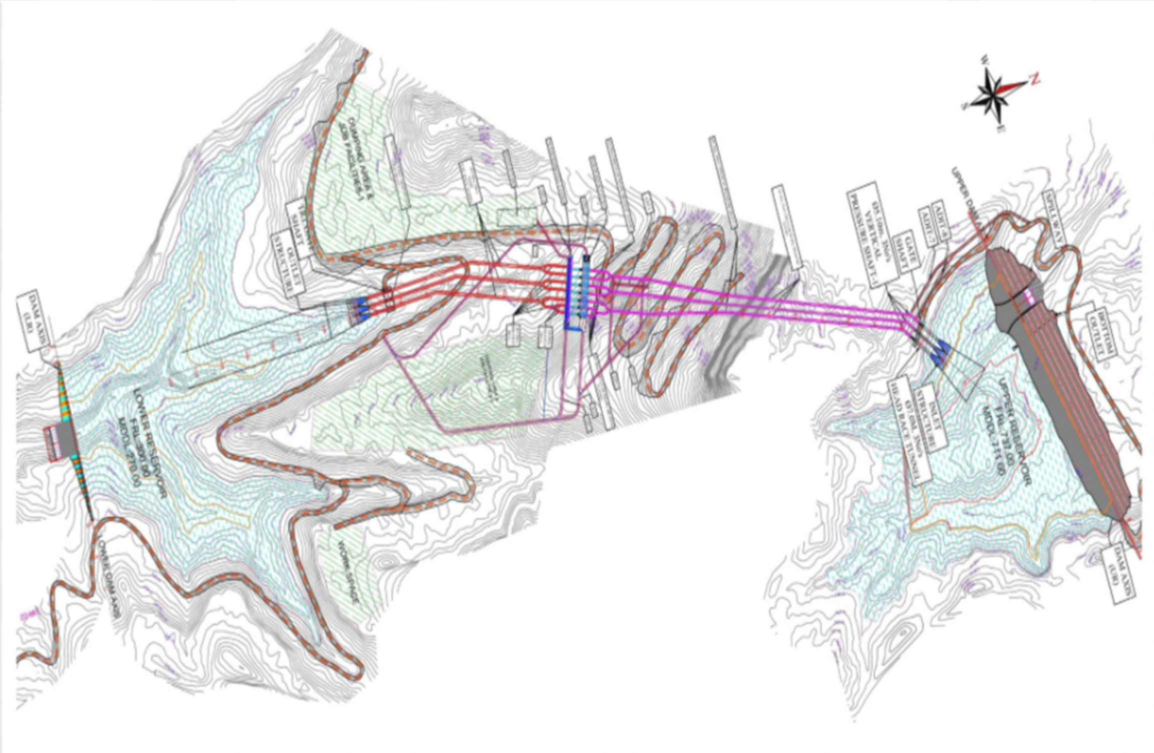
*Report on*

# Study on assessment and mitigation of impact of blasting operations on flora and fauna, nearby man-made structures and the environment during construction of JSW Bhavali Pumped Power Storage Project, Nashik



**Submitted to**

## JSW ENERGY PSP TWO LIMITED

## BKC Mumbai

By


**CSIR-Central Institute of Mining and Fuel Research**

**Council of Scientific and Industrial Research, Ministry of Sct & Tech. GOI**

**CSIR-CIMFR Regional Research Centre Bilaspur**

**Ph +91-7752271581-88, Fax: +91-7752-271450, www.cimfr.res.in**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***Report on***

Study on Assessment and Mitigation of Impact of Blasting Operations on Flora and Fauna, Nearby Man-Made Structures and the Environment during Construction of JSW Bhavali Pumped Power Storage Project, Nashik

***Sponsored Research Project Report***

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24.09.2025

(Dr. Harsh Kumar Verma)
Sr. Pr. Scientist and Head of Section

अनुभागाध्यक्ष / Head of the Section
सीएसआईआर-केन्द्रीय खनन एवं ईंधन अनुसंधान संस्थान
क्षेत्रीय केन्द्र, बिलासपुर

# Executive Summary

M/s JSW Energy PSP Two Ltd. is developing Bhavali Pumped Storage Project (BPSP) with an installed capacity of 1500MW/11670 MWH. The project is located in Igatpuri taluka of Nashik district of Maharashtra state. The project comprises of development of upper & lower reservoirs with a gross storage capacity of 0.436 TMC & 0.468 TMC respectively, out of which upper reservoir to be constructed on the hilltop with maximum dam height of 49.57 m to create the desired storage capacity while the lower reservoir will have maximum dam height of 48.15 m constructed in a natural depression downhill. As per a rough estimate approximately 30.0 lakh cum of hard rock excavation will be carried out using controlled blasting technique during construction of the Bhavali PSP.

JSW Energy PSP Two Limited requested to CSIR-Central Institute of Mining and Fuel Research for technical support and guidance for carrying out control blast design operation during construction of Bhavali PSP with special emphasis to prevent any adverse impact of blasting operation to flora and fauna of Kalsubai Harishchandragad Wildlife Sanctuary. Team of Scientists and staff members conducted a preliminary field investigation to assess the possible impact of blasting operation and evaluate the required mitigation measures.

Construction planning details of Bhavali PSP revealed that the actual operating distance of the quarry boundary from ESZ is 253 m, although, the minimum distance of FRL boundary of upper reservoir is 12.5 m from ESZ at Saddle dam point (fig. 6 of the report). Similarly housing structures of Jamunde village is also approx.. 250 m from the nearest blasting points. As per prevailing standard, the safe permissible limit of 5 mm/s peak particle velocity for all the structure may be considered as safe permissible limit.

CSIR-CIMFR Team made field investigations, reviewed the available safe limit of blast induced ground vibration, air overpressure, Noise, Dusts generation etc. Optimised controlled blast design pattern have been evolved considering the propagation characteristics of vibration and air overpressure in the prevailing rock mass condition. A comprehensive plan to implement various measures for controlling adverse impact of the blasting operation have been suggested.

Recommended measures include, use of advanced explosive and initiating system such as shock tube initiation system, emulsion explosive, varying blast hole dia., and blast design parameters considering the proximity of the ESZ, dust and flyrock control measures, use of blasting mats to suppress noise etc.

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## 1.0 INTRODUCTION

Pumped Storage Projects (PSPs) are crucial in India's energy ecosystem for balancing supply and demand, ensuring grid stability, and integrating renewable energy sources. They function as a reliable energy storage technology, storing power during periods of low demand and releasing it when needed, particularly during peak hours. PSPs also help smooth out fluctuations in renewable energy generation from sources like wind and solar, preventing grid instability. The Pump storage offers multiple benefits to a power system. In addition to providing energy storage, pumped storage can provide power immediately and can be rapidly adjusted to respond to changes in energy demands. Multiple PSP project are under construction in the country.

M/s JSW Energy PSP Two Ltd is developing Bhavali Pumped Storage Project (BPSP) with an installed capacity of 1500MW/11670 MWH. The importance for Bhavali PSP, indicative installed capacity 1500 MW, in Nashik and Thane district, Maharashtra, has therefore been considered in context of the focus of State Government to increase the share of renewable energy which is available in plenty within the state in general and in the country as whole.

The Project comprises of development of upper & lower reservoirs with a gross storage capacity of 0.436 TMC & 0.468 TMC respectively, out of which upper reservoir to be constructed on the hilltop with maximum dam height of 49.57 m to create the desired storage capacity while the lower reservoir will have maximum height of 48.15 m constructed in a natural depression downhill. Other project components are Geomembrane Faced Rockfill Dam, & Concrete Spillway, Upper Intake, Penstock, Powerhouse and GIS, Tailrace Tunnel TRT Intake/Lower Intake etc.

As per a rough estimate approximately 64.0 lakh cum of hard rock excavation will be carried out using controlled blasting technique during construction of the Bhavali PSP.

Uncontrolled blasting operation gives rise to problem of ground vibration, noise, flyrock and air over pressure and dust related problem leading to damage to the surrounding environment and structures. All these adverse impact can be reduced to safe tolerance limit by optimising the controlled blast design parameters, use of suitable advance technology and modern scientific methodologies.

Considering the availability of expertise in development and application of various controlled blasting techniques in various similar infrastructure projects with the institute, M/s JSW vide P.O. Letter No. CORP-PSP2/2025-26/1483000148 dated 16.05.2025, requested CSIR-Central Institute of Mining and Fuel Research for carrying out a scientific study initially to assess impact of blasting on surrounding environment and propose mitigation techniques of adverse impact, if any. JSW also requested CSIR-CIMFR to provide technical support in supervision controlled blasting operation during construction of project by deputing scientist and technical staff at site on continuous basis.

This report is an interim report incorporating details of preliminary assessment of impact of blasting operations on nearby environment and structures. It also contains suggestions on techniques and mitigation measures to minimise the impact of blasting operation. During course of the study, emphasis is given to the possible adverse impact to flora and fauna of Kalsubai Harischandragarh Wildlife Sanctuary.

## 2.0 PROJECT DETAILS

The Geographical co-ordinates of the proposed Pumped Storage Project component of upper reservoir located near to Jamunde Village in Igatpuri Taluk of Nashik district with latitude 19$^0$36'31.69''N, and Longitude 73$^0$35'45.06''N and that of lower reservoir at Kalbhonde village in Shahpur Taluk of Thane district with latitude 19$^0$34'56.38''N and longitude 73$^0$35'10.00''E.

