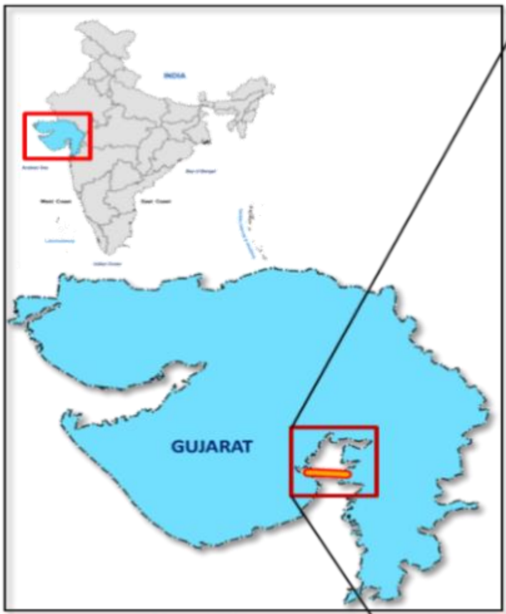

Survey Line ID	Survey Points	Description	Coordinates	
			Longitude	Latitude
L3	A.	Intersection of L-3 on Bhavnagar side cable stayed bridge, Start point	72° 9'2.02"E	21°48'25.22"N
	B.	Intersection of L-3 on gulf side Bhavnagar.	72°15'28.91"E	21°48'25.60"N
	C.	Intersection of L-3 on gulf side Dahej.	72°30'58.03"E	21°48'26.00"N
	D.	Intersection of L-3 on intertidal Dahej side paniyadra, End Point	72°38'51.17"E	21°48'25.71"N

Instrumentation Report

For

Kalpasar Dam Project

Contents

List of Tables

1 INTRODUCTION

The Saurashtra region of Gujarat has been experiencing severe droughts for few decades due to reduction in the groundwater table and scarcity of freshwater. To meet the freshwater demand for drinking and irrigation, the Government of Gujarat (GoG) proposes an ambitious project, called Kalpasar Dam Project, which involves constructing a ~51 km long dam across the Gulf of Khambhat and create a freshwater reservoir by storing the run-off of 10,000 million cubic meter of water from east-flowing rivers, namely Sabarmati, Mahi, Dhadhar and Narmada rivers on the upstream of the dam.

The project location is influenced by a higher tidal range (~9m) and currents (velocities ~3 m/s) at the head of the Gulf. It involves constructing a ~51 km earth dam across the Gulf of Khambhat to create a massive freshwater coastal reservoir for irrigation, drinking and industrial purposes, with about 2.3 km concrete spillway for emptying saltwater or flood water. A 10-lane road along with 2-lane permanent way for rail transport was planned to be built over the dam; this will reduce the travel distance from 350 km around the Gulf to 50 km across the Gulf. Also, the project involves flood protection in the upstream area, supply of freshwater to the Saurashtra region and renewable energy for the Lift irrigation system. The project site is located in the Moderate Seismic Zone and about 700 km to the west of the Gulf from the Makran fault.

Kalpasar dam includes a 51 km long Earthen Embankment/ Rock Fill Dam, which consist of an Embankment of 10.9 km on the Bhavnagar side, 13.4 km on Dahej side and 26.2 km in deep Gulf region (Figure 1). This document provides the requirement for instrumentation for Kalpasar Project.

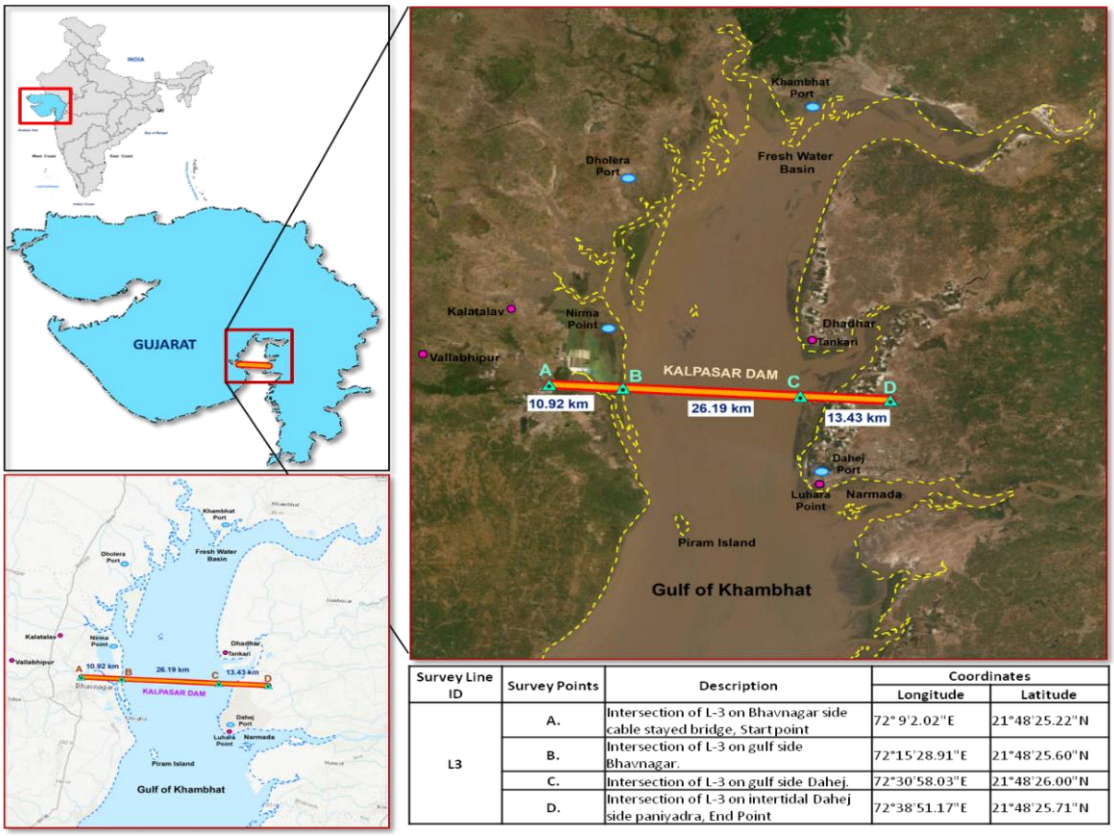

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Figure 1: Proposed Alignment of Kalpasar Dam

1.1 Description of the Project Environment (NCCR)

The proposed Kalpasar Dam is broadly segmented into five different sections as Earth cum rock dam, Spillway and approach structure, Reservoir side, sea side and water outtake as given in figure 1 for the instrumentation monitoring and measurement purposes. This section was segmented based on the structural design configuration and the water environment. The dam reservoir has a water spread area of about 2,000 sq. km. The different suitable instruments were proposed to deploy and measure the geotechnical, structural, hydrological, meteorological and oceanographic parameters using real-time monitoring through data acquisition system(DAS).

The earth cum rock dam section on seas side is designed as breakwater consists of Armor layer (primary layer), secondary, Core and toe berm. The armour layer of rubble mound consists of concrete accropode units to protect the structure from wave attack on sea side. The under layer and core layer consist of stones and a toe berm is provided on the sea side, to protect structure from scouring. The sand fill embankment on the reservoir side is protected by providing the rock toe protection.

The Spillway and approach structure is proposed in two locations nearer to the possible coast line in the intertidal zone and the other towards East, where ground levels are relatively higher and flatter. The construction of dam at this location would be very easy and similar to land construction. The spillway and gates would also be subjected to lower wave conditions considering the location of spillway. However, this will require larger lengths of approach channel and tail channel.

The primary purpose of the instrumentation is to measure and monitor the performance of the structure and the ecosystem to mitigate any risks or impacts through effective monitoring using the sophisticated instruments.

1.2 Objectives of Measurements (NCCR)

The objectives of the instrumentation of the dam is to measure parameters related to the performance of the spillway and the earthen & rockfill dam. The measurements carried out will aid in monitoring the performance of the components and help detect any distress on the structure. The monitoring will help aid in providing any remedial measures that maybe implemented to mitigate the distress. This plays a huge role in monitoring the safety of large projects.

Adequate instrumentation for monitoring also helps in understanding the behavior of the structure while under construction, and during its service life. The analysis of the data collected is very crucial in operational, safety, and verification and validation of analysis results used in initial design. Symptoms of dam distress can be detected by effective monitoring scheme designed with the right instrumentation. Instrumentation consists of the various electrical and mechanical devices used to measure pressure, water flow, movement, stress, strain, and temperature at a dam and its appurtenant structures.

