

Executive Summary

1.0 National Perspective Plan for Water Resources Development

The erstwhile Union Ministry of Irrigation and Central Water Commission formulated, in the year 1980, a National Perspective Plan (NPP) for water resources development which comprises of two components: Himalayan Rivers Development Component, and Peninsular Rivers Development Component. The distinctive feature of the National Perspective Plan is that the transfer of water from surplus basin to deficit basin would essentially be by gravity and only in small reaches it would be by lifts not exceeding 120 meters. These two components are briefly outlined in the following paragraphs.

Himalayan Rivers Development

Himalayan Rivers Development envisages construction of storage reservoirs on the principal tributaries of the Ganga and the Brahmaputra in India, Nepal and Bhutan, along with inter-linking canal systems to transfer surplus flows of the eastern tributaries of the Ganga to the west, apart from linking of the main Brahmaputra and its tributaries with the Ganga and Ganga with Mahanadi and augmentation of flow at Farakka.

Peninsular Rivers Development

This component is divided into four major Parts:

- i. Interlinking of Mahanadi – Godavari - Krishna- Pennar - Cauvery rivers and building storages at potential sites in these basins
- ii. Interlinking of west flowing rivers, north of Mumbai and south of the Tapi

- iii. Interlinking of Ken-Chambal Rivers
- iv. Diversion of other west flowing rivers

The National Water Development Agency (NWDA) after carrying out the detailed technical studies identified 30 link proposals for preparation of Feasibility Reports/ Detailed Project Reports; 14 links under Himalayan Rivers Development Component and 16 links under Peninsular Rivers Development Component. Damanganga – Pinjal link project is one of the 16 link proposals under Peninsular Rivers Development Component.

2.0 MoU amongst Centre and concerned States & Inter-State Aspects

The Feasibility Report of Damanganga-Pinjal Link Project was prepared by NWDA during November, 2004 and circulated to all concerned State Governments and members of Technical Advisory Committee (TAC) of NWDA. Since then continuous efforts were made by National Water Development Agency, Central Water Commission (CWC) and Ministry of Water Resources to arrive at the consensus between two beneficiary states of Gujarat and Maharashtra. As a result of these efforts, consensus was arrived amongst the Central Government and concerned States of Gujarat and Maharashtra for preparation of Detailed Project Report (DPR) of Damanganga-Pinjal link project.

The Water Resources Department, Government of Maharashtra and Narmada, Water Resources, Water Supply & Kalpasar Depart, Government of Gujarat conveyed their concurrence to Union Ministry of Water Resources during May 2008 for preparation of Detailed Project Report (DPR) of the project. Subsequently, the work for preparation of DPR was entrusted to National Water Development Agency (NWDA).

A tripartite Memorandum of Understanding (MoU) was signed by the states of Gujarat and Maharashtra and the Union Government on 3rd May, 2010 at New Delhi for preparation of Detailed Project Report of Damanganga-Pinjal Link Project. The tripartite Memorandum of Understanding indicates that the

Maharashtra Government will get the benefits through the Damanganga-Pinjal Link Project by way of augmentation of water supply to meet the domestic water requirement of Mumbai city, while Government of Gujarat will be free to utilise remaining water spilled from Bhugad & Khargihill dams.

Accordingly, NWDA has prepared the DPR of Damanganga-Pinjal link project with active support and co-operation of Central Water Commission (CWC) and other domain expert organisations like Central Soil & Material Research Station (CSMRS), Geological Survey of India (GSI), Central Water and Power Research Station (CWPRS), Tehri Hydro Development Corporation India Ltd (THDC), India Meteorological Department (IMD), National Remote Sensing Center (NRSC), Water & Power Consultancy Services (WAPCOS), Regional Remote Sensing Centre (RRSC), Nagpur etc.

It is indicated in the tripartite Memorandum of Understanding that the issue of water sharing, quantum of diversion in link canal, exploring the possibilities of hydropower generation in Damanganga basin, extending the link to Tansa reservoir etc., raised by States will be addressed and resolved before the finalisation of the DPR. Accordingly, the issue of water sharing was taken-up for discussion with both Maharashtra and Gujarat States. The water availability study of Damanganga – Pinjal link project has been carried out by Central Water Commission (CWC) for NWDA. This study was sent to both the States. So far two meetings have been held with the Water Resources Departments of Maharashtra and Gujarat Governments at the level of Chief Engineers (CEs). The water availability study report has been accepted by both the States. It has also been agreed by both the States that the sharing of water shall be based on the catchment area of the respective States duly accounting for the variation in catchment rainfall.