Lay out of the project in plan and L-Section is presented in Fig 1 and Fig. 2 respectively. The project envisages creation of an upper reservoir (gross storage: 12.35 MCM & live storage:11.08 MCM) by constructing 962.47 m long dam comprising of 822.47 m long Geomembrane faced rockfill dam (GRFD) with maximum height of 48.64 m from foundation, 60 m long and 61 m height ungated spillway with 4 bays of 12.5 m each; 4 blocks of 20 m length each non-overflow section of maximum height of 49.57 m from foundation, two each on either side of spillway. 80 m long saddle dam (maximum height 10 m from foundation) to reduce backwater to enter ESZ area. The lower reservoir (gross storage:13.26 MCM; live storage: 11.71 MCM) shall be created by constructing concrete gravity dam 365.5 m long at top with maximum height of 48.15 m from foundation and 104 m long, 74 m high (from foundation) ungated spillway with 8 bays of 10.5 m each. Diffuser type Intake structure with 3 intakes (25.5 m x 10.5 m) of 42.44 m length shall be provided.

The water conductor system shall comprise of 67.96 m long three intake tunnels of 7 m diameter each with design discharge of 131.74 cumec each. 5.2 m diameter, followed steel lined pressure shaft 3 nos. of independent, 5.2 m diameter with length varying from 1568.09 m to 1594.89 m, six 3.8 m diameter branch pressure shaft after first bifurcation of design discharge 65.96 cumec each; two 2.9 m diameter 46.83 m long steel lined branch pressure shaft after second bifurcation of design discharge 32.98 cumec each.