Instrumentation and monitoring of dam bodies serves two purposes, namely (a) assessment of dam safety, and (b) improvement of design procedures and practice. Various considerations regarding physical properties, loading and boundary conditions are adopted during the design phase. These considerations need to be validated and verified to be reasonably accurate for the actual structure. The interpretation of the results obtained from the monitoring of the actual structure can then be used to evaluate their validity. This also facilitate in fine-tuning the analytical simulations and improve design procedures based on the monitoring data.

With large, one-of-a-kind projects like Kalpasar, it is imperative that the behavior of the structure be monitored for the overall safety of the project, as well as to help extend the knowledge for similar future endeavors.

1.3 Types of Measurements (MNIT)

Monitoring instruments are of four basic types, namely, (a) *mechanical*, (b) *hydraulic*, (c) *pneumatic* (d) *electrical* and e) *Optical Fibres*

Mechanical, pneumatic, and hydraulic type instruments are simple, rugged, reliable, low cost, and easy to operate. But these have lower response and lower accuracy. Mechanical type instruments cannot be or need additional arrangements for remote reading. Pneumatic and hydraulic type instruments can be read remotely. But these need adequate protection of the have connecting tubes against blocking and breaking.

Electrical type instruments include two types (a) *unbonded resistance* and (b) *vibrating wire*. Electrical type instruments facilitate easy remote reading, use of data logger and computers. They also have high sensitivity, resolutions, and accuracy.The unbonded resistance wire type and vibrating wire type of instruments have long term stability and are in use extensively.

Optic Fibres…

1.4 Selection of Instruments (NCCR)

There is no simple rule which can determine the number of monitoring instruments, their exact type, and location. Their determination remaining primarily a matter of experienced judgement. The number of devices installed in a dam is less important than the selection of proper types of instruments, their location and intelligent interpretation of the data. However, care should be used to maximize the observations with minimal number of instruments. The quality of instruments should be of paramount importance since these are expected to work for very long periods, say 25 - 30 years. In a selection of monitoring instruments, service requirements must be carefully weighed; an instrument with robustness that gives reasonably accurate results may be preferable to a more precise but delicate instrument. The robustness aspect is considered both from the durability of instrument, adaptability to saline/ marine environment and the aggressive loading coming from the environment. The consideration of accessibility and maintenance also plays a major role as the instruments may have to be replaced or repaired occasionally or maintained periodically.

Once the measurements required to be made in any project are known, it becomes necessary to identify the type of instruments and their locations in the structure, where the measurements are critical and would be required to be monitored. Each structure is unique and one must evaluate and decide which types of instruments are essential or desirable and where to install them in a particular structure.

While making choice for instrumentation scheme following factors need to be essentially considered:

a. The instruments should be simple having minimum moving parts
b. These should be reliable, robust, accurate, low overall cost and simple to read
c. Easy installation and ideal for underground works requiring no maintenance as these are not accessible once installed
d. Can measure negative pressure and have very small-time lag
e. The data obtained should be meaningful and in a form in which it can be easily interpreted
f. Capable of transmission of signals as a frequency over long cable length
g. Almost all of its components have to deal with saline & fresh water and therefore, while selecting and/or procuring the instruments and related components and fittings shall have to be worthy of being operated in marine environments
h. In the present times the electric type instruments based on the vibrating wire type principle suitable for marine conditions and saline water do meet all the above said requirements
i. The equipment should also be easily replaceable.

2 EARTH CUM ROCK DAM

The parameters that are to be observed are as follows:

2.1 Pore Pressure (IITM)

Water *level* and water *pressure* at a point in the dam is directly related by the height of water above the point. Thus, measurements or water *pressure* can be readily converted to water *level* and vice-versa. The headwater, tail-water, and varying pressure across the dam section produce differential head that must be properly accounted for.

Monitoring of pore pressure can be used to quantify the effectiveness of internal formed drains and water pathways within the body of the dam. Any sudden increase in pore pressure indicates chocking of these pathways, and sudden decrease in pore pressure is indicative of formation of cracks and/or disruption of the pathways. The monitoring of pore pressure during construction would enable appropriate remedial measures if high construction pore pressure develops. After steady seepage condition is established, the measurement of pressure that develops in the embankment, when the water levels are full, enables to assess the efficacy of seepage prevention and disposal measures. In some situations, effects of sudden drawdown may also become critical for water side slope stability and may require monitoring. The device for measuring pore pressure could be *hydraulic*, *pneumatic,* or *electrical* type. The electrical pore pressure cell (Piezometer) is either of (a) unbonded resistance wire type, or (b) vibrating wire type.

Name of Sensor	
Parameter Measured	
Type of Sensor	
Location of Placement	
Number of Instruments	
Range (Max. and Min.)	
Resolution (Least Count)	
Sensitivity	
Specification	
Frequency of collection	
Indian Standards	

2.2 Vibrations (MNIT)

As per recommendations of IS 4967, a seismological observatory for the entire project is to be established at the project site for evaluation of seismic parameters for large dams. The location of observatory should be so selected that the firm rock or suitable ground is available for founding the instrument pillars. The observatory is to be located at site which is unaffected by vibrations caused by powerhouse operations, etc.

Strong motion accelerographs and structural response recorders are to be installed at the base of the dam (in a recess provided in the foundation gallery and at the top of the dam. The location may be suitably selected to avoid the background seismic noise created due to the vibration originating from the appurtenant works of the dam. The instruments located in the foundation gallery are meant for observing the input ground motion in the event of major earthquake. The instruments located at the top of the dam are expected to provide information about response of the structure to the earthquake.

2.2.1 Ambient Vibrations (MNIT)

Ambient vibration tests use the response of the dam under ambient sources of excitation, such as wind, vehicular motion, machinery operating in the vicinity, and flow of water into the reservoir and over the spillways. The level of response due to ambient vibration is small, in general. But it can be captured using sensors having high sensitivity. Also, under normal conditions of the dam and under ambient vibrations, the response of the dam is in the linear elastic range. As the input excitation due to ambient vibration is random in nature, the structure is always in its transient state of response, and hence, vibrates at all its natural frequencies. Further, considering that the ambient excitation has fairly uniform energy distribution over all the frequencies, the fundamental mode will dominate the response, as it requires the least amount of energy for excitation.

Velocity meter for tidal and seismic

Name of Sensor	
Parameter Measured	
Type of Sensor	

Location of Placement	
Number of Instruments	
Range (Max. and Min.)	
Resolution (Least Count)	
Sensitivity	
Specification	
Frequency of collection	
Indian Standards	

2.2.2 Forced Vibrations (MNIT)

Forced vibration test is based on the concept of resonance. When a structure is excited by an external vibratory force (harmonic, random, or impact) at the frequency near its natural frequency, the response of the structure is amplified significantly. The dynamic harmonic force is applied using an eccentric mass shaker on the crest of the dam and the sensors placed on the down the downstream face. The dam is excited at its natural frequencies; the frequency of harmonic excitation can be changed gradually in small steps within the range of the natural frequencies of interest to obtain the frequency sweep response of the dam. At each resonant state corresponding to a natural frequency, the response will indicate a local peak. These frequency response curves can be used to obtain the natural frequency and damping. Also, at each natural frequency, the shape of the deformation of the dam is captured by the relative values of the lateral response of the dam recorded by the sensors on the downstream face of the dam. In this manner, the dynamic characteristics of the dam are obtained.

Accelerometer for traffic and performance evaluation

Name of Sensor	
Parameter Measured	
Type of Sensor	
Location of Placement	
Number of Instruments	
Range (Max. and Min.)	
Resolution (Least Count)	
Sensitivity	

Specification	
Frequency of collection	
Indian Standards	

2.2.3 Seismic Vibrations (MNIT, NGRI)

Seismic instruments have to be installed prior to construction to record tremors including micro-tremors in and around the project area and in the embankments to measure the effects of seismic events that occur subsequent to the construction. Data thus collected would also help to take a view on the question of induced seismicity in the area. The seismic instruments provide seismic data such as acceleration, velocity and displacement.

As per recommendations of IS 4967, a seismological observatory for the entire project is to be established at the project site for evaluation of seismic parameters for large dams. The location of observatory should be so selected that the firm rock or suitable ground is available for founding the instrument pillars. The observatory is to be located at site which is unaffected by vibrations caused by powerhouse operations, etc.