3.0 Aim & Objective of the Project and Description of works

The objective of Damanganga-Pinjal Link Project is to divert surplus waters of Damanganga river at Bhugad and Khargihill reservoir to Pinjal reservoir in Vaitarna basin (proposed by Government of Maharashtra) from

where the combined waters of Damanganga and Pinjal rivers will be further taken to Mumbai city for augmentation of its domestic water supply.

Due to continuous improvement in the living standards of the people, increase in urban population and the pace of industrial and other development, many of our metropolitan cities are facing acute shortage of water for domestic and industrial purposes. The rate of population growth of metropolitan city of Greater Mumbai over the decades is unprecedented. Mumbai being the capital city of the state of Maharashtra, is also the commercial and financial capital of the country. With a population of more than 18 million, it is one of the ten largest mega cities of the world. With the present pace of development of Greater Mumbai, it is anticipated that there would be acute shortage of domestic water in the year – 2050. As per the assessment of Municipal Corporation of Greater Mumbai (MCGM) the present domestic water demand for Mumbai City (year 2012) is 4529 MLD (1653 Mm³) and the cumulative water supply from all the sources is 3675 MLD (1341 Mm³). The projected domestic water demand for Greater Mumbai by the year – 2041 is 6680 MLD (2438 Mm³) and the projected supply as 4980 MLD (1818 Mm³) (on completion of Gargai and Pinjal projects) leaving a shortage in supply of 1700 MLD (620 Mm³). The shortage in water supply will further increase as the demand will reach to 7000 MLD (2555 Mm³) by the year - 2060 and the cumulative water supply from various sources including from middle Vaitarna, Bhatsa and Gargai projects will remain 4980 MLD (1818 Mm³) only.

The preliminary water balance study of Damanganga basin and at proposed Bhugad and Khargihill dam sites (Technical Study No. 24) was carried out by NWDA which indicates that the surplus water is available in Damanganga basin. Accordingly, Preliminary Feasibility Study to ascertain whether the project is feasible, was carried out for diversion of surplus waters of Damanganga basin to Pinjal reservoir for augmentation of domestic water requirement of Mumbai city. The project was found techno- economically viable and accepted by the TAC of NWDA.

The proposed storage reservoirs in Damanganga-Pinjal link project will provide additional 1586 MLD (579 Mm³) of water from Bhugad and Khargihill

reservoirs in Damanganga basin to Pinjal reservoir in Vaitarna Basin and about 865 MLD (316 Mm³) of water from Pinjal reservoir (a separate project of Government of Maharashtra in Vaitarna basin) for augmentation of domestic water supply to Mumbai city. Thus, the total water supply from Damanganga – Pinjal link and Pinjal project shall be 2451 MLD (895 Mm³)

4.0 Interlinking of the Proposed Project with other existing and future projects

Narmada, Water Resources, Water Supply and Kalpasar Department, Government of Gujarat had constructed Madhuban dam across river Damanganga river in the down-stream of proposed Bhugad and Khargihill dams. The Bhugad dam proposed under Damanganga – Pinjal link will intercept about 141 square km of Gujarat catchment of existing Madhuban reservoir in Gujarat. To compensate the quantity of water that could be generated from the Gujarat catchment intercepted by proposed Bhugad reservoir 91 Mm³ water will be released from Bhugad reservoir. Damanganga

– Pinjal link project has been planned to augment the domestic water supply of Mumbai city.

The Water Resources Department, Government of Maharashtra has proposed Pinjal dam across river Pinjal in Vaitarna basin. The surplus Damanganga waters available at proposed Bhugad and Khargihill reservoirs will be first transferred to proposed Pinjal dam, from where the combined surplus waters of Damanganga and Vaitarna basins will be taken to Mumbai city as per the plans of Mumbai Metropolitan Region Development Authority. Thus, while planning Damanganga – Pinjal link project, the other projects located in the vicinity have been considered.

5.0 Methodology Adopted

The Feasibility Report of Damanganga-Pinjal Link Project prepared by National Water Development Agency formed the basis for proceeding further for preparation of Detailed Project Report and make suitable changes based on detailed survey and investigations and up-dated hydrological and other studies.