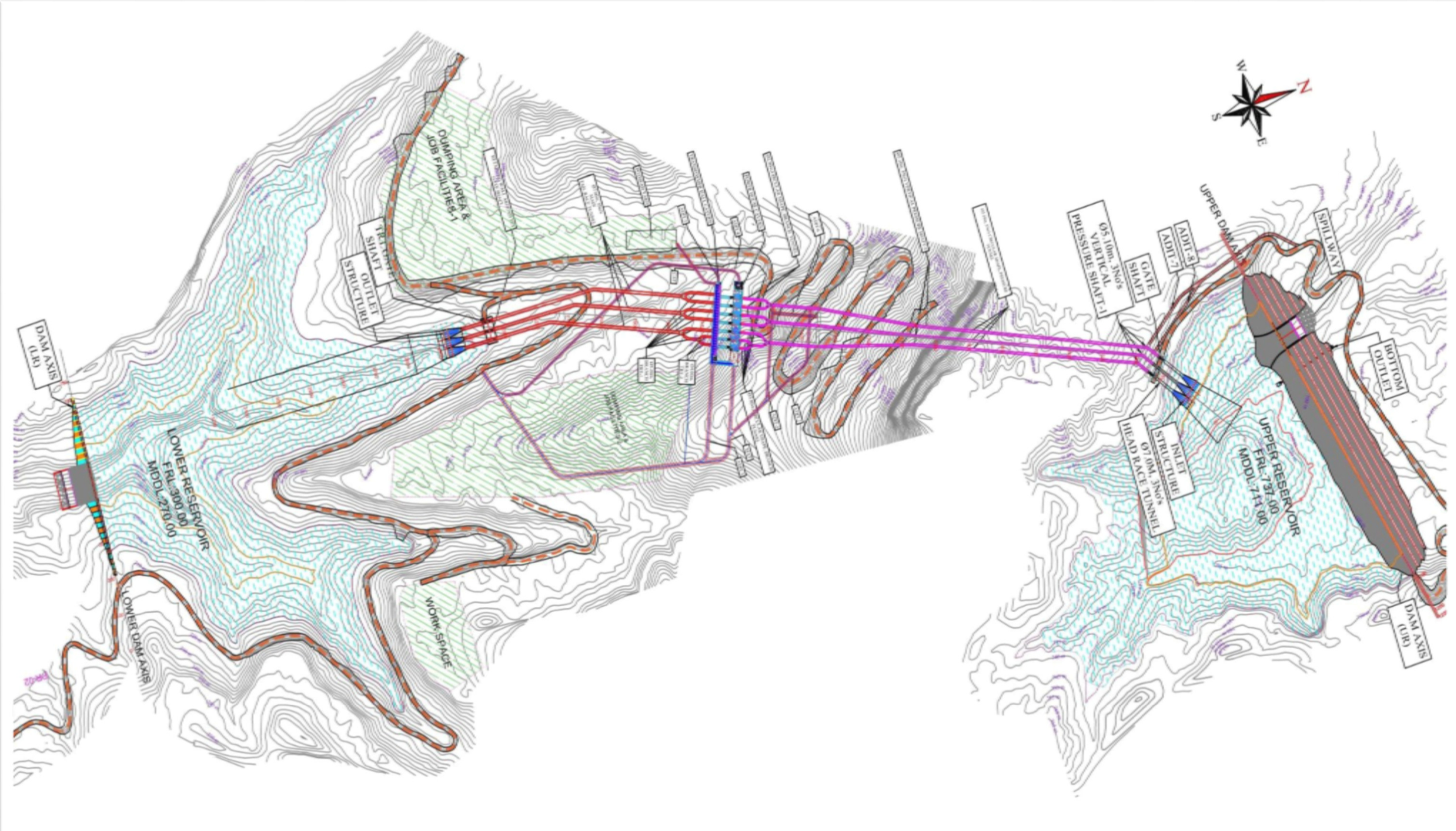


Fig. 1: Lay of Bhavali PSP Project, Igatpuri

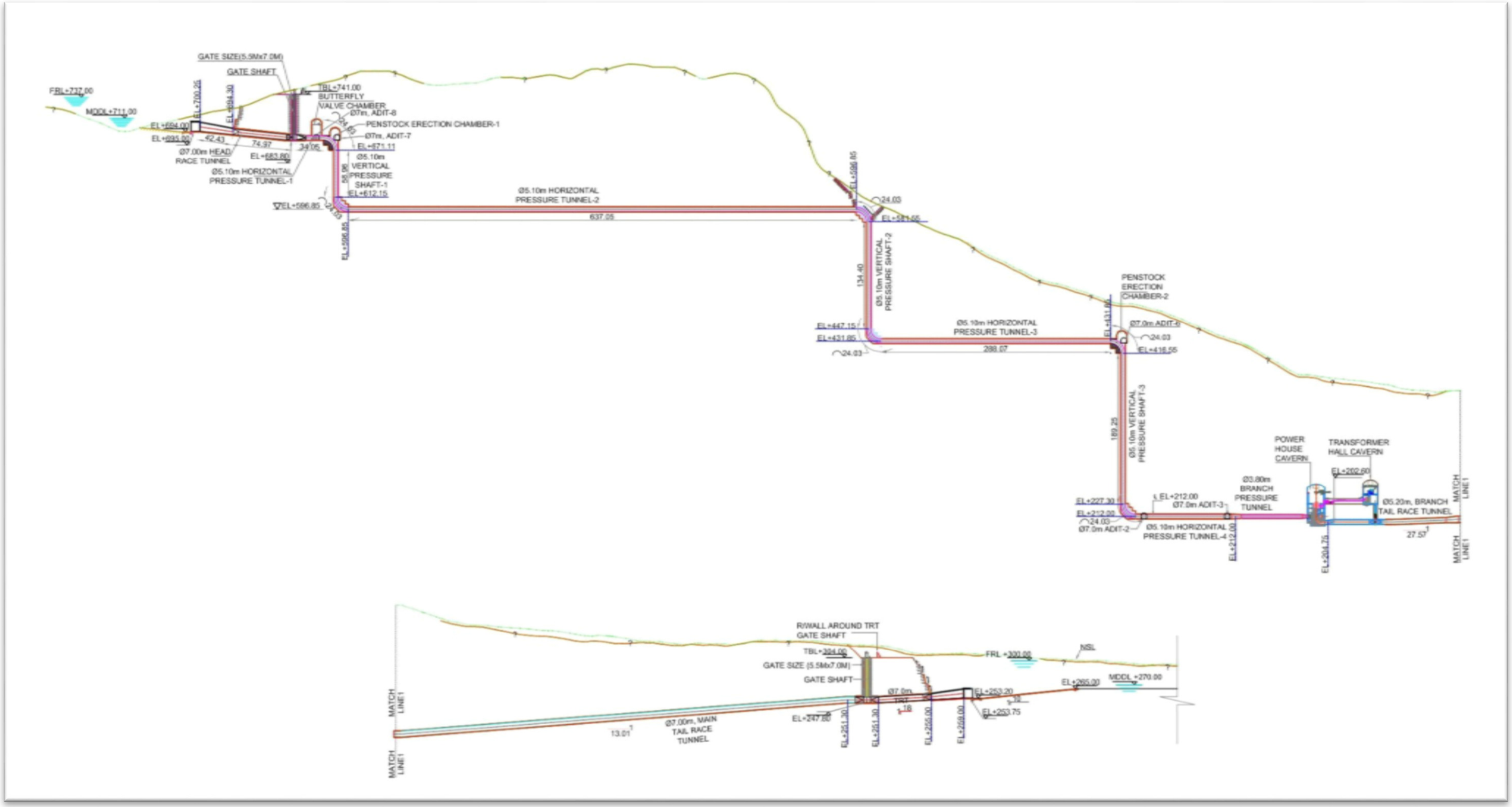

Fig. 2: L- Section Layout of Bhavali PSP Project, Igatpuri

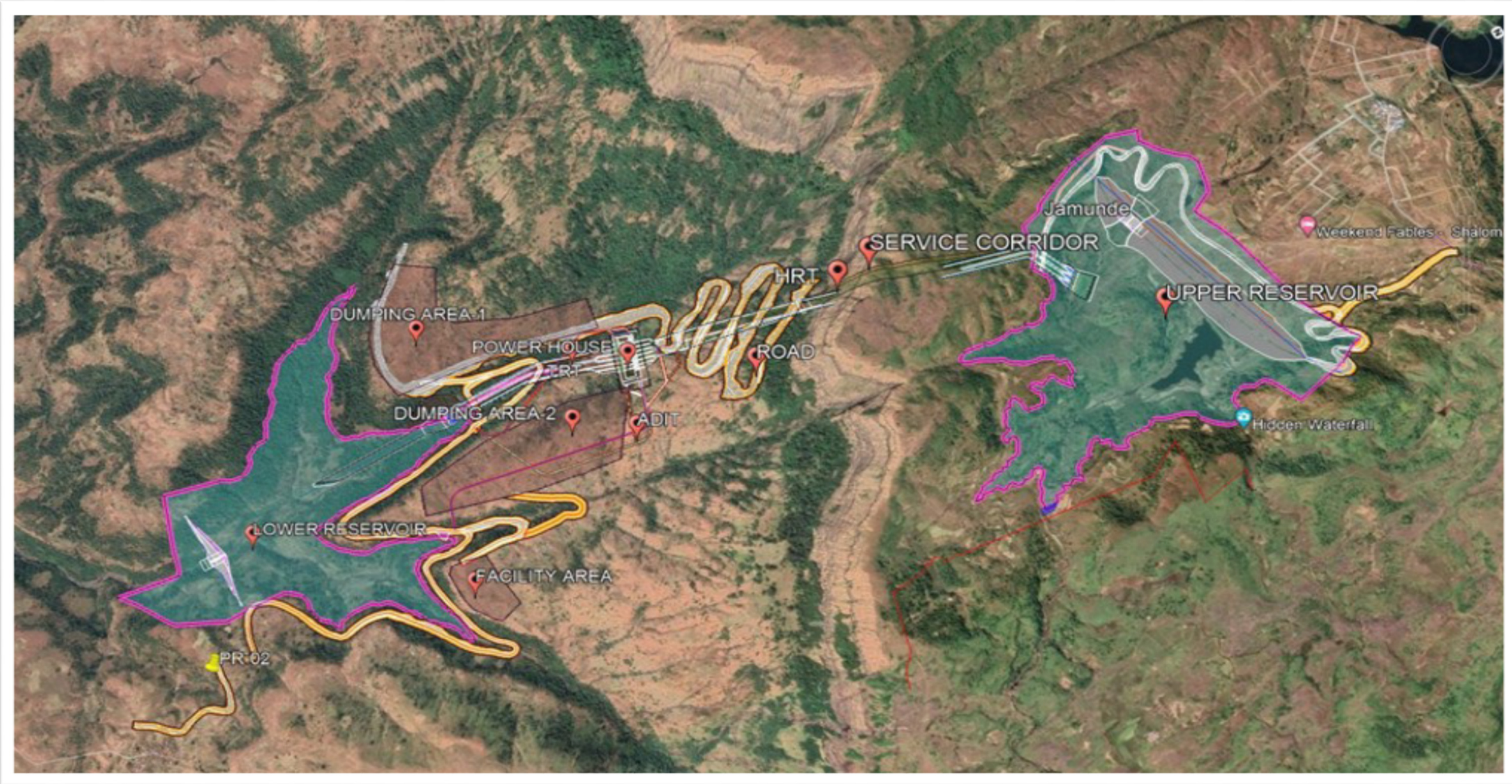


Figure 3: Photograph showing Bhavali PSP Project site location in a google map

Underground powerhouse (167 m x 22 m x 52.9 m) housed with 7 No's. Francis vertical shaft reversible pump-turbine (5 X 250 MW & 2 X 125 MW) discharging into circular draft tube 5.20 m and 4.0 m diameter for large and small unit; two four meter diameter concrete lined branch tail race tunnel for 32.98 cumec discharge after 3rd bifurcation; six 5.2 meter diameter concrete lined branch tail race tunnel for 65.78 cumec discharge after 4th bifurcation; followed by three 7 m diameter main tail race tunnel with length varying from 621.17 m to 646.57 m, each discharging 131.74 cumec, 105 m long trapezoidal tail race pool followed by 560 m long trapezoidal tail race channel.

The project will generate 1500 MW by utilizing a design discharge of 394.84 cumecs that includes, 65.78 cumec with rated head of 425.23 m (for larger unit of 250 MW) and 32.98 cumec with rated head of 424.03 m (for smaller unit of 125 MW) for 7.78 hr. The PSP will utilize approx.. 1600 MW to pump 0.391 TMC of water to the upper reservoir in 8.79 hours. Annual energy generation by Bhavali PSP in turbine mode is 4044.06 MU whereas annual energy consumed in pump mode is 5120.53 MU.

## 3.0 GEOLOGICAL SET-UP OF THE PROJECT

Geological set-up of the project site play important role in controlled blasting operations and it governs propagation characteristics of the blast induced ground vibration and air overpressure. Therefore investigation of geological set-up and review of the geotechnical data of the project site was also carried out.

Figure 4: Photographs of field visit of CSIR-CIMFR team to Bhavali Project site

The proposed PSP site is located on the western margin of Western Ghats of Indian Peninsula, which are occupied by thick pile of Thoilitic Basalt flows, which are stratigraphically termed as 'Deccan Traps'. The Deccan Traps cover a large area of 52000 sq.km covering a major part of Maharashtra, parts of Gujarat, Madhya Pradesh and small parts of coastal Andhra Pradesh. The basalt rock prevailing in the project area make it as hard rock terrain. It is strong rock covering all the component locations such as upper and lower reservoir areas, water conductor system, powerhouse complex and entire length of Tailrace tunnel/channel area.

As per the regional geological setup at and around the project area, the area is occupied by strong basalt rocks/Deccan trap. The rock types, as per this map, mainly belong to the Lower Ratangarh formation which prevails in the upper reservoir/dam, part of the WCS, and powerhouse complex area. In the case of the TRT, the Lower dam/reservoir area, the basalt rocks belong to the Salher formation. Both formations come under the Sahyadri group within the Deccan Trap Super group, belonging to the Cretaceous to Paleocene age. The basalt rock exposed in the project area has been observed to show thick flows and is massive and strong in nature. Amygdaloidal basalt is also observed in the Upper dam area. Weak lithological strata like red bole/green bole beds, which are observed at places in Deccan basalt rocks, are not found in the project area. No such weak layers are encountered in any of the drill holes completed in the project area, right from the upper reservoir, water conductor system, powerhouse complex, TRT/TRC, and lower dam site.

The general trend of the flow direction of basaltic rock in the area, mainly in the upper reservoir area, is observed to be in SE, SW, and NW directions, dipping at $8^0$ to $38^0$ degree at places. Besides flow joints, there are 3-4 sets of joints spaced and are moderately to widely spaced. Rocks are generally strong to very strong, fresh at depth, with slight to moderate weathering effect near the ground surface.

Review of the investigation reports reveals that all the sites of major components of the project are geologically mapped and explored by geophysical survey and number of drill holes. The exploration results confirm the availability of strong basalt rock at both the dam foundations and also along the underground media of tunnels, shafts, caverns etc.

The typical soil type of the area is the medium black cotton variety. There are, however, variations in the type of soil and several different varieties of soils, i.e., greyish black, brownish black, and reddish black soils are also observed. The major geomorphic landforms demarcated are scarp slopes, hills and ridges, dyke ridges, and pedimented plains, The eastern boundaries of both Bhatsa and Kalu basins are marked by steep scarps, while the central and western parts of both basins are marked by gently undulating topography interspersed with hills and ridges.

Geophysical survey using Seismic refraction method and MASW (Multi channel Analysis of Surface wave) have been carried out covering all the major components of Bhavali PSP. The broad findings are given as under. Generally, the S-waves are found to be in the range of 91-110 m/s near ground surface for unconsolidated deposits to 750m/s for the weathered/fragmented rock. Below this zone, increased Swave velocity greater than 2000m/s represents sound quality basement rock which are seen in all the profiles.

Comprehensive investigation through 23 boreholes have been carried out covering entire project components. Investigation report of bore hole survey show a good correlation with the Geophysical survey findings. In general, it is noted that the drill hole data corroborate these geophysical survey findings. The unconsolidated soil or overburden deposits, as described in the preceding paragraphs, also range from less than a meter to a couple of meters. Even the fracture zones or moderately weathered zones, with RQD values less than 50%, are generally confined to depths of 5-7 meters or a maximum of up to 10 meters from the ground level. Beyond this depth, generally, fresh, strong, and massive basalt rocks are recovered even in deeper holes.

# 4.0 STANDARDS ON SAFE LIMIT OF GROUND VIBRATION AND AIR OVERPRESSURE/NOISE

## 4.1 Ground Vibration

Ground vibration is an important and integral aspect of any blasting process. Damage to the surface or underground structures has been widely correlated with peak particle velocity (PPV) of ground vibrations induced by blasting. In the present study, review of blast vibration monitoring data from different tunnel construction sites with similar geological set-up have been carried out and attenuation characteristics of vibrations in tunnels have been evolved to compute near field vibration level.

When an explosive is detonated inside a blast hole explosive energy is rapidly released in the form of chemical energy in short span of time generating tremendous pressure and temperature. High temperature and pressure environment causes surrounding rock material melt, flow, crush and fracture. After certain distance away from the bore hole, these inelastic process stops and the elastic processes begin to occur. Decay of the energy is very rapid and only apportion of the explosive/ chemical energy is transformed into elastic form. The elastic disturbance propagates away in the form of seismic waves which is also termed as vibration generation zone.

Attenuation of the shock wave energy is very fast due to utilization of this energy in crushing and fracturing. Beyond fracture zone, the energy propagates as seismic wave elastically which is termed as ground vibration. Intensity of the ground vibration is governed by the blasting parameters and characteristics of the propagating medium. Generation of blast induced ground vibrations is shown in Fig 2.28 in the form of flow-chart. It may be noted that the explosive energy inside a holes instantaneously converts in to shock and gas energy forms. The shock component causes cracks in the rock mass through high intensity of the strain pulse and stress. The cracks formed by the shock energy are further widened by the gas component of the explosive energy. After fragmentation, the energy is utilized in displacement of the rock. Unutilised explosive energy travels in the surrounding rock mass in the form of seismic waves which are termed as blast induced ground vibrations.