2.2.3.1 Accelerations

Strong motion accelerographs and structural response recorders are to be installed at the base of the dam (in a recess provided in the foundation gallery and at the top of the dam. The location may be suitably selected to avoid the background seismic noise created due to the vibration originating from the appurtenant works of the dam. The instruments located in the foundation gallery are meant for observing the input ground motion in the event of major earthquake. The instruments located at the top of the dam are expected to provide information about response of the structure to the earthquake.

Name of Sensor	
Parameter Measured	
Type of Sensor	
Location of Placement	
Number of Instruments	

Range (Max. and Min.)	
Resolution (Least Count)	
Sensitivity	
Specification	
Frequency of collection	
Indian Standards	

2.2.3.2 Velocity

Seismic velocity is the speed with which an elastic wave propagates through a medium. For non-dispersive body waves, the seismic velocity is equal to both the phase and group velocities; for dispersive surface waves, the seismic velocity is usually taken to be the phase velocity. Seismic velocity is assumed usually to increase with increasing depth and when measured in a vertical direction it may be 10–15% lower than when measured parallel to strata.

Name of Sensor	
Parameter Measured	
Type of Sensor	
Location of Placement	
Number of Instruments	
Range (Max. and Min.)	
Resolution (Least Count)	
Sensitivity	
Specification	
Frequency of collection	
Indian Standards	

2.2.3.3 Displacement

Seismic displacements have a horizontal and a vertical component. The horizontal component is often clearly visible along fault lines activated by the earthquake, though more or less regular horizontal deformation may extend along the surface of nearby crustal blocks. In coastal areas, the vertical component is easily measurable and most important from a geodetic point of view, because it changes the relation to sea level.

Name of Sensor	
Parameter Measured	
Type of Sensor	
Location of Placement	
Number of Instruments	
Range (Max. and Min.)	
Resolution (Least Count)	
Sensitivity	
Specification	
Frequency of collection	
Indian Standards	

2.3 Settlement (IITM)

Based on the geometry and relative compressibility, embankments may be subject to deformations parallel or transverse to the axis of the structure and may be in vertical and/or horizontal plane or in any intermediate direction. These deformations may be internal or on the surface of the embankment. Measuring horizontal, vertical, and transverse settlements both inside and on the embankment surface to understand how the embankment-foundation system is behaving is necessary. Unexpected movement or displacement is very good indicators of distress conditions prior to jeopardizing the safety of the dam. The movement may be sub-divided into (a) foundation movement, (b) Surface settlement (Horizontal & Vertical).

2.3.1 Foundation Settlement (IITM)

Foundation displacement can either be *vertical* and/or *horizontal*. Movement of the foundation is a very critical indicator of the structural performance of the dam. Any excessive or unexpected movement should be carefully investigated to preclude any impact on the safety of the dam. The monitoring data can also be used for studying the elastic and in elastic properties of dam and foundation.

Ideally the instruments should be located as close as possible to the founding level, generally, these are placed in the foundation gallery of the dam. The extensometers should be installed near the founding level at a spacing of 20 m, along each transverse section, which is spaced at 1 km along the length of the dam.

Name of Sensor	
Parameter Measured	
Type of Sensor	
Location of Placement	
Number of Instruments	
Range (Max. and Min.)	
Resolution (Least Count)	
Sensitivity	
Specification	
Frequency of collection	
Indian Standards	

2.3.2 Surface Settlement (Horizontal & Vertical) (IITM)

Measurement of relative displacement of two parts of the dam observed for the first few years reveal critical information about the adequacy of the structural performance of the dam, with respect to the design considerations. The relative movement of the parts of the dam, with other supporting data may be used to study the elastic behaviour of the dam, and to validate the design considerations. Any unexpected movement should be carefully investigated to preclude issue with the safety of the dam.

These observations can be made using permanent *prism targets* installed at 1 km spacing along the length of the dam. Additional prism target may also be installed on natural ground at the two ends of the dam. The positions of the prism targets can then be monitored using geodetic observations using a total station. It may also be possible to monitor the locations of these target using GPS.

The prism target may be located at 1 km spacing along the length of the dam.

Name of Sensor	

Parameter Measured	
Type of Sensor	
Location of Placement	
Number of Instruments	
Range (Max. and Min.)	
Resolution (Least Count)	
Sensitivity	
Specification	
Frequency of collection	
Indian Standards	

3 SPILLWAY AND APPROACH STRUCTURES

3.1 Pore Pressure and Uplift Pressure(IITM)

The effect of uplift on a dam is to *reduce* its *effective weight* due to the *upward water pressure*. The value of uplift pressure is indicative of *operating reservoir head*, *effectiveness of grout curtain* close to U/s face, and *effectiveness of drainage curtain* provided in foundation. It is important to determine the magnitude of uplift pressure at the base of the dam. Uplift pressure beneath the dam structures is generally varying linearly from headwater to tail-water or D/s ground surface – the presence of grout curtain near the U/s face can change this linear variation. If foundation drains exist and are adequately maintained, the uplift pressure is usually reduced at the line of drains in accordance with the effectiveness of the drainage system.

The measurement of uplift pressure is of paramount importance for monitoring the structural behavior of a dam. It is required to determine the actual uplift pressures occurring below the barrage floor at different points especially just downstream of the gate seals and below the end of the pucca floor and to locate the zones where pressure is exceeding the safe balancing weight of the structure. It is also used to monitor piping phenomenon if occurring anywhere below the floor area. It helps ensure that the hydraulic gradient of the subject-soil seepage flow is safe towards the end of the floor, so as not to exceed the safe exit gradient at the tail end of the dam and to compare the theoretically computed uplift pressures with those actually observed.

The device for measuring uplift consists of pipes, fitted with a T-section and a Bourdon type pressure gauge for observing water pressure, installed at the point where uplift pressure is to be measured, that is, typically at the foundation gallery, such that it terminates in a gallery directly above the measuring point which is generally 1 m below the base of a dam. Uplift pressure cells based on *vibrating wire* or *unbonded resistance wire* principle are to be used for remote monitoring.

Name of Sensor	
Parameter Measured	
Type of Sensor	
Location of Placement	
Number of Instruments	
Range (Max. and Min.)	
Resolution (Least Count)	
Sensitivity	
Specification	
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Indian Standards	

3.2 Vibrations (MNIT)

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3.2.1 Ambient vibrations (MNIT)

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Velocity meter for tidal and seismic

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Range (Max. and Min.)	
Resolution (Least Count)	
Sensitivity	
Specification	
Frequency of collection	
Indian Standards	

3.2.1.1 Traffic vibration (MNIT)

The traffic induced vibrations on dam strength and concrete compressive strength effects to be studied for full-depth to measure the structural performance. The traffic induced vibrations are not detrimental to the quality of repair concrete when low slump concrete is used and the reinforcing bars are securely fastened to the structure before the concrete placement.

Name of Sensor	
Parameter Measured	
Type of Sensor	
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Indian Standards	

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Accelerometer for traffic and performance evaluation

Name of Sensor	

Parameter Measured	
Type of Sensor	
Location of Placement	
Number of Instruments	
Range (Max. and Min.)	
Resolution (Least Count)	
Sensitivity	
Specification	
Frequency of collection	
Indian Standards	

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Seismic instruments have to be installed prior to construction to record tremors including micro-tremors in and around the project area and in the embankments to measure the effects of seismic events that occur subsequent to the construction. Data thus collected would also help to take a view on the question of induced seismicity in the area. The seismic instruments provide seismic data such as acceleration, velocity and displacement.

As per recommendations of IS 4967, a seismological observatory for the entire project is to be established at the project site for evaluation of seismic parameters for large dams. The location of observatory should be so selected that the firm rock or suitable ground is available for founding the instrument pillars. The observatory is to be located at site which is unaffected by vibrations caused by powerhouse operations, etc.

3.2.3.1 Accelerations

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Name of Sensor	
Parameter Measured	
Type of Sensor	
Location of Placement	
Number of Instruments	
Range (Max. and Min.)	
Resolution (Least Count)	
Sensitivity	
Specification	
Frequency of collection	
Indian Standards	

3.2.3.2 Velocity

Seismic velocity is the speed with which an elastic wave propagates through a medium. For non-dispersive body waves, the seismic velocity is equal to both the phase and group velocities; for dispersive surface waves, the seismic velocity is usually taken to be the phase velocity. Seismic velocity is assumed usually to increase with increasing depth and when measured in a vertical direction it may be 10–15% lower than when measured parallel to strata.