During preparation of DPR detailed field investigations such as topographical surveys at both dam axis and along both the tunnels were carried out by NWDA using in-house expertise and also private agencies where ever required. Detailed geological and geotechnical investigations etc were carried out through Geological Survey of India, Central Soil and Material Research Station; hydrological studies were carried out through Central Water Commission. To complete the work in time bound manner private agencies were hired where Government agencies were not available for the works like drilling and submergence area survey. Based on these investigations and studies the layout and designs of various components of the project have been finalised.

The DPR has been prepared with active support and co-operation of Central Water Commission (CWC) and other domain expert organisations like Central Soil & Material Research Station (CSMRS), Geological Survey of India (GSI), Central Water and Power Research Station (CWPRS), Tehri Hydro Development Corporation India Ltd (THDC), India Meteorological Department (IMD), National Remote Sensing Center (NRSC), Water & Power Consultancy Services (WAPCOS), Regional Remote Sensing Centre (RRSC), Nagpur etc.

The Union Ministry of Water Resources has constituted a Committee under the Chairman, CWC to monitor and supervise the work of preparation of DPR; and also a Steering Committee under Secretary (WR). These two Committees monitored the progress of work and guided NWDA in preparation of DPR.

The DPR of the project is in 7 Volumes. The main report of the DPR is contained in Volume – I. The data and detailed reports of various expert agencies associated with work are contained in Volume II to V as Annexures/Appendices. The relevant drawings are furnished in Volume VI and VII.

5.1 Data Collection

The preparation of Detailed Project Report of Damanganga-Pinjal Link Project requires various data / information. The rainfall and meteorological data were collected from India Meteorological Department (IMD), Pune; hydrological data collected from Central Water Commission and State Irrigation Departments; Remote sensing data (LISS- IV) from NRSC, Hyderabad; topo-sheets from Survey of India. The data / information required by various Designs Directorates of Central Water Commission were collected during the field surveys.

Laboratory testing of rock core samples and various construction material samples were carried out by Central Soil & Material Research Station; geological mapping and investigations were carried out by Geological Survey of India, Nagpur. These data formed the in-puts for design of various components of the project. Simulation analysis was carried out for optimising the height of Bhugad and Khargihill dams. The simulation analysis formed in-puts for the power potential studies carried out by Tehri Hydro Development Corporation (THDC) and the out-put given by THDC in the form of power potential studies formed in-put for civil designs of hydel structures. Thus, there were many activities apart from the normal data collection and these activities were successfully managed by National Water Development Agency officers and various data required by the consultants were supplied to them for carrying out various consultancy works for preparation of Detailed Project Report of Damanganga-Pinjal Link assigned to them.

5.2 Planning and Lay-out

The objective of the link Project is to transfer surplus waters available in Damanganga and Pinjal river basins to Mumbai city for augmentation of its domestic water supply. For this purpose a dam at Bhugad across river Damanganga; a dam at Khargihill across river Vagh along with a saddle dam have been proposed by NWDA. In addition, a dam across river Pinjal has been proposed by Government of Maharashtra. Two tunnels: (i) Connecting Bhugad reservoir with Khargihill reservoir; and (ii) Connecting Khargihill

reservoir with Pinjal reservoir are also proposed. The power houses at the toe of both Bhugad and Khargihill dams are also planned to generate the hydro-power by utilising water proposed to be released to meet the water requirements downstream of the respective dam sites. Various components of the project are described below:

5.2.1 Bhugad Dam

Bhugad dam is proposed across river Damanganga near village Bhugad in Trimbak taluka of Nasik district of Maharashtra state. The total length of Bhugad dam is 851.50 m of which 527.5 m is concrete face rock fill dam (CFRD) and remaining 324 m length will be of concrete. The spillway has been proposed in the river portion. The FRL of Bhugad dam has been kept at 163.87 m and the corresponding gross storage capacity of the reservoir is 427.07 Mm³. A penstock is proposed in extreme left of the concrete portion of the dam for taking water to the power house located at the toe of the dam.

The surplus water available at Bhugad reservoir is to be transferred to proposed Khargihill reservoir through a tunnel. The tunnel will take-off from the left flank of the Bhugad reservoir upstream of Bhugad dam. The diameter of the tunnel is 3.2 m and the bed slope is 1:1342.