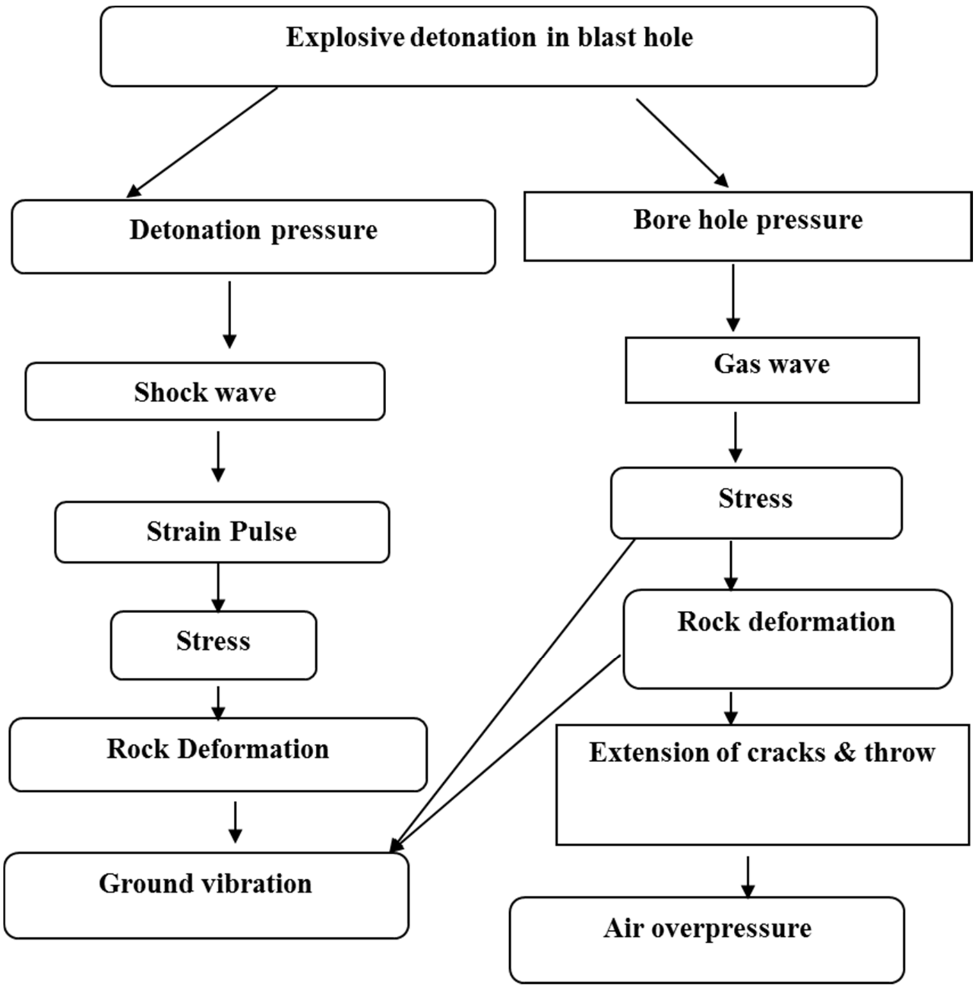


**Fig. 5: Generation of Ground Vibrations due to Blasting**

Most of the researchers, while formulating prediction model for blast vibration, correlated the amplitude of vibration with quantity of explosive used in a blast round and distance of monitoring location (Blair and Duvall, 1954; Duvall and Petkof, 1959). They concluded that any linear dimension of charge should be scaled to the cube-root scaled distance due to spherical symmetry. However, in case of long cylindrical explosive charges, the linear dimension will be scaled with square-root of maximum charge per delay.

Review of different prediction models reveal that most of the empirical models provide relations among blast induced ground vibrations (peak particle velocity, $V_{ppv}$, in mm/s), distance of monitoring point to source (R, m) and maximum explosive charge per delay ($W$). United States Bureau of Mines (USBM) conducted extensive study on prediction of blast induced vibrations and structural damage. Daemen, (1983) and researchers of USBM (Duvall and Fogelson,1962; Duvall et al., 1963; Siskind et al.,1980) concluded that any linear dimension should be scaled to square root of the explosive charge as shown in Eq. 1.

$$V_{ppv} = K\left(\frac{R}{\sqrt{\mathrm{W}}}\right)^{-\beta} \qquad \text{(Eq. 1)}$$

Over the years, numerous vibration criteria and standards have been suggested by researchers, organizations, and governmental agencies. Much of this work originated from the mining industry, where vibration from blasting is a critical issue. Different countries have set their own standard on the basis of experimental investigation in the mining industry. As per the present Indian Standards, as mentioned in DGMS (Tech) (S&T) Circular No. 7 dated 29$^{th}$ August, 1997 depending on the type of structures and dominant excitation, the Peak Particle Velocity (PPV) on the ground adjacent to the structure shall not exceed the values given below in the Table 1.

As given in Table 1, DGMS criterion being followed in whole of the country is frequency based damage criterion. The standard specifies that damage potential of the PPV will primarily depend on the frequency of vibration. As the frequency increases, the damage potential of the vibration reduces and hence the safe permissible PPV also goes on increasing. The frequency of the vibration depends on local geological conditions. A hard massive rock will have higher frequency and a soft jointed rock will have lower frequency. Higher the geological disturbances, less will be the frequency of vibration and therefore safe permissible PPV will also be lesser. Table 7 also reveals that the type of housing structures will decide the maximum safe PPV it can sustain. A domestic house of Kachha brick and cement/ mud-clay can sustain less value of PPV whereas an industrial building with RCC frame will sustain higher level of PPV without incurring any damages

**Table 1**: Permissible Peak Particle Velocity (PPV) in mm/sec as per DGMS (India) Standard

| Type of Structures | Dominant Frequency, Hz | | |
|---|---|---|---|
| | **<8 Hz** | **8-25 Hz** | **>25 Hz** |
| *(A) Buildings/structures not belonging to the owner* | | | |
| i. Domestic houses /structure (Kuchha brick and cement) | 5 | 10 | 15 |
| i. Industrial buildings (RCC and framed structures) | 10 | 20 | 25 |
| ii. Objects of historical importance and sensitive structures | 2 | 5 | 10 |
| *(B) Building belonging to owner with limited span of life* | | | |
| i. Domestic houses /structures (Kuchhabrick and cement) | 10 | 15 | 25 |
| ii. Industrial buildings (RCC and framed structures) | 10 | 25 | 50 |

In DGMS standard as mentioned above in Table 1, special provision has been given to the owner of the structure close to the blasting activities. Limit of safe vibration for residential houses not owned by the project authorities are more restrictive than the one owned by the project authorities on account of temporariness of the structures. However, irrespective of ownership and type of construction material, historical objects have been given special emphasis and the safe limit of PPV has been most restricted.

### 4.2 Air overpressure

When a blast is fired, it is frequently accompanied by a loud noise called air blast. Air blast is an atmospheric pressure wave consisting of high-frequency sound that is audible and low frequency sound that is sub-audible and cannot be heard. Either one or both of the sound waves can cause damage if the sound pressure is high enough. Air blast, generally is an annoyance problem, does not cause damage but may result in confrontation between the operator and those effected (Konya and Walter, 1990). Air blast is measured in decibels (dB) or in pounds per square inch (psi). Because of the wide range of over pressure, the decibel is usually used. The decibel is defined in terms of the overpressure, by the equation

$$\mathbf{AOP\ (dB) = 20\ LOG\ (P/P_o)} \qquad \text{(Eq. 2)}$$

Where,

dB = sound level in decibels,

P = overpressure in psi,

$P_o$ = overpressure of the lowest sound that can be heard, and

$P_o$ = $3 * 10^{-9}$ psi

Review of various standards reveals that at sound pressure levels below 130dB there will be audible rattle, mainly from windows and doors and from objects standing on shelves. With increasing amplitude, window panes begin to break at about 152dB. Most windows in an area would break at amplitude of 172dB, and structure damage would occur at 182dB or over (Siskind et a1. 1980b., Anon, 1998., Konya et a1. 1990).

For construction and quarry blasting specification, there has been long history of using 140 dB as an overpressure limitation. Recently it has become more common to make use of more restrictive limitation that were developed for surface mining operation and to apply them to all forms of blasting. For large scale surface mining operations, air overpressure can be characterized by lower frequency. For such large scale operation, a common overpressure limit of 134 dB is recommended by United States Bureau of Mines (USBM) RI8485 (Siskind et al, 1980) as given below in Table 2.

**Table 2: Typical Air overpressure criterion**

| Air Overpressure limits | Damage potential |
|---|---|
| 180 dB | Some structural Damage |
| 171 dB | General window breakages |
| 140 dB | Occasional Window breakage |
| 134 dB | US Bureau of mines recommendations for large scale surface mine blasting. |

DGMS Circular suggests 90dB as the threshold for continuous occupational exposure upto 8 hours duration. However, there is no Circular from DGMS or Indian Bureau of Mines (IBM) regarding permissible safe level for air overpressure produced due to blasting. The permissible levels of air overpressure recommended by Siskind et. al, 1980(b) (Table 3) is most comprehensively used and hence same is adopted in this case also.

**Table 3: Permissible level of Air overpressure (Siskind et. al, 1980(b))**

| Type of instruments | Permissible level (dB) |
|---|---|
| 0.1 Hz high pass time | 134 |
| 2.0 Hz high pass time | 133 |
| 6.0 Hz high pass time | 129 |
| C-slow weighing scale (Event less than 2 sec duration | 105 |

The following suggestions are made to control air over pressure:

1. A deeper charge or a better-confined charge produces a low pressure pulse.
2. Detonating cord used to interconnect down line for initiating detonation in the explosive in drill holes produces more sound pressure. The sharp air shock wave

from the detonating cord is a major cause of disturbance and is annoying to the neighbors. Hence, detonating cord is to be avoided except in remote locations.