Name of Sensor	
Parameter Measured	
Type of Sensor	
Location of Placement	
Number of Instruments	
Range (Max. and Min.)	
Resolution (Least Count)	
Sensitivity	
Specification	
Frequency of collection	
Indian Standards	

3.2.3.3 Displacement

Seismic displacements have a horizontal and a vertical component. The horizontal component is often clearly visible along fault lines activated by the earthquake, though more or less regular horizontal deformation may extend along the surface of nearby crustal blocks. In coastal areas, the vertical component is easily measurable and most important from a geodetic point of view, because it changes the relation to sea level.

Name of Sensor	
Parameter Measured	
Type of Sensor	
Location of Placement	
Number of Instruments	
Range (Max. and Min.)	
Resolution (Least Count)	
Sensitivity	
Specification	
Frequency of collection	
Indian Standards	

3.3 Movements (MNIT)

The abutment blocks, divide walls, wing walls are tall and isolated structures that may undergo tilt particularly in seismic regions or where deep scour and differential pressures are expected on these structures. Instruments like plumb lines or inclinometers or a set of them can be installed for monitoring the tilts. The deflection of the barrage components is the only single parameter affected by all the loads on the barrage foundation system and therefore, is an important aspect that would give a significant measure of deflections.

3.3.1 Internal Joint Movement (MNIT)

Dams are generally built in blocks separated by transverse joints. It is essential to monitor any relative movement between the blocks. The movement is likely to be due to differential foundation behaviour. The devices for monitoring joint movement are (a) unbonded resistance wire type, and (b) vibrating wire type. Joint movement meters should be provided in between all blocks. The rigidity/flexibility of the block should be the deciding factor for the spacing along the joint; this will require inputs from the structural designer of the dam.

Name of Sensor	
Parameter Measured	
Type of Sensor	
Location of Placement	
Number of Instruments	
Range (Max. and Min.)	
Resolution (Least Count)	
Sensitivity	
Specification	
Frequency of collection	
Indian Standards	

3.3.2 Surface Joint Movement (MNIT)

Surface joint movement are monitored either on the surface or at locations accessible from galleries. The measurements are made by calibrated tapes by fixing two reference points one each side of the joint and by accurately measuring the distance between the two points at desired intervals. Measurement of joint movement at the *surfaces* which are accessible from galleries and/or exterior surface of the dam may be monitored by using *detachable gauges*. Portable *gauges with dial indicators* and *crack meters* are most common mechanical gauges for measurement of surface movements. 1D, 2D and 3D measurements are possible.

These devices should be located across the known joints. The surface joint measurements are also taken where surface cracks are noticed.

Name of Sensor	
Parameter Measured	
Type of Sensor	

Location of Placement	
Number of Instruments	
Range (Max. and Min.)	
Resolution (Least Count)	
Sensitivity	
Specification	
Frequency of collection	
Indian Standards	

3.3.3 Relative Movement between Parts of Dam (MNIT)

Measurement of relative displacement of two parts of the dam observed for the first few years reveal critical information about the adequacy of the structural performance of the dam, with respect to the design considerations. The relative movement of the parts of the dam, with other supporting data may be used to study the elastic behaviour of the dam, and to validate the design considerations. Any unexpected movement should be carefully investigated to preclude issue with the safety of the dam.

These observations can be made using permanent *prism targets* installed at 1 km spacing along the length of the dam. Additional prism target may also be installed on natural ground at the two ends of the dam. The positions of the prism targets can then be monitored using geodetic observations using a total station. It may also be possible to monitor the locations of these target using GPS.

The prism target may be located at 1 km spacing along the length of the dam.

Name of Sensor	
Parameter Measured	
Type of Sensor	
Location of Placement	
Number of Instruments	
Range (Max. and Min.)	
Resolution (Least Count)	
Sensitivity	

Specification	
Frequency of collection	
Indian Standards	

3.3.4 Movement of Dam Relative to Surrounding Area (MNIT)

The basis for monitoring the movement of the dam with respect to the surrounding area is identical to that employed in the movement between dam parts. This measurement gives the absolute displacement of the dam with respect to surrounding area.

In the *geodetic method* piers with *prism targets* are constructed at desired locations on the crest and the tail end of the dam. The locations of the prism targets are then monitored for movement with respect to a fixed reference point.

Name of Sensor	
Parameter Measured	
Type of Sensor	
Location of Placement	
Number of Instruments	
Range (Max. and Min.)	
Resolution (Least Count)	
Sensitivity	
Specification	
Frequency of collection	
Indian Standards	

3.3.5 Tilt (MNIT)

Tilt is measurement of rotation in vertical plane. It is normally measured with the help of *tilt meter system* consisting of *tilt meter sensor*, *tilt plates* and *indicator*. Tilt plates are bonded to the surface of mass of structure under observation. The sensor is oriented on three pegs of tilt plate and senses change in tilt of tilt plate. The portable indicator gives the degree of rotation. Tilt measurements are available as *vibrating wire inclinometers*. Vibrating wire type inclinometers are either surface mounted or embedded in the body of dam. A cylindrical core houses a special pendulum surrounded by damping oil. A vibrating wire is stretched between the pendulum and the core. The instrument works on the principle that any change in the position of pendulum will change the tension in the vibrating wire and its frequency of vibration will change. The change in the frequency of vibration of the wire is calibrated with the tilting of the instrument.

The tilt meters may be located at 1 km spacing along the length of the dam.

Name of Sensor	
Parameter Measured	
Type of Sensor	
Location of Placement	
Number of Instruments	
Range (Max. and Min.)	
Resolution (Least Count)	
Sensitivity	
Specification	
Frequency of collection	
Indian Standards	

3.3.6 Strain (MNIT)

The theoretical calculations in the dam structural reinforcement in the concrete are generally done with simplified assumptions. It is, therefore, necessary to know the actual stress and strain developing in the raft at least at the vulnerable locations. This can be done by embedding suitable instruments in the concrete below the piers and middle of the bay. It is also sometimes necessary to know the soil pressure under the barrage floor, piers or abutments particularly when the foundation is soft, weak or when differential settlement is apprehended.

Factors like temperature, chemical action, moisture change and physical loading result in volume changes in the body of the dam, which can be quantified by measuring the strain are specific points. For large structure like dams, the behaviour under the expected service life loads is elastic – portions of the dam body are expected to behave elastically. With this basis, once the *elastic modulus* of the dam material is estimated reasonably, the measurement of strain can be used to estimate the stress.

As the design of structures is based on stress it is essential to measure the stresses developed in the structures during its lifetime. Instruments available for measurement of stresses can measure only compressive stress and not the tensile stress. Further, the stress measuring instruments are more expensive and delicate than strain meters and hence, it is a common practice to measure the strain and to calculate the corresponding stress.

Strain meters are available as (a) surface mounted, and (b) embedded. Surface strain devices are useful for superficial and short-term measurements. Embedded strain devices are useful for long term strain measurements, and for evaluating the structural behaviour. The surface strain gauges consist of a sensitive dial gauge which measures the *linear movement* (strain) between two fixed points. Since linear movement is expected to be very small, the measuring devises are equipped with *mechanical* and/or *optical* amplification mechanisms.

The embedded strain meters are available as (a) *unbonded resistance wire type* and the (b) *vibrating wire type*. Unbonded resistance wire type works on the principle that the *electrical resistance* of the wire *changes* with the *strain*. Vibrating wire type measures strain with respect to the change in the frequency of vibration with applied strain.

Name of Sensor	
Parameter Measured	
Type of Sensor	
Location of Placement	
Number of Instruments	
Range (Max. and Min.)	
Resolution (Least Count)	
Sensitivity	
Specification	
Frequency of collection	
Indian Standards	

3.4 Water **(NCCR)**

The water level at the upstream side of the spillway is at +3m for full reservoir level while during flooding, the maximum Flood level is at +5m, beyond which the water is released.

3.4.1 Level **(NCCR)**

The measurement of water levels on the upstream and downstream of dam is useful for calculating the discharges passing over the dam and for comparing the hydraulic jump behavior observed. Measurement of water levels on the upstream of the barrage beyond the drawdown effect as well as on the downstream beyond the stilling basin need to be measured for correct computations. A measurement of water surface profile on either side on the left and right side be made to assess the hydraulic jump conditions.