5.2.2 Khargihill Dam

Khargihill dam is proposed across river Vagh, a tributary of river Damanganga near village Behadpada in Jawhar taluka of Thane district of Maharashtra state. The total length of Khargihill dam is 618.20 m of which 341.0 m is concrete face rock fill dam (CFRD) and remaining 277.20 m length will be of concrete. The spillway has been proposed in the river portion. The FRL of Khargihill dam has been kept at 154.52 m and the corresponding gross storage capacity of the reservoir is 460.896 Mm³. A penstock is proposed in extreme left side of the concrete portion of the dam for taking water to the power house located at the toe of the dam. A Saddle dam is proposed on the left flank of the Khargihill reservoir near village Vavar. The length of the

saddle dam is about 400 m and the maximum height above NSL is 25.92 m. The top width of the saddle dam is 8 m.

The combined surplus water available at Khargihill reservoir is to be transferred to proposed Pinjal reservoir through a tunnel. The tunnel will off take from the left flank of the Khargihill reservoir upstream of Khargihill dam. The diameter of the tunnel is 4.00 m and the bed slope is 1:1717. The combined surplus waters of Damanganga (Bhugad and Khargihill reservoirs) and Pinjal will be taken further to Mumbai by Mumbai Metropolitan Region Development Authority (MMRDA) as per their own plan.

5.2.3 Pinjal Dam

The Water Resources Department, Government of Maharashtra and Municipal Corporation of Greater Mumbai (MCGM) have proposed the Pinjal dam across river Pinjal, a tributary of Vaitarna river near village Khidse in Wada taluka of Thane district of Maharashtra. As per the recent planning of MCGM the dam at Pinjal will be a roller compacted concrete gravity dam and the total length of Pinjal dam will be 545.0 m. The length of saddle dam will be 190 m. The spillway has been proposed on the right flank. The length of spillway will be 80.0 m with 5 gates of size 14 m X 12 m. Provision for construction of penstock has been made to generate hydro power through the release of water to Mumbai city and also from the release for meeting irrigation requirement.

The surplus water available at proposed Pinjal reservoir along with the water to be transferred from proposed Bhugad and Khargihill reservoirs of Damanganga basin is to be taken upto Mumbai city through suitable conveyance system as per the planning of Municipal Corporation of Greater Mumbai (MCGM) and Mumbai Metropolitan Region Development Authority (MMRDA).

5.3 Surveys & Investigations

On receipt of concurrence from Government of Maharashtra and Gujarat, the work for preparation of Detailed Project Report of Damanganga-Pinjal Link Project was taken-up by National Water Development Agency during January, 2009. The work for preparation of DPR of the Project was taken-up by National Water Development Agency utilising one Circle Office located at Valsad. Based on the location of the various components of the project and accessibility, one division office at Nasik was opened during January, 2009 for carrying out Survey & Investigation works for preparation of Detailed Project Report of Damanganga-Pinjal link project.

The permission for carrying out the Survey & Investigation works in the forest area was obtained from Forest Department of Gujarat vide office of Principal Chief Conservator of Forest, Gandhinagar letter No. Land/29/B/2756/08-09 date 21st November, 2008. Similar permission for Maharashtra area has been obtained from Forest Department of Maharashtra vide Deputy Conservator of Forest (West), Nasik letter No. Land/CA/4294/2008-09 Dated 25th November, 2008 for Nasik district; and vide Deputy Conservator of Forest, Jawhar letter No. B/20/Land/CA/ 4714/2008-09 date 2nd January 2009 for Thane District. In the beginning the dam axis survey of Bhugad and Khargihill dam sites was taken-up using in-house expertise and completed during first field season of 2009. Later on the topographical surveys for both the tunnel alignments, power house areas and alternative tunnels alignments were completed. The drilling work was carried out through private agency. The other specialised Survey & Investigation works like construction material survey, borrow area survey, geological survey, archeological survey, mineral survey etc were out sourced to Government Agencies like CSMRS, GSI, Archeological Survey of India (ASI) etc.

Certain Survey and Investigations, which could not be completed due to resistance from local peoples in the project area are proposed to be carried out at pre-construction stage.