3. As each detonating hole will produce its own fingerprint in the air pressure, it is recommended to connect holes in row and holes are to be fired sequentially in such a way that the initiation sequence is moving away from the sensitive object, thereby minimizing the risk for building up more severe blast waves propagating in a direction toward the sensitive object.
4. Avoid heavy charges too close to the ground surface where they may blowout, or "crater". Such charges may also generate flyrock. Having charges too close to the ground surface is a condition comparable to having charges, which are too far apart for the depth of stemming. The closest relief is upward.
5. Avoid heavy charges too close to an open face where they may also blowout, as above. These charges may also generate flyrock. The action is similar to the above, but may take place horizontally to an open face rather than vertically to the ground surface.
6. It is helpful to avoid placing charges in open seams, clay filled seams, highly fractured zones or other weaknesses, where they may allow explosive gases to be vented.
7. Use a depth of stemming which is sufficient to prevent flyrock and blowout.
8. Less stemming will be required if interlocking in the material is of good quality. If possible, avoid the use of fine stemming or light weight stemming which can't be compacted.
9. Higher pressures may be generated by large quantities of exposed detonating materials, such as detonating cord, surface delays and portions of down lines. If the air blast overpressures is too high, it may be necessary to cover these products with sand or similar material.
10. Although it is not directly related to increased overpressures, another factor of

interest is the time related to the occupancy of the area and residential activities. Certain times may be unfavorable for the residents of a given area, such as night, evening, early morning, or times when most of the people in the area are home and conditions are relatively quiet.

### 4.3 FLYROCK

The rock fragments ejected from the blast called "flyrock" is a serious hazard of blasting operations, particularly when the blast is conducted in the vicinity of village and structures of ecologically sensitive zone(ESZ). The factors which influence the flyrock distance include:

- Height of stemming column in the blast holes and type/quality of stemming material
- Irregular shape of free face/top of the bench
- Excessive large burden or blasting without free face
- Muffling of the blast area and the muffling material type.
- Scattering and overlapping of delay timings of the delay detonators/relays.
- Presence of water in blastholes

The first four parameters can be controlled by properly designing the blasting pattern whereas the last two parameters are not easily controllable. The risk from flyrock can be minimised to a great extent by proper design and execution of the design. FLyrock can be further eliminated using muffle blasting and same is recommended for the blasting operation near ESZ at Bhavali PSP site.

### 4.4 Noise

Blasting operations in ecologically sensitive zones can cause significant noise pollution, leading to various negative impacts on wildlife, vegetation, and human health. The resulting noise can disrupt habitats, affect communication and reproductive behavior of animals, and potentially damage structures and ecosystems. As per prevailing regulation as specified in guidelines of ministry of Environment & forests, The Noise Pollution (Regulation and Control) Rules, 2000; (As amended till 10/08/2017 vide S.O. 2555(E)), the safe permissible limit for different types zones are as given below.

Table 4: Safe limit of Noise for various zones as per The Noise Pollution (Regulation and Control) Rules, 2000

| **Area Code** | **Category of Area/Zone** | **Limits in dB(A)** | |
|---|---|---|---|
| | | **Day Time** (6.00 am to 10 pm) | **Night Time** (10.00pm-6.00am) |
| A | Industrial area | 75 | 70 |
| B | Commercial area | 65 | 55 |
| C | Residential area | 55 | 45 |
| D | Silence Zone | 50 | 40 |

During optimisation of controlled blasting techniques, efforts will be made to optimise blast design parameters in a as way that the noise produced at source is minimum. Further, the explosive and initiating devices used will be of highest quality which produces less sound such as NONEL and Shock tube initiation system. Further, all blasting operation will be taken as muffle blasting so that noise is further reduced and it remains well within the specified limit.

Other measures to be implemented during blasting operation includes measures such as using quieter explosives, optimizing blast designs, and using noise barriers. Limiting blasting activities to specific times of day or year to minimize disruption to wildlife and sensitive ecosystems is also effective way to reduce adverse impact of noise. Similarly establishing buffer zones around sensitive areas to reduce the impact of blasting on ecologically sensitive zones.

Monitoring noise levels during blasting operations will be carried out by CSIR-CIMFR Team to ensure compliance with regulations and to assess the impact on the surrounding environment

### 4.5 Dust Generated from the Blasting Operations

Drilling and blasting are processes of detaching rock material from the parent rock. Dust causes environmental, health, safety and operational problems affecting workers and surrounding environment. The distance from the drill and blast site determines the dust concentration produced. Different types of dust particle size are produced from drilling and blasting. These include >PM10, PM10, PM2.5, Total Suspended Particles and deposited dust.

Wet blasting technique is recommended for the dust control. This technique involves mixing water with the abrasive material in the blasting nozzle. This creates a slurry that captures dust particles at their source and prevents them from becoming airborne.

Installing ventilation systems can help to remove dust particles from the air and prevent them from accumulating in the workspace.  Creating barriers or enclosing the blasting area can help to contain dust and prevent it from spreading to other areas. Implementing restricted zones around blasting operations can help to protect nearby workers and prevent dust from contaminating other areas. Providing workers with proper respiratory equipment, such as respirators, can help protect them from inhaling dust particles.

## 5.0 IMPACT ASSESSMENT OF BLASTING OPERATION ON WILD LIFE, MAN MADE STRUCTURES AND ENVIRONMENT

Blasting shall have adverse impact on fauna using the area contiguous with the surrounding habitation area as habitat. Construction and operation activities generate noise and artificial light, which can disturb wildlife. Nocturnal animals may be particularly affected by light pollution, altering their behavior and disrupting natural processes. The noise generation has an adverse impact on terrestrial fauna and avifauna.

Intervention in the project area will impact butterflies and birds which are quite sensitive to noise and human presence. The traffic noise has detrimental effect on the survival rates and breeding success of such fauna which reside in the small habitats along roadside communicating using acoustic signals. Sometime as a result of habitat loss and physical disturbance, the fauna shall move from the habitat along roadside. Based on the field observations and interaction with local people and forest officials, it was noted that the Project area does not constitute part of any wildlife migratory routes and construction activities won't affect animal movement. All precautions shall be taken as envisaged under the relevant acts in respect of handling of explosive material and blasting which shall invariably be carried out by a qualified blaster.

CSIR- CIMFR team visited the site to physically evaluate the proximity of various sensitive structure around the project site. Exploratory trekking was done along the main component of the project, particularly the upper reservoir area where the Kalsubai Harischandragarh Wildlife Sanctuary is in close proximity of the rock excavation works. A detailed investigation on proximity of the ESZ area with the possible blasting operation was made by the visiting team. A detailed discussion on the construction methodologies and sequence of the rock excavation was done with the JSW team to evaluate the blasting impact on the flora and fauna.

## 5.1 Kalsubai Harischandragarh Wildlife Sanctuary

Kalsubai Harishchandragad Wildlife Sanctuary (KHWF) located on the Sahyadri mountain ranges which is part of the Western Ghats of Maharashtra and is situated between Latitude 19°25'57" to 19°34'04" North and Longitude 73°37'51" to 73°46'25" East covering an area of 225 sq. km (15 km × 15 km dimension). The elevation of the area varies from 148 m to 1508 m above MSL while most of the area is situated near the crest line of Western Ghats. Geologically this area is part of the Deccan Trap. The Kalsubai Harishchandragad Wildlife Sanctuary is replete with abundant kinds of flora and fauna. This region receives excessive rainfall of about 600 cm. The green landscape is stocked with beautiful vegetation and shrubs like Beheda, Avali, Gulchavi, Kharvel, Siras, Aashind, Parjambhual, Hirda, and Lokhandi under the bracket of trees. The different animals in the study area, like the leopard, jackal, hyena, barking deer, Palm civet, Indian giant squirrel, mongoose, jungle cat, and also many species of mammals and birds. The Pravara River originates on the eastern slope of Sahyadri in between Kulang and Ratangad forts.

Figure 6 is a layout of the ecologically sensitive zone (ESZ) showing the distance of the quarry of the Bhavali PSP Project. In this figure, various distances are marked from the closest blasting site. Although the minimum distance of FRL boundary of upper reservoir is 12.5 m from ESZ at Saddle dam point, the actual operating distance of the quarry boundary from ESZ is 253 m. Therefore, for all blasting operation from ESZ will be minimum 253 m.

Various researcher have performed experimental blast vibration monitoring in basalt rock formation, similar to prevailing rock mass in Bhavali Project site, near pune and Mumbai. They found that the vibration attenuation. The observed vibration data in basalt rock formation were analysed to obtain the vibration attenuation characteristics. The plot of observed vibration data in terms of peak particle velocity and square root scaled distance is presented in Fig 7. The attenuation characteristics of vibration in basalt rock formation is presented in Eq. 2 and 3 at 50% and 95% confidence intervals.

