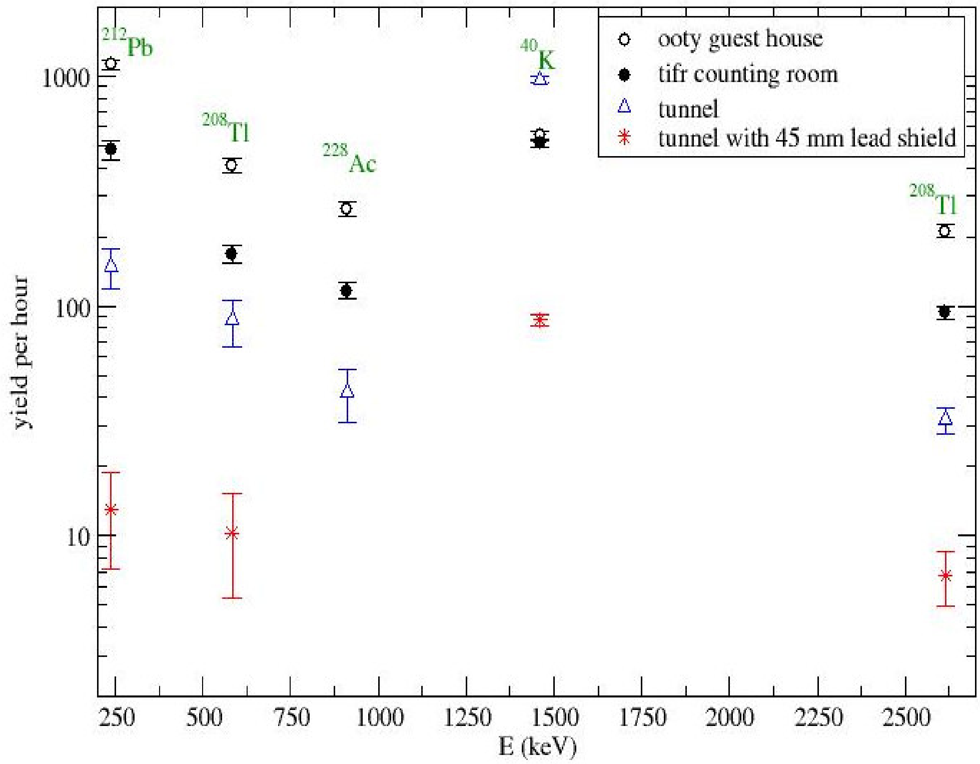
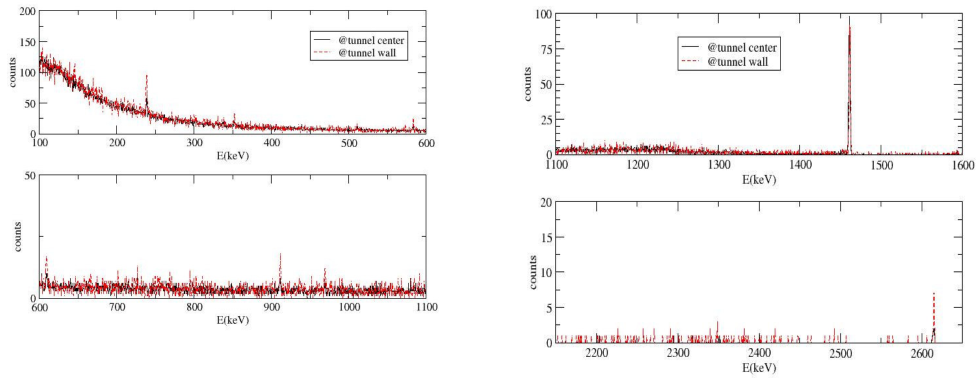