Name of Sensor	
Parameter Measured	
Type of Sensor	
Location of Placement	
Number of Instruments	
Range (Max. and Min.)	
Resolution (Least Count)	
Sensitivity	
Specification	
Frequency of collection	
Indian Standards	

3.4.2 Flow **(NCCR)**

The flow is to be considered as a major parameter in the design of dam and spillway. The flow provides the velocity from which other parameters like specific discharge, discharge, etc. can be derived.

3.4.2.1 Spillways (NCCR)

Spillway water flow rapidly varies from the crest till the jump condition is achieved. Two processes simultaneously occur in the flow over the crest, the change in the height of water and instantaneous velocity for the water level.

Name of Sensor	
Parameter Measured	
Type of Sensor	
Location of Placement	
Number of Instruments	
Range (Max. and Min.)	
Resolution (Least Count)	
Sensitivity	
Specification	
Frequency of collection	
Indian Standards	

3.4.2.2 Fish Pass (NCCR)

Fish passages promote and regulate safe fish migration across the dam. The measurement of Flow Parameters i.e. Discharge & Velocity etc. are very important in case of Fish Pass Channel of the Dam so that the fishes can migrate comfortably which helps sustain aquatic life. Hence, it's necessary to monitor and optimize the design based on currents.

Name of Sensor	
Parameter Measured	
Type of Sensor	
Location of Placement	
Number of Instruments	
Range (Max. and Min.)	
Resolution (Least Count)	
Sensitivity	
Specification	
Frequency of collection	
Indian Standards	

3.5 Traffic (L&T)

The assessment of traffic helps in both surveying the predicted growth rate and also help regulate the traffic based on the information obtained. The following parameters are to be determined:

3.5.1 Volume (L&T)

The volume indicates the number of vehicles that commute over the structure, be it the roadways or the railways. This helps determine the growth rate of traffic and validate the assumptions, in turn validating the life of the transportation components.

Name of Sensor	
Parameter Measured	
Type of Sensor	
Location of Placement	
Number of Instruments	
Range (Max. and Min.)	
Resolution (Least Count)	
Sensitivity	
Specification	
Frequency of collection	
Indian Standards	

3.5.2 Loading (L&T)

The pavements and the railway lines are designed based on some permissible loading. That will be the maximum loading that can commute over the corridor. The use of this is two-fold. It helps design the next pavement after the design life and also regulate the traffic, should loads higher than that permissible above the dam passes.

Name of Sensor	
Parameter Measured	
Type of Sensor	
Location of Placement	
Number of Instruments	
Range (Max. and Min.)	

Resolution (Least Count)	
Sensitivity	
Specification	
Frequency of collection	
Indian Standards	

3.5.3 Frequency (L&T)

Understanding the frequency of commuting volume over time will help determine and regulate the traffic better.

Name of Sensor	
Parameter Measured	
Type of Sensor	
Location of Placement	
Number of Instruments	
Range (Max. and Min.)	
Resolution (Least Count)	
Sensitivity	
Specification	
Frequency of collection	
Indian Standards	

4 RESERVOIR SIDE

4.1 Water (NCCR)

The storage of water is one of the main objectives of the dam and therefore, monitoring of the water quality and quantity becomes imperative in the reservoir of the project. The parameters that are to be also considered in the reservoir side, is the inflow of water from the rivers and canal as it is important that no poor quality water is led into the reservoir.

4.1.1 Quality (NCCR)

The water qualities in the dam will changes in seasons and periods due to the longitudinal profile of the river flux also both upstream and downstream of the dam.

The quality of water varies periodically due to several factors such as duration of storage, the nutrient load, the depth of reservoir, inland flooding, the turbidity, temperature and sea water intrusion. The quality of water needs to be assessed for potability of the water and its use in agriculture.

Name of Sensor	
Parameter Measured	
Type of Sensor	
Location of Placement	
Number of Instruments	
Range (Max. and Min.)	
Resolution (Least Count)	
Sensitivity	
Specification	
Frequency of collection	
Indian Standards	

4.1.2 Level (NCCR)

The water level in the dams changes due the inflow of river water into the dam during different seasons primarily due to rainfall. The level water in the sea side area of dam also changes to different extent due to sea tidal level variation. Hence it is necessary to monitor the water level for the safety of dams.

Name of Sensor	
Parameter Measured	
Type of Sensor	
Location of Placement	
Number of Instruments	
Range (Max. and Min.)	
Resolution (Least Count)	
Sensitivity	
Specification	
Frequency of collection	

Indian Standards	

4.1.3 Inflow from 3 rivers and canal (NCCR)

The water quality and quantity is one of the major parameter that needs to be considered. The quality of water, if poor, might lead to pollution of the water in the reservoir and thus the whole water system. The quantity of water helps determine the sectional outflow of each river/ canal to determine the actual increase in reservoir volume, due to outflow.

Name of Sensor	
Parameter Measured	
Type of Sensor	
Location of Placement	
Number of Instruments	
Range (Max. and Min.)	
Resolution (Least Count)	
Sensitivity	
Specification	
Frequency of collection	
Indian Standards	

4.2 Geophysical Measurement (NGRI)

Geophysical measurement can be used for ascertaining the safety of embankment dams when additional quick data are needed. In most cases, experience up to now shows that these methods have been used to varying degrees of success to check the integrity of dams that might have been affected by development of new seepage paths in the dam itself and/or its foundation and development of excessive seepage, or to observe changes in the material properties and development of dangerous cavities or sinkholes.

4.2.1 Seismic (NGRI)

Name of Sensor	
Parameter Measured	

Type of Sensor	
Location of Placement	
Number of Instruments	
Range (Max. and Min.)	
Resolution (Least Count)	
Sensitivity	
Specification	
Frequency of collection	
Indian Standards	

4.3 Meteorological Measurements (NCCR)

The parameters include humidity, temperature, rainfall, etc. These are measured around the vicinity of the dam for co-relation and to observe rainfall collected in the reservoir.

4.3.1 Temperature (NCCR)

Name of Sensor	
Parameter Measured	
Type of Sensor	
Location of Placement	
Number of Instruments	
Range (Max. and Min.)	
Resolution (Least Count)	
Sensitivity	
Specification	
Frequency of collection	
Indian Standards	

4.3.2 Air Pressure (NCCR)

Name of Sensor	
Parameter Measured	
Type of Sensor	

Location of Placement	
Number of Instruments	
Range (Max. and Min.)	
Resolution (Least Count)	
Sensitivity	
Specification	
Frequency of collection	
Indian Standards	

4.3.3 Wind (NCCR)

Name of Sensor	
Parameter Measured	
Type of Sensor	
Location of Placement	
Number of Instruments	
Range (Max. and Min.)	
Resolution (Least Count)	
Sensitivity	
Specification	
Frequency of collection	
Indian Standards	

4.3.4 Precipitation (NCCR)

Name of Sensor	
Parameter Measured	
Type of Sensor	
Location of Placement	
Number of Instruments	
Range (Max. and Min.)	
Resolution (Least Count)	
Sensitivity	

Specification	
Frequency of collection	
Indian Standards	

4.3.5 Humidity (NCCR)

Name of Sensor	
Parameter Measured	
Type of Sensor	
Location of Placement	
Number of Instruments	
Range (Max. and Min.)	
Resolution (Least Count)	
Sensitivity	
Specification	
Frequency of collection	
Indian Standards	

4.3.6 Solar Radiation (NCCR)

Name of Sensor	
Parameter Measured	
Type of Sensor	
Location of Placement	
Number of Instruments	
Range (Max. and Min.)	
Resolution (Least Count)	
Sensitivity	
Specification	
Frequency of collection	
Indian Standards	

4.4 Energy generated (NIWE)

4.4.1 Wind

Name of Sensor	
Parameter Measured	
Type of Sensor	
Location of Placement	
Number of Instruments	
Range (Max. and Min.)	
Resolution (Least Count)	
Sensitivity	
Specification	
Frequency of collection	
Indian Standards	

4.4.2 Solar

Name of Sensor	
Parameter Measured	
Type of Sensor	
Location of Placement	
Number of Instruments	
Range (Max. and Min.)	
Resolution (Least Count)	
Sensitivity	
Specification	
Frequency of collection	
Indian Standards	

5 SEA SIDE

5.1 Water (NCCR)

The water on the seaside consists of two classifications, namely, the freshwater that exits the reservoir into the open sea and the saline water that exists on the seaside of the dam.