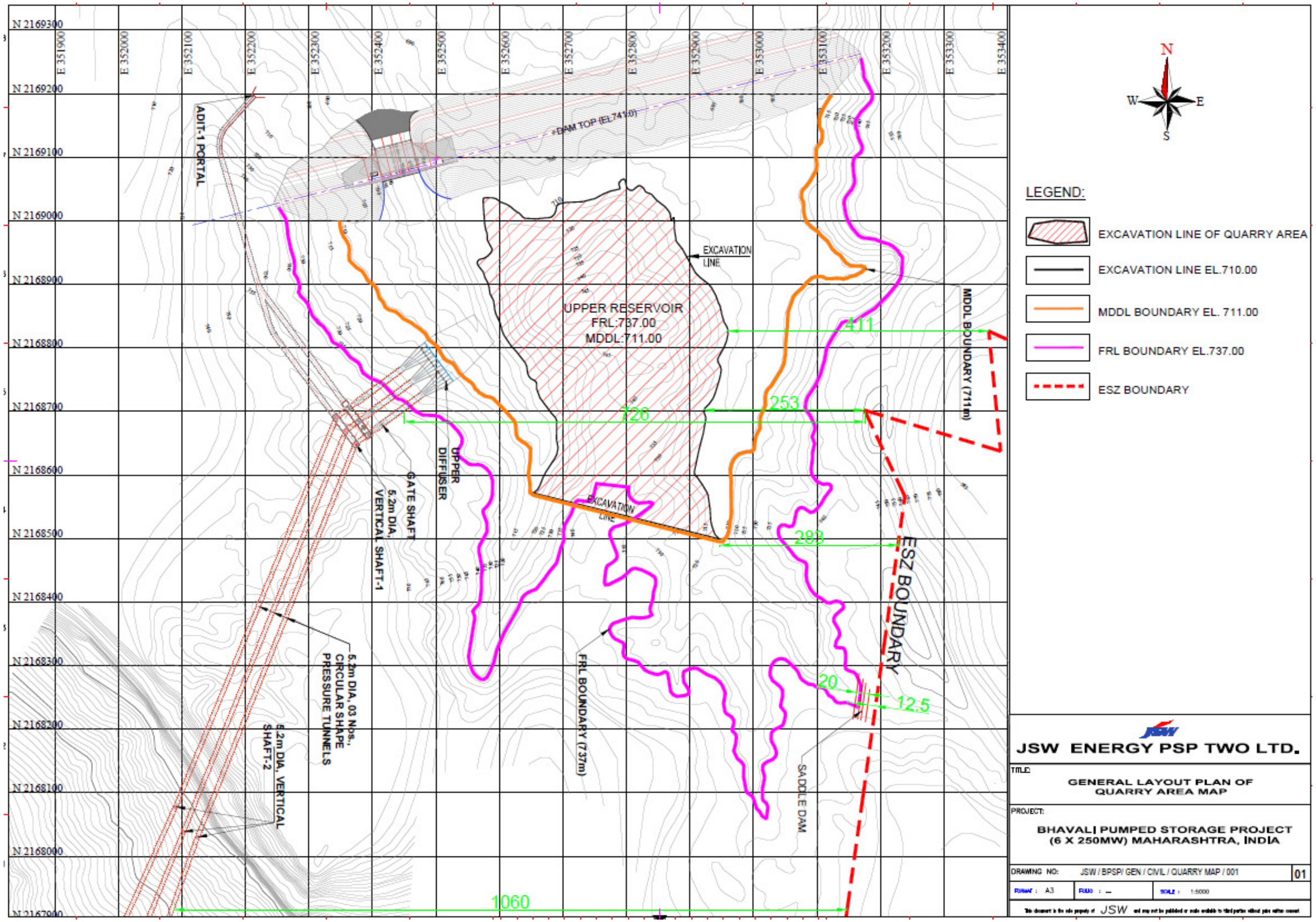


Figure 6: Layout of quarry area indicating proximity of the blasting site from ESZ.

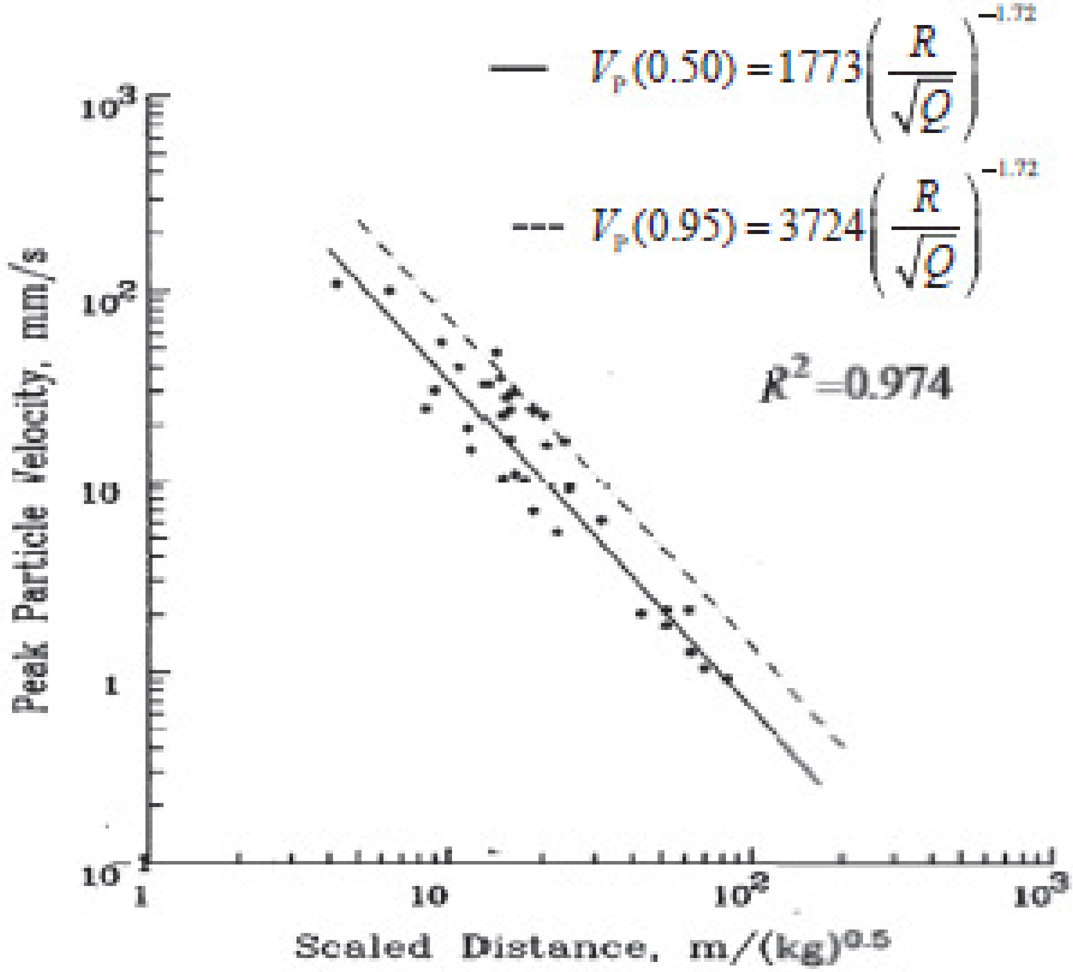


Figure 7: Plot showing attenuation characteristics of blast vibration in Basaltic rock mass formation

$$V_{ppv} = 1773 \left(\frac{R}{\sqrt{W}}\right)^{-1.72} \qquad (3)$$

$$V_{ppv} = 3724 \left(\frac{R}{\sqrt{W}}\right)^{-1.72} \qquad (4)$$

Where *R* is the distance (m) between the observation and blast and W is the quantity of explosive charge used per delay;

In Bhavali project site, the attenuation characteristics of the vibration will follow Eq. 3 and Eq. 4 at 50 % and 95% confidence intervals respectively. Equation 4 may be used for computation of safe charges and other Controlled blast design parameters considering Eq. 4. The minimum distance of 253 m is the value of R in Eq 4. The Eq. 4 will be further refined using filed data obtained by actual measurement of vibration during construction phase.

In addition to the surface excavation, underground excavation will also be done using controlled blast design parameters for rock excavation of tunnel, power house tail race tunnel etc. In all this blasting operations also, blast induced ground vibration will be controlled using optimised blast design parameters and the charge weight per delay. In underground blasting operation, problem of air overpressure, flyrock, dust and noise will not be there.

All efforts will be made to ensure that the vibration remains well with the 5.0 mm/s of peak particle velocity in all ESZ with the help of use of advanced explosive and initiating devices such as shock tube initiation systems, electronic detonators, etc. Such low vibration and AOP level will not create any problem to flora and fauna of Kalsubai Harishchandragad Wildlife Sanctuary.

## 5.2 IMPACT ASSESSMENT OF BLASTING OPERATIONS MAN-MADE STRUCTURES

During the course of filed investigation of the CSIR-CIMFR to Bhavali PSP site, efforts were made to locate and identify the man-made structure in and around the project site. The project site is scarcely populated and there are very few houses. It was informed that affected house within the project site have been suitably compensated and relocated. It was observed that the nearest village is Jamunde village which is close to Upper reservoir. The houses in the village are mostly mud house. This village is approx. 250 m from the site of blasting operations (Fig 8). Few more houses made of brick-mortar also observed. However, theses house are far off (>600 m) from the project site and the impact of controlled blasting operations will be insignificant on these houses (Fig 9).

Figure 8: Housing structures of Jamunde village (<250 m)

Figure 9: Housing structures in project site (> 600 m)

As per present Indian standard the safe vibration limit of vibration in terms of Peak Particle velocity is 5.0 mm/s. Base on this assessment, controlled blast design parameters will be recommended to ensure that the vibration remains less than the safe recommended PPV value of 5.0 mm/s and accordingly other parameters such as AOP, NOISE and Dust control measures will be implemented during the blasting operations.

## 6.0 RECOMMENDED MITIGATION MEASURES AND METHDOLOGIES

CSIR-CIMFR Team conducted a field investigation to identify and assess sensitivity of various wild life and man-made structures around the proposed Bhavali PSP Project, Igatpuri with due consideration to the proximity of the ESZ of Kalsubai Harishchandragad Wildlife Sanctuary. Following remedial measures are suggested to for mitigating adverse impact of blasting operation to ensure minimum disturbance to the nearby flora and fauna of Kalsubai Harishchandragad Wildlife Sanctuary and also the man-made structure in the close proximity of the rock excavation works.