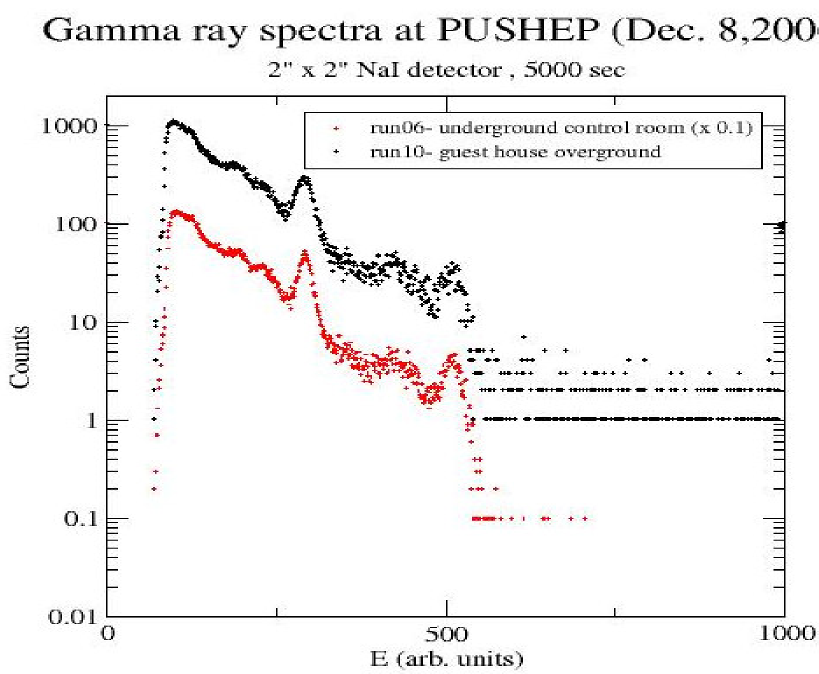
Fig. 2

Bgd/KeV/hr				
Energy Range	Ooty	TIFR	Tunnel (No shield)	Tunnel (With Shield)
2250-2330 KeV	3.72(0.15)	1.54(0.07)	0.6(0.07)	0.07(0.02)
2268-2308 keV	3.88(0.22)	1.39 (0.09)	0.7(0.1)	0.08(0.03)



@tunnel center
@tunnel wall
counts
E(keV)

Fig. 3



Gamma ray spectra at PUSHEP (Dec. 8,2006)
2" x 2" NaI detector , 5000 sec
run06- underground control room (x 0.1)
run10- guest house overground
Counts
E (arb. units)

Fig. 4

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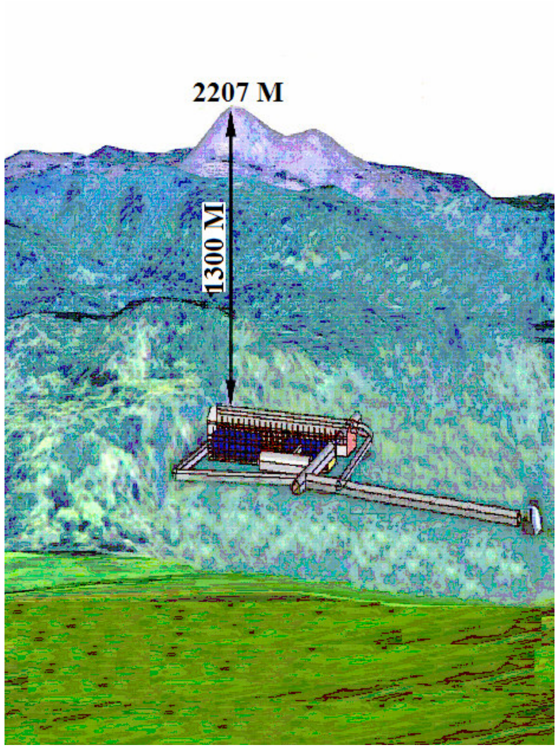

Report submitted to

INSTITUTE OF MATHEMATICAL SCIENCES, CHENNAI

PA Azeez, S Bhupathy, P Balasubramanian, Rachna Chandra and PP Nikhilraj

SACON

Sálim Ali Centre for Ornithology & Natural History

Coimbatore, Tamil Nadu

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