5.1.1 Quality (NCCR)

The water qualities at location of dispersion of freshwater into saline water will be influenced by the outflow volume from the spillway into the sea. The quality of water at spillway location channel end helps determines the dispersion. The variation of water quality along the dam alignment is also measured.

Name of Sensor	
Parameter Measured	
Type of Sensor	
Location of Placement	
Number of Instruments	
Range (Max. and Min.)	
Resolution (Least Count)	
Sensitivity	
Specification	
Frequency of collection	
Indian Standards	

5.1.2 Level (NCCR)

The water level in the seaside is predominantly due to tide while a sudden increase might also be felt due to storm surge.

Name of Sensor	
Parameter Measured	
Type of Sensor	
Location of Placement	
Number of Instruments	

Range (Max. and Min.)	
Resolution (Least Count)	
Sensitivity	
Specification	
Frequency of collection	
Indian Standards	

5.1.2.1 Dam (NCCR)

The water level in the seaside is predominantly due to tide while a sudden increase might also be felt due to storm surge. The measurement of water level helps understand the tidal variation post-construction of dam.

Name of Sensor	
Parameter Measured	
Type of Sensor	
Location of Placement	
Number of Instruments	
Range (Max. and Min.)	
Resolution (Least Count)	
Sensitivity	
Specification	
Frequency of collection	
Indian Standards	

5.1.2.2 Eastern Coast (NCCR)

There is a tidal variation on the downstream side, post-construction of the dam and the tidal influence on the coasts downstream of the dam needs to be studied.

Name of Sensor	
Parameter Measured	
Type of Sensor	
Location of Placement	
Number of Instruments	
Range (Max. and Min.)	

Resolution (Least Count)	
Sensitivity	
Specification	
Frequency of collection	
Indian Standards	

5.1.2.3 Western Coast (NCCR)

There is a tidal variation on the downstream side, post-construction of the dam and the tidal influence on the coasts downstream of the dam needs to be studied.

Name of Sensor	
Parameter Measured	
Type of Sensor	
Location of Placement	
Number of Instruments	
Range (Max. and Min.)	
Resolution (Least Count)	
Sensitivity	
Specification	
Frequency of collection	
Indian Standards	

5.2 Geophysical Measurement

5.2.1 Seismic Measurement (NGRI)

Name of Sensor	
Parameter Measured	
Type of Sensor	
Location of Placement	
Number of Instruments	
Range (Max. and Min.)	
Resolution (Least Count)	
Sensitivity	

Specification	
Frequency of collection	
Indian Standards	

5.3 Meteorological Measurements (NCCR)

The parameters include humidity, temperature, rainfall, etc. These are measured around the vicinity of the dam for co-relation and to observe rainfall collected in the reservoir.

5.3.1 Temperature (NCCR)

Name of Sensor	
Parameter Measured	
Type of Sensor	
Location of Placement	
Number of Instruments	
Range (Max. and Min.)	
Resolution (Least Count)	
Sensitivity	
Specification	
Frequency of collection	
Indian Standards	

5.3.2 Air Pressure (NCCR)

Name of Sensor	
Parameter Measured	
Type of Sensor	
Location of Placement	
Number of Instruments	
Range (Max. and Min.)	
Resolution (Least Count)	
Sensitivity	
Specification	

Frequency of collection	
Indian Standards	

5.3.3 Wind (NCCR)

The wind data is observed for both determination of velocity of wind, direction both during normal and extreme events. The wind data helps determine the directionality of the wave

Name of Sensor	
Parameter Measured	
Type of Sensor	
Location of Placement	
Number of Instruments	
Range (Max. and Min.)	
Resolution (Least Count)	
Sensitivity	
Specification	
Frequency of collection	
Indian Standards	

5.3.4 Precipitation (NCCR)

Name of Sensor	
Parameter Measured	
Type of Sensor	
Location of Placement	
Number of Instruments	
Range (Max. and Min.)	
Resolution (Least Count)	
Sensitivity	
Specification	
Frequency of collection	
Indian Standards	

5.3.5 Humidity (NCCR)

Name of Sensor	
Parameter Measured	
Type of Sensor	
Location of Placement	
Number of Instruments	
Range (Max. and Min.)	
Resolution (Least Count)	
Sensitivity	
Specification	
Frequency of collection	
Indian Standards	

5.3.6 Solar Radiation (NCCR)

Name of Sensor	
Parameter Measured	
Type of Sensor	
Location of Placement	
Number of Instruments	
Range (Max. and Min.)	
Resolution (Least Count)	
Sensitivity	
Specification	
Frequency of collection	
Indian Standards	

5.4 Oceanographic Parameters

5.4.1 Wave Climate (NCCR)

Real-time measurement of wave climate is necessary to analyze the wave characteristics in and around the Kalpasar dam region. The wave climate incorporates data such as Multidirectional waves, current modified wave steepness, wave period, wave spectrum, energy and wave height measured using wave rider buoy.

Name of Sensor	
Parameter Measured	
Type of Sensor	
Location of Placement	
Number of Instruments	
Range (Max. and Min.)	
Resolution (Least Count)	
Sensitivity	
Specification	
Frequency of collection	
Indian Standards	

5.4.2 Currents (NCCR)

The currents on the seaside are measured to determine the velocity of currents along the dam alignment

Name of Sensor	
Parameter Measured	
Type of Sensor	
Location of Placement	
Number of Instruments	
Range (Max. and Min.)	
Resolution (Least Count)	
Sensitivity	
Specification	
Frequency of collection	
Indian Standards	

5.4.3 Run up (NCCR)

The breakwater on the rockfill dam is designed for theoretical over-topping discharge. Calculating the wave runup helps determine the actual discharge and flow on the seaside of the dam.

Name of Sensor	
Parameter Measured	
Type of Sensor	
Location of Placement	
Number of Instruments	
Range (Max. and Min.)	
Resolution (Least Count)	
Sensitivity	
Specification	
Frequency of collection	
Indian Standards	

6 WATER OUTTAKE

6.1 Irrigation and Drinking water (NCCR)

One of the main purposes of Kalpasar dam is to provide fresh water for irrigation and Drinking. The water will not be used if the salinity or other chemical, physical or biological impurities are present.

6.1.1 Water Quality (NCCR)

The quality of water determines its suitability for agriculture. The chemical, biological and physical parameters are tested for its utilization in agriculture.

Name of Sensor	
Parameter Measured	
Type of Sensor	
Location of Placement	
Number of Instruments	
Range (Max. and Min.)	
Resolution (Least Count)	
Sensitivity	
Specification	
Frequency of collection	
Indian Standards	

6.1.2 Water Volume (NCCR)

The amount of water drawn up for agriculture is to be determined for the understanding on the distribution of water along various canals.

Name of Sensor	
Parameter Measured	
Type of Sensor	
Location of Placement	
Number of Instruments	
Range (Max. and Min.)	
Resolution (Least Count)	

Sensitivity	
Specification	
Frequency of collection	
Indian Standards	

6.1.3 Power consumed (NCCR)

As the power is drawn from wind and solar plants situated at the vicinity of the dam, it is useful to monitor the power consumed by the water outtake components.

Name of Sensor	
Parameter Measured	
Type of Sensor	
Location of Placement	
Number of Instruments	
Range (Max. and Min.)	
Resolution (Least Count)	
Sensitivity	
Specification	
Frequency of collection	
Indian Standards	

7 DATA COLLECTION, PROCESSING AND STORAGE (MNIT, IITM, NCCR)

7.1 Measurement and Telemetry *(MNIT, IITM, NCCR)*

All the Instruments shall be connected to a Computer (Server) Driven Data Acquisition System (DAS) and the data shall be transmitted in real time to the Project Office for further processing through wireless (Wi-Fi) means using Data Loggers and Servers. A Conceptual Sketch showing the details of a building structure proposed to house the Data Acquisition System (DAS) and Strong Motion Accelerographs (SMA) and Switch Boards is presented in Drawing Layout.

7.2 SCADA *(MNIT, IITM, NCCR)*

Real-time data collection gives you insights to maximize efficiency, reduce overhead costs, and streamline operations. Many remote observations rely on a Supervisory Control and Data Acquisition (SCADA) system. It helps operators access actionable data and manage equipment. SCADA is a powerful control system that is designed to collect, analyze, and visualize data from remote instruments. Operators can view critical measurements like temperature, vibration, power usage, and levels across different equipment. Using modern SCADA solutions, operators can access actionable data and manage hundreds of assets without visiting every field device.