## 6.0 Optimisation of controlled blast design parameters

The controlled blasting operation will only be implemented with optimised blast design parameters. The maximum charge weight of explosive in blast round will be decided using Eq. 4, which is attenuation characteristics of the blast induced ground vibration in predominant rock mass. This will ensure peak particle velocity of the vibration well within the recommended safe permissible limit as per India standard.

### 6.1 Controlled Blast Design Pattern

#### 6.1.1 Formation of Benches

Any excavation that needs to be started has to be done under constricted blasting condition till a free face is created and benches are developed systematically. Initially shallow benches are formed and merged to achieve the desired bench height. Depending on the topography, hole are drilled and the desired bench height is achieved by conducting development blasts. In Bhavali PSP site, development will on a sloping area as it forms a part of the of hill. Bench preparation will be carried out by drilling shallow holes (2.5 to 3.0m) with a burden and spacing of 2.0 m x 2.5 m with a hole diameter of 45 mm. In some areas the hole depths as low as 1.5m will be required depending on the field conditions. In area more than 500 m from ESZ, higher dia hole and greater depth may also be used with controlled blasting operations.

#### 6.1.2 Bench Height

Bench height is normally decided depending on the local geology, production size, type of loading machine and slope stability. For a blasting engineer the bench height is a fixed parameter. In this project site the benches are of height ranging from 3.0 m to 5.0 m to be developed in a systematic manner to form stable benches. The bench height shall match to the rock excavator for easy mucking and maneuver.

#### 6.1.3 Blasthole Diameter

The suitability of the hole diameter is evaluated based on the compatibility to the bench height. The hole diameter is also decided on the minimum length of the charge in a blasthole, blast vibration constraints, rock structure and minimum cost of production. The minimum length of bottom charge in a blast hole should be at least 20 times the charge diameter to yield good results. Depending on the site conditions and the need for controlling flyrock, ground vibrations etc., the hole diameter up to 45 mm can in area close to ESZ and upto 105 mm in sites at least 500 m away be used. However, the permissible maximum charge per delay needs to be complied with and control the vibrations/air overpressure and flyrock within safe limits.

### 6.1.4 Burden and Spacing

Burden (B) is defined as the distance from the blast hole to the nearest free face at the time of detonation. It is conventionally measured in the direction parallel to the free face. Burden with regard to delay pattern is called effective burden or true burden. Spacing (S) is defined as the distance between adjacent holes measured perpendicular to burden. The burden is the most important parameter and its assessment is made in the light of available literature.

Various burden formulae are available in the literature and all are of empirical nature. Rustan (1990) has shown that the formula developed by Langefors and Kihlstom (1963) is only valid for hole diameters in the range of 30-89 mm. Pearson formula (Gregory, 1984) is not easy to use as the input data such as maximum tensile strength of rock and maximum detonation pressure are not readily available. Burden can be calculated taking into account the hole diameter, the bench height, density of explosive, density of rock, bucket capacity of the loading machine and mean joint spacing.

Burden generally varies from 0.25 to 0.5 times bench height. Burden also varies from 20 to 35 times the hole diameter. For the hole diameter of 45 mm proposed near ESZ, the burden value range is 2.0 – 2.5 m. For higher diameter of hole up to 105 mm, burden of 2.5 to 3.2 m may also be used.

Spacing is calculated as a function of the burden. In most of the blasting operations, spacing to burden ratio has been found to vary between one and two.

Spacing is initially calculated as 1.2 times the burden. For any other spacing to burden ratio, burden and spacing can be adjusted provided the area (B x S) remains constant. A pattern of 3x5m is equivalent to a pattern 3.4x4.4m. Greater spacing to burden ratio is preferred for row by row initiation system. For diagonal or V pattern, S/B ratio will be between 1.0 and 1.4.

### 6.1.5 Charge Factor

Charge factor is the mathematical relationship between the weight of explosives and a given quantity of rock. It is normally expressed in kilograms per cubic meter. Since explosives vary in their energy content and the energy released on detonation, the charge factor is not a constant figure even for the same rock. Further, Konya and Walter (1990) have shown that the same amount of explosives can break different volumes of rock depending upon the orientation of holes with respect to the free face.

The charge factor is used basically to estimate the quantity of explosives in the hole or to plan for the explosive requirements. If soft rock is some what undercharged, it will still be muckable and if it is somewhat overcharged, excessive throw rarely occurs. On the other hand, undercharging of hard rock frequently results in a tight and blocky muckpile. Overcharging of hard rock may cause flyrock and airblast. The design of blasts in hard rock requires tighter control than in soft rock (Olofsson, 1991).

### 6.1.6 Blasthole Pattern and Initiation Sequence

Blast hole pattern could be square, rectangle or staggered. Each pattern has got its own place of application and needs to be initiated in a defined sequence depending on the end results. Row by row initiation with staggered pattern gives good results in blast casting and this is rarely used for conventional production blasting. Drilling errors are more in case of staggered patterns as compared to others. For a set of blast holes, several initiation sequences are possible. The initiation sequence significantly affects the blast results in respect of direction of throw, fragmentation and damage to the rock mass. Hagan (1983) suggests that the initiation sequence for multi-row blasts should be such that (a) each charge shoots to a free face (b) effective spacing to burden ratio is as per the design (c) blasthole are effectively staggered. In order to satisfy these requirements he recommends staggered V pattern (Figure 10). To avoid blowouts in the back rows, one delay period is generally skipped.

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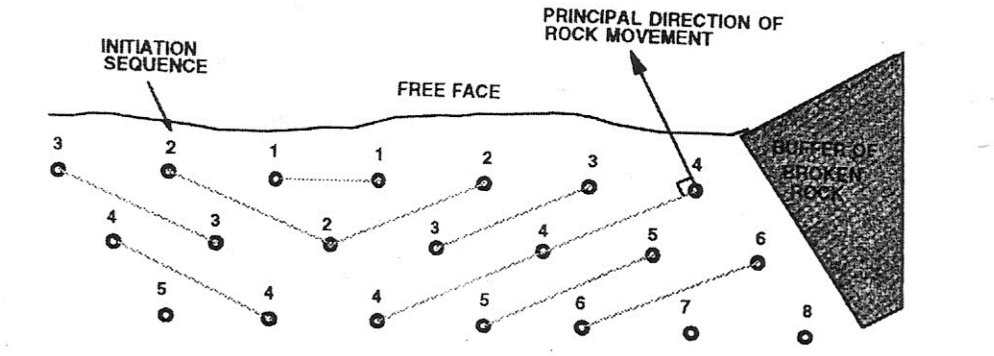


Figure 10: Staggered V pattern when blasting along side a buffered end

Figure 11 shows a diagonal sequence for a staggered pattern. Figure 12 shows the traditional V cut, but instead of blasting a rectangular block, a trapezoidal area is prepared in order to eliminate the problem of heavy confinement on the longest delay. If this pattern is employed, a comer cut as shown in the Figure 13 can be followed to further develop the bench. The last row of holes in this sequence breaks at obtuse angle in the comer, thereby causing less wall damage and a lower probability of blowout. Figures 14 and 15 show rectangular pattern initiated with a V cut or diagonal pattern depending on the block orientation and the general face conditions

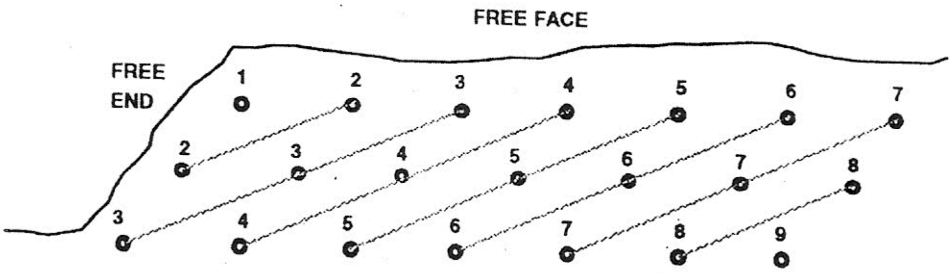


Figure 11: Staggered diagonal pattern shooting to a free face

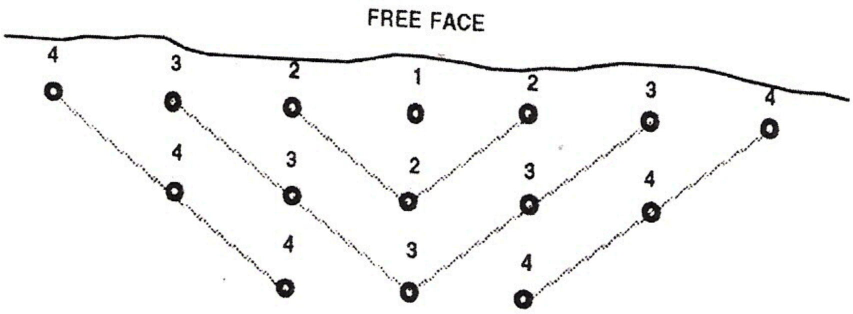


Figure 12 V cut (angle corner) progressive delay

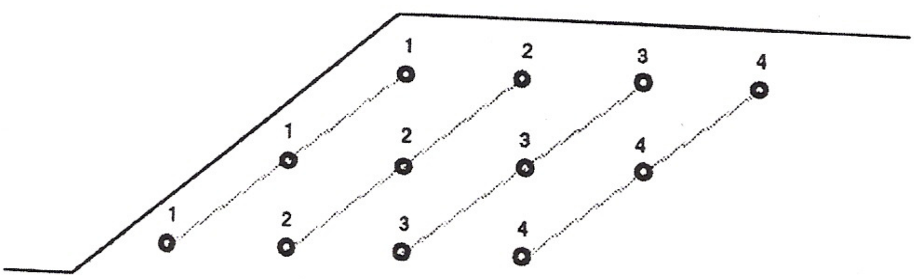

Figure 13: Angled corner cut fired on echelon pattern

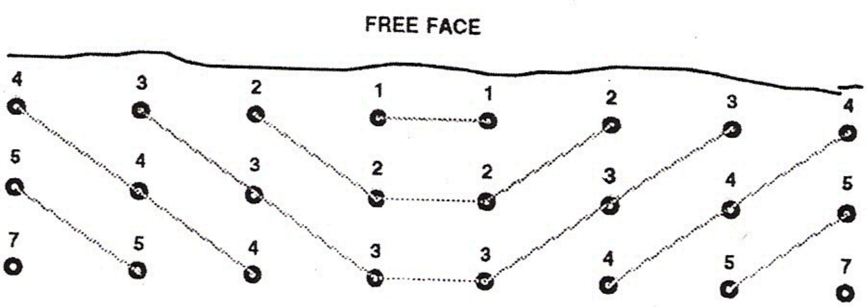


Figure 6: V cut for a rectangular pattern

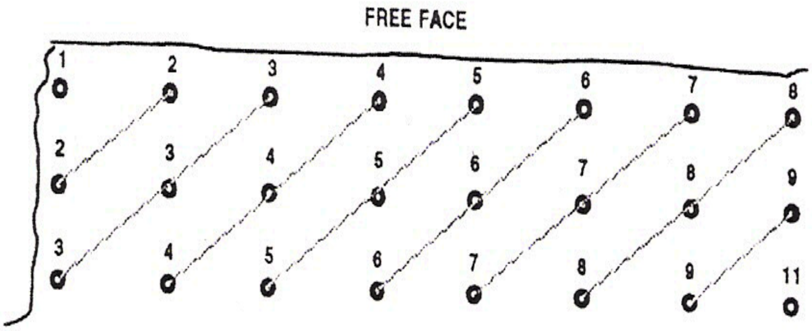


Figure 14: Diagonal sequence for a rectangular pattern

### 6.1.7 Delay Timing

For multi-row blasting, the rock must be allowed to move 1/3$^{rd}$ of the burden distance before the next row detonates. The delay intervals between the rows may vary from 10ms/m of the burden for hard rock to 30ms/m of burden for soft rock (Olofsson, 1991). An optimum inter-row delay gives good fragmentation and displacement without cut-off. Improper delay gives rise to problem of flyrock, vibration, toe and back break. For large diameter blast holes, the optimum inter-row delay usually varies from about 5ms/m of effective burden for strong massive rocks to about 10ms/m for weak/highly fissured strata (Hagan, 1983). In addition to burden and rock type Konya and Walter (1990) have suggested delay timing depending on the desired end results based on their priority. The best possible fragmentation can be achieved with delay timing of 10 - 20ms/m of burden.

### 6.1.8 Stemming

Stemming is an inert material filled on top of the explosive charge in a blast hole. It is essential to enhance the explosive efficiency and reduce the environmental problems related to blasting. If the stemming is inadequate, the explosive gases will vent prematurely reducing blast hole pressure and resulting in poor displacement and tight muckpile. It is also accompanied by flyrock torn from the collar region plus air blast. Often there is a further perceptible waste of energy in the form of flame indicating that the explosive reaction is incomplete at the time of venting. Stemming length varies from 0.7 to 1.5 times burden depending on the rock being blasted and the concern for fragmentation and flyrock problems (Table 5).

**Table 5: Suggested stemming length for surface blasting**

| Case | Rock being blasted | Flyrock problem | Stemming length, m |
|---|---|---|---|
| 1 | Hard | Yes | 1.0 – 1.3 times |
| 2 | Hard | No | 0.7 – 1.0 time burden |
| 3 | Soft | Yes | 1.0 – 1.3 time burden |
| 4 | Soft | No | 0.7 – 1.0 time burden |

There are several kinds of material that have been used for stemming. Water, mud, soil, wet clay and drilling dust are easily ejected. On the other hand, dry angular material under the effect of impulse gas pressure tends to form a compaction arch, which locks into the wall of a blasthole, thus increasing its resistance to ejection. Stemming materials can be ranked in this order from the least efficient to most efficient; air, water, wet drill cuttings, wet sand, paper cartridge of rock dust, clay dummies, wet crushed stone, dry drill cuttings, dry sand, dry crusher run stone, dry screened stone (Lippincott, 1992).

In water filled holes, gravel and crushed rock quickly settle to form a plug of stemming, not as effective as that in a dry hole but still effective. The behavior of drill cuttings can be quite different. The drill cuttings are converted to a sludge, which has little to offer, other than its own mass, in opposing explosion gas pressure.

In general, drill cuttings are preferred, as they are readily available and conveniently located at the collar of the hole, whereas other material is to be brought to the site. The optimum size of stemming material is about 5 - 25mm depending on the blast hole diameter. For a diameter of 102/115mm, 5 - 10mm crushed stone is recommended (Konya and Walter., 1990, Anon., 1993).

### 6.2 Noise and Air overpressure Control Measures

Noise and air overpressure control measure such as use of explosive and initiating system such as Shock Tube Initiating system (NONEL), Twin-Det/ Dual Det system for making circuitry arrangement in a blast rounds will only be used.

No conventional initiating devices such as detonating fuse will be used. Shock tube initiating systems  produces significant less air overpressure/Noise as compared to conventional Detonating fuse. AOP and Noise level will be maintained as per recommended safe permissible limit of CPCB/DGMS etc.

**6.3 Restricted Timing of Blasting Operation**

Blasting operation shall be conducted only in day time, preferably in afternoon so that due to phenomenon of temperature inversion, all the air overpressure wave/Noise wave are refracted to open sky rather than reflected back to the ground surface level and travelling to longer distance. In morning and evening hours, due to higher density of air near ground surface level, more amount of the air overpressure wave tend to travel longer distance and hence may be given rise to higher level of air overpressure and noise level. No surface blasting operation shall be conducted beyond sunset and sunrise. Air overpressure/ Noise due to Air pressure pulse and rock pressure pulse will be controlled using the blast design parameters such as No. of Holes, Hole Depth, bench height etc.

**6.4 Dust Control Measures**

During drilling operation only wet drilling shall be carried out so that no dust is produced. In blasting operation and breakage of the rock mass, dust is invariably produced. However, with muffle blasting i.e. covering the blast round with blasting mats reduced the dust generation to more than 90%. Blasting mats are used in blasting operations to contain the blast, prevent flyrock (rock fragments ejected during blasting), and reduce noise and vibrations. They help protect nearby structures, people, and the environment from potential damage and harm.

Figure 15: Photographs of blasting operation with blasting operation with blast mats

## 6.5 Flyrock Control Measures

As discussed in preceding section of this report a comprehensive flyrock control measure will be adopted while carrying out the blasting operation which included, designing the controlled blast design parameters as per the prevailing rock mass, use of blasting mats, charging holes after identifying the weak zone in the strata , adequate stemming length and stemming materials. In area close to ESZ, a provision of the barricade is also recommended. It will not only prevent any flyrcok crossing the construction but will also be helpful in reducing noise/ air overpressure level.

## 6.6 **CSIR-CIMFR Supervision of the Blasting Operation**

JSW Energy PSP two Limited have requested CSIR-Central Institute of Mining and Fuel Research for technical support and guidance during construction of Bhavali PSP project considering not only its proximity with ESZ of Kalsubai Harishchandragad Wildlife Sanctuary but also to prevent rock mass damage to the surrounding structures during construction of various components of the project. CSIR-CIMFR Team have accepted the same and agreed to supervise and guide the team for all day to day to blasting operation by deputing the technical staff with necessary equipment at site.

## 6.7 Continuous monitoring of vibration and air overpressure/ noise level

All day to day controlled blasting operation will be carried out under supervision of expert team of CSIR-CIMFR who will be stationed at site. The team will guide execution team and follow the optimised blast design pattern. During blasting operations, blast induced ground vibration and AOP/Noise level will be monitored in all sensitive location such as closest ESZ points using advance tri-axial seismographs. Multiple seismographs will be used to monitor the parameters at different locations simultaneously.

## 6.8 Documentation of Blasting parameters

CSIR-CIMFR team will develop a system of documentation for each round of the blasting operations. Records of the blast induced ground vibration and air overpressure/ Noise will be also maintained meticulously and same may be submitted to the regulatory agencies, if required.

# 7.0 CONCLUSION AND RECOMMENDATIONS

JSW Enegry PSP 2 Limited requested to CSIR-Central Institute of Mining and Fuel Research for technical support and guidance for carrying out control blast design operation during construction of Bhavali PSP with special emphasis to prevent any adverse impact of blasting operation to flora and fauna of Kalsubai Harishchandragad Wildlife Sanctuary. Team of Scientists and staff members of CSIR-CIMFR Team conducted preliminary field investigation to assess the possible impact of blasting operations and evaluated the required mitigation measures.

CSIR-CIMFR team suggested a series of mitigation measures to prevent the adverse impact on flora and fauna of Kalsubai Harishchandragad Wildlife Sanctuary, man-made structures and surrounding environment.

Based on the input on rock mass obtained from the geotechnical investigation report, Controlled blast design parameters are suggested to ensure that ground vibration level remains well within the safe permitted limit as per prevailing Indian Standard. These parameters will be further calibrated and optimised during construction of the project as per data obtained through real time measurement using advance seismographs. Mitigation measure for control of Air overpressure/ Noise/ Dust and flyrock is given in this preliminary report.

CSIR-CIMFR Team also agreed to provide continuous technical support during construction phase of Bhavali PSP by deputing project staff with necessary equipment such as blast induced ground vibration and AOP/Noise monitoring system. Entire blasting operation will be supervised by the CSIR-CIMFR team. A system of documentation will be developed and meticulous record of each blasting round together with the vibration and AOP observed from each blast rounds will be kept for future review also

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# NOTE