7.2.1 Master Station *(MNIT, IITM, NCCR)*

7.2.2 Data Acquisition *(MNIT, IITM, NCCR)*

7.2.3 Processing *(MNIT, IITM, NCCR)*

7.2.3.1 Method (MNIT, IITM, NCCR)

7.2.3.2 Frequency of Processing (MNIT, IITM, NCCR)

The frequency of data that needs to be processed in provided in table 3.

Table 1 Frequency of data processing

S. No.	Components	Measurement Parameters	Instruments	Processing Data Frequency
1	Earth and Rockfill dams	Pore Pressure	Piezometers	Daily
		Seepage	Piezometers, Water quality sensors	Daily
		Movement	Surface Settlement laser point, Inclinometer	Daily
		Strain	extensometer	Daily
		Earth Pressure	Earth Pressure Cells	Daily
2	Spillway	Water Level	Automated Radar Water level Sensor	Weekly
		Uplift Pressure	Uplift Pressure Cells, Earth Pressure Cells	Daily
		Displacement	Parapet Settlement laser point, Joint Meters	Daily
		Water Flow	Flow meter	Weekly
		Tilt	Inverted Plumb Lines	Daily
		Strain	Strain Meters	Daily
		Water quality	Salinity and pH meter	Weekly
		Fish pass	Current Meter	Weekly
3	Seismic observation	Accelerations	Strong Motion Accelerographs (SMAs)	Daily
		Velocity	Velocity Meter	Daily
		Displacement	GPS sensor	Daily
4	Hydro-meteorological observation	Water Levels	Automated Radar Water level Sensor	Weekly
		Wave Climate	X- band radar	Monthly
		Currents		Monthly
		Runup	Parallel steel wire	Daily
		Atmospheric Weather Parameters	Automated Weather Station	Monthly
		Water quality Parameters	Water quality Data buoy and Turbidity meter	Monthly

7.2.4 Display (MNIT, IITM, NCCR)

7.2.5 Action (MNIT, IITM, NCCR)

8 SUMMARY OF INSTRUMENTS

9 BUDGETARY COST (NCCR)

The number of instruments and the budgetary estimate has been detailed in tables 4 and 5.

Table 2 Number of Instruments for Kalpasar

	Name of instrument	Dam / barrage components				Total
		Spillway	Earthen Embankment	Seismic Observation	Hydro-Meteorological	
1	Parapet Settlement Laser Points					
2	Surface Settlement Laser Points					
3	Extensometer					
4	Automatic Water Level Recorders					
5	Uplift Pressure Cells					
6	Strain Meters					
7	Joint Meters					
8	Inverted Plumb Lines					
9	Inclinometers					
10	Strong Motion Accelerographs (SMAs)					
11	Velocity meter					
12	GPS sensor					
13	Current Meter					
14	Piezometers					
15	Earth Pressure Cells					
16	Water Quality Sensor					
17	Turbidity Meter					
18	Flow meter					
19	X-band Radar (Wave and Currents)					
20	Parallel Steel Wire Resistivity Gauge					
21	Automated Weather station					
22	Data Acquisition System (DAS)					
23	Switch Boards	Type and quantity of Switch Boards, Junction Boxes, Cables, Tool Kit and				
24	Junction Boxes					

	Name of instrument	Dam / barrage components				Total
		Spillway	Earthen Embankment	Seismic Observation	Hydro-Meteorologic al	
25	Cables, Tool Kit and Spares	Spares to be worked out at the Tender Stage				

Table 3 Budgetary Estimate of the Instruments

S. No.	Name of instrument	Number of instruments	Rate (INR)	Amount (INR)
1	Parapet Settlement Laser Points		-	-
2	Surface Settlement Laser Points		-	-
3	Extensometer		-	-
4	Automatic Water Level Recorders		-	-
5	Uplift Pressure Cells		-	-
6	Strain Meters		-	-
7	Joint Meters		-	-
8	Inverted Plumb Lines		-	-
9	Inclinometers			
10	Strong Motion Accelerographs (SMAs)			
11	Velocity meter		-	-
12	GPS sensor		-	-
13	CurrentMeter		-	-
14	Piezometers		-	-
15	Earth Pressure Cells		-	-
16	Water Quality Sensor			
17	Turbidity Meter			
18	Flow meter			
19	X-band Radar (Wave & Currents)			
20	Parallel Steel Wire Resistivity Gauge			
21	Automated Weather station			
22	Data Acquisition System (DAS)			
23	Switch Boards	Lump Sum		
24	Junction Boxes			
25	Cables, Tool Kit and Spares			
			GRAND TOTAL (INR)	

Detailed Annexure I

Technical Specifications of Instruments

i. *Strong Motion Accelerographs (SMAs)*

I. In built Accelerometer (Internal)

i. Triaxial, Force balanced, Orthogonal oriented transducers (one vertical and two horizontal) along with the data acquisition system in a single sealed unit.
ii. Full Scale Range: Selectable±4g and ±2g
iii. Frequency response flat (within ±3dB) to ground acceleration in the range of DC to 200 Hz
iv. Dynamic Range: 150dB or more (3-30Hz Range)
v. Linearity: Less than 0.1% of full scale
vi. Cross axis sensitivity: Less than 0.5% of full scale
vii. Leveling: Bubble level indicator for leveling the transducer.
viii. Orientation: Suitable mark to indicate the direction of relative orientation of the transducer.
ix. Calibration facility from the Data Acquisition System locally or remotely from central recording station through DAS
x. Detailed user manual, data sheets and calibration data sheet of the accelerometer to be provided.

II. Data Acquisition System(DAS)

ADC	Independent 24-bit digitizers, one for each channel
Number of channels	3
Sampling Rate	User selectable up to 1000 SPS per channel
Dynamic Range	130dB or more @ 100sps
Input Voltage Range	to be matched with the accelerometer output
Channel-to-Channel Skew	None
System response	±3dB flat from DC to Nyquist frequency
Noise level	Noise level of the unit including the accelerometer and the data acquisition system should be less than 0.001% of the

	full-scale level in the frequency range from DC to 50Hz
Timing System	Internal GPS receiver-based timing system Timing accuracy of 0.1msec or better when GPS is locked Record of GPS status information GPS antenna should be enclosed in weather proof sealed enclosure with lightning protection.
Recording Mode	continuous, triggered
Triggering	The DAS should be capable of recording the acceleration data in the STA/LTA ratio trigger, threshold trigger and time window
Trigger selection	Independent selection for each channel
Threshold Trigger	User selectable from 0.01% to 100% of the full scale
Pre event Recording length	User selectable up to 30 sec or more
Post event length	User selectable up to 90 sec or more
Data Storage	User accessible removable mass storage media The mass storage media should have the capacity of 32GB or more. One spare mass storage media of same capacity for each digitiser to be supplied The mass storage media should be rugged and suitable to withstand extreme temperature variations. The bidder should attach the data sheet of the mass storage media to be supplied with the unit.

Recording format	Standard seismic data format compatible to Windows and Linux platforms. Conversion utilities to Miniseed, SAC, SEISAN, ASCII formats to be provided DAS firmware should support the following features Web browsing support/ communication over TCP/ IP protocol. Full Duplex communication between field station and Central Receiving Station (CRS) Triggered or continuous data transmission Support off-the- shelf communication equipment Extensive error correction
Humidity	Up to 100% RH
The DAS should be capable of recording the accelerometer data on the local mass storage media as well as support real-time data telemetry to a central site through VSAT telemetry network simultaneously. DAS should have facility to retrieve the old data in the storage media from Central Recording Station manually through VSAT network. The DAS should have the facility to check the state of health of the system including system voltage, temperature, GPS status etc. The DAS should have the facility for Calibration of the Accelerometer. DAS should resume data acquisition automatically when the power is restored after disruption.	
Communication	Ethernet Interface for real time telemetry RS-232 interface for real time telemetry / parameter setup 10BaseT Ethernet port, RS-232 port, USB port should be provided Detailed user manual and data sheet of the DAS should be provided. Accelerograph Unit

	Input voltage range 9-24V DC Power consumption <3.0 watts at 12V DC (3 channel, GPS) for both accelerometer and digitiser together Provision to connect external 12V battery source Supply power isolated from signal ground Reverse voltage protection Over voltage protection
Operating temperature	-20° to 60°C
Accelerometer and DAS should be enclosed in weather and shock proof sealed single enclosure with lightning protection.	
The lowest frequency that is measured should less than 10% of the fundamental natural frequency of the dam and lower than excitation frequencies of the earthquake spectrum. Recording from 0 Hz is recommended. Similarly, the upper frequency that is measured should be higher than the frequency of the highest mode of variation that contributes to the dam response and greater than the excitation frequencies of the earthquake spectrum. The strong motion accelerometer with frequency response flat (within ±3 dB) of the ground acceleration in the range of DC to 200 Hz is Preferable	
Objectives of the SCADA System	(i) Provide a graphical overview of the operational state of the entire Dam Automation System on real time basis and with historical perspective. (ii) Real time Control of Gates for executing desired decisions at site. Real time data display from all gate positions (iii) Dam upstream pond water level, water level downstream of Dam in the river, water levels downstream of head regulators, rainfall, depths etc. (iv) Water Levels at confluence of two tributaries joining the river Dam upstream of barrage. (v) A provision shall be made to establish a stage discharge curve for assessing inflow of tributaries into the Dam River.

	(vi) Collection and transmission of inflow /release data of River Upstream of Dam. Kalpasar Project Authority shall ensure availability of data on real time through GSM/GPRS which is to be displayed integrated at all three Work Station monitors. (vii) Discharge values of river at the weir and both end off-take canal head regulators. (viii) Alarm generation in case of Unexpected / Uncommon Conditions for Necessary Action. (ix) Automatic fault/Non compliance to Set Benchmarks Reporting for the entire Dam system. (x) Monitoring of Unplanned and Unauthorized Gate Operations to minimize errors and identify the malfunctioning sensors and other equipments on the video walls. (xi) Communication protocol for other stakeholders such as downstream habitants, farmers and other users or interested parties. (xii) Database archive for retrieval and analysis of historical and/or current data for entire operational activities of Dam system.
Database:	Completely developed Operational Database Management System (ODMS)/ Operational Historian shall be provided for the Dam Project, which shall be interfaced with SCADA for complete information management of the Dam operations. The SCADA software database shall be of true relational database/historian designed and optimized for real-time SCADA operation. The database/historian builder and editor (DBE) shall be an integral part of the SCADA commercial package. The DBE shall allow the user to examine the contents of an existing database, monitor the running database, edit an existing database or create a new database, add, delete or change an existing tag's name, data type, I/O address, source ID, I/O interface or any other tag attribute or

	characteristic in the database. All changes made to the system should be promptly reflected by revising the documentation and the database and distributing copies of the revised documentation and updated database to the field.
Processing in database	a. The SCADA system shall be able to manage the amount of variables requested by the number of-sites of the project. b. The SCADA software shall have a single global database. The physical implementation of the database can rely on several files, but does not depend on the number of nodes or points in the system. c. Administration of the database shall be performed through dedicated windows and menus allowing listing, adding, deleting or modifying the definition of process variables. e. Changes to the global process database shall be made from Master Controller Workstation. This function shall be protected by password. f. The process database shall have facility of remote administration. g. The database shall have facility to retrieve past archives for the process variables. h. The same database shall integrate both process data and alarm/events data.
Database Builder and Editor (DBE)	The Database Builder and Editor shall be delivered as part of the SCADA software package. It will be used to: (a) create a new database (b) edit an existing database: i.e. add new variable definitions, remove existing variable definitions, edit existing variable definitions or browse an existing database. With the DBE, it shall be possible to import/export an existing database via an ASCII readable file in CSV format. Changes in the SCADA database are automatically communicated to the other SCADA server

General features of historical data management	The SCADA software shall include features for the management of historical data collections. a. The SCADA software shall record historical values of analog variables on a periodic basis and values of digital variables on an event basis (change of state). b. There shall be no limit by the SCADA software for the number of data values recorded in a historical collection. c. The SCADA software shall support recording of historical data on one or more files, defined by the user. d. The database files holding the historical values shall be automatically sent towards a distant secured rented server on a periodical basis. This function shall be available when broadband internet is available.
HMI for curves management	The HMI shall provide the capability for display/plotting of real-time and historical data as curves. a. The plot function shall provide pre-scaled display of selected process variables (pre-defined scales on type curves). b. The operator shall select subsets of the displayed data. The plot function shall automatically scale the requested data to fit the time frame requested by the operator. The plot function shall display these data as a multiline chart with each variable easily determined by color. c. The SCADA HMI software shall support curve display with the following features: Line graphs with time on a linear, continuous horizontal axis and the trended variable on the vertical axis. Simultaneous display of up to six plots, reporting up to 10,000 points within a user specified time range.
Alarm management **General features of alarm management**	a. The SCADA software shall support alarm and event logging, including description text and time stamp. b. The alarms shall be logged to the SCADA database without any limit on the number of alarm occurrences. c. In order to logically divide process into smaller units, it shall be possible to define alarm groups.

	d. The SCADA software shall allow viewing of alarms without disrupting data collection or alarm processing. e. Alarm data shall be stored on the shared disk unit to allow uninterrupted logging.
Principles for 'Alarm' generation	Alarms shall be either generated by the PLCs/RTUs or by the SCADA software. The SCADA software shall allow input of events by the operator. The logged information shall include: username, action, date & time, value, and free-format comment. a. To enable alarm generation at structure level, the thresholds on analog variables (e.g. high level, low level) shall be sent by the SCADA software to the PLCs/RTUs. b. The SCADA software shall monitor analog and digital variables and calculate conditions, to determine if a variable is in an alarm condition. c. For each analog variable, the SCADA software shall trigger an alarm for each of the following conditions: variable LOW-LOW, variable LOW, variable HI, variable HI-HI, rate of change, bad sensor input. Adjustable dead bands shall be managed. It shall also be possible to disable alarm generation for a variable. All analog alarm properties shall be modified without restarting the SCADA software. Changes shall be automatically saved to the database so that if the system is restarted, the alarm settings shall be as last adjusted. d. For each digital variable, the SCADA software shall trigger an alarm for each of the following conditions: variable ON, variable OFF.
SMS messaging software	The SCADA software shall be able to send SMS using dedicated gateway including a SIM card. The features are as follows: a. SMS shall be sent to specified list of mobile phone numbers or a list,

	b. The lists of phone numbers for customization can be imported from a text file. Duplicate entries shall be detected. c. In case of a list of phone numbers, delay between messages shall be customized to minimize load of SMS d. Sent messages shall recorded, documented and stored in computer servers for future reference (storage to archive file)
Web Server	a. A web server if decided by Authority may be added to the system to allow data display in remote sites in the frame work of the project. This web server is not installed and data display is performed on the Monitoring Workstations only. b. This server allows the viewing of real-time and historical data from multiple locations managed by the SCADA software (mimics, curves). c. Information displayed in the web server window can be personalized using access configuration.
Human Machine Interface (HMI)	The SCADA HMI applications shall present the operators with control screens that provide for all the control interaction to operate the gate structures. The HMI shall present an overview and detailed state of the operational conditions of the canals based on customized views of the project area ("mimics"). It shall allow users to input commands to the structures and also access the historical data for reporting or trending. The mimics are created using a graphics editor. They will display key process variables as digital and graphical data. Navigation between mimics is made by selection in a menu or selection of buttons or similar graphic objects. The HMI part of SCADA software shall be based on requirements of Dam Project and shall be duly customized as per the operational and other requirements of the Project, as explained by project officials. The SCADA screen builder and editor shall be an integral part of the SCADA package, supporting user building and editing of user friendly control screens in the project. Authority shall provide full explanation of tags and assigned registers and their

	associated recommended values that need to be designed and displayed in HMI. The screen builder shall allow users to edit existing screens, create new screens or save existing screens to new screen definitions.
Monitoring workstations	A SCADA Software system shall be installed at two locations on dedicated PCs named "Monitoring work stations". The Main Master Controller Server with 110 “LED Video wall of single screen monitor would be at the control room. These Monitoring workstations shall be connected to the SCADA Server using INSAT/VSAT and GSM/GPRS communication modules, which shall be available at the chosen sites. The Monitoring workstations shall have the HMI of the SCADA software. From this HMI, the users shall monitor and control the structures under their management (possibility to enter commands to control the structures in a dedicated area). The data acquisition shall be performed in a centralized manner, where satellite equipment is available, and then dispatched for display to the Monitoring Workstations. The SCADA HMI will be protected by access control (login) by Bio Metric System.