6.0 Climate

The climate of the Damanganga-Pinjal link project area is characterised by dryness except in south-west monsoon season. The year may be divided into four seasons, the cold season from December to February followed by the hot season from March to May and the south-west monsoon season from June to September followed by the post-monsoon season from October to November. The basins receive 97% of annual rainfall during monsoon season from June to September. The average annual rainfall in Damanganga basin varies from 1657 to 2983 mm whereas the same in Vaitarna basin varies from 1748 to 7798 mm.

There are two meteorological observatories: Dahanu maintained by IMD; and Valsad maintained by Gujarat Government, located in the vicinity of the project area. In the region May is the hottest month with the mean daily maximum temperature at 33.6°C at Dahanu and 32.8°C at Valsad. The mean daily minimum temperature in this month is 26.9°C at Dahanu and 25.2°C at Valsad. From November onwards temperature decreases and January is the coldest month with the mean daily minimum temperature at 16.7°C at Dahanu and 13.1 °C at Valsad. The mean daily maximum temperature in this month is 27.6°C at Dahanu and 28.2°C at Valsad.

The air is very humid during south-west monsoon season. In the post-monsoon, cold and summer seasons the air is dry. The relative humidity increases with the onset of monsoon and attains higher values upto 88% in the month of August at Dahanu and 89% at Valsad observatories. The relative humidity is as low as 64% at Dahanu in the month of February and 42% at Valsad in the month of February. The mean maximum and minimum wind velocities observed at Dahanu station are 20.4 km/hr in August and 8.1 km/hr in November and the same for Valsad observatory are 12.33 km/hr in June and 4.3 km/hr in December.

The mean maximum cloud cover is observed during the month of August whereas the minimum cloud cover is observed during the month of February. The mean monthly evapotranspiration values observed at Dahanu

observatory varies from 124 mm (December) to 226.3 mm (May) and the same at Valsad observatory varies from 120.9 mm (December) to 238.7 mm (May).

7.0 Topography & Physiography

Bhugad reservoir: At Bhugad dam site, the Damanganga river flows through a well defined channel with a change in direction from North-East to South-South West. The deepest bed level of the river Damanganga at the proposed Bhugad dam site is 101.16 m. The proposed Bhugad dam site is flanked by steep slope (40°) at the right bank rising up to RL 245 m and forming a prominent rock scarp between RL 220 m and RL 245 m. On the left bank, the river is characterised by a narrow river terrace (RL 106 m to 110 m) with a microscarp (23 m) exposing cross stratified sandy and bouldary river fill. Beyond the river terrace, the left bank is characterised by a wide spread area of highly guilled undulating and hummocky topography with hummocks rising to a maximum height of RL 132 m. The left abutment rises at moderate slopes (20°) to a level of RL 190 m.

Khargihill reservoir: The Vagh river near Khargihill dam site flows in northerly direction through a well defined channel and its deepest bed level is 84.825 m. The area of Khargihill dam is flanked on the right bank by steep rock-cut slopes attaining a maximum level of RL 185 m with a prominent 35 m vertical scarp at the crown. On the left bank, beyond the boundary zone, the channel bed lies as 258 m wide section of alluvial fill characterized by terrace between RL 91 m and RL 96 m and undulatory topography. The left abutment rises at a slope of 30° and terminates into plateau with a scarp between RL 147 m and RL 174 m. Further 1.5 km towards south-west of dam site, the plateau comes down to a level of RL 137 m forming a prominent saddle at north of village Vavar.

8.0 Population

The population of Damanganga basin upto proposed Bhugad and Khargihill dam sites based on 2011 Census is 1.73 lakh and that of Mumbai city is 184 lakh. Damanganga – Pinjal link project has been planned to

augment the domestic water supply of Mumbai city. As such the population of Mumbai city will be benefitted by this project. The project will also provide water to the local population in the vicinity of the reservoirs for meeting the various requirements such as domestic, irrigation etc.

9.0 Geology, geophysical, Geo-technical & seismic Study i Local Geology

The Damanganga – Pinjal Link Project lies west of Trimbak in northern part of Western Ghats and is characterised by highly dissected terrain with flat summits, mural slopes, serrated ridges and deeply entrenched valleys. The area exposes thick pile of Deccan lava flows consisting of compound Pahoehoe and simple flows that are grouped as Salher and Ratangarh formations. The detailed geological mapping and traverses in the area revealed that the main dams, reservoirs and the other appurtenants of Damanganga - Pinjal link project are located within the oldest compound pahoehoe flow of the Salher formation exposed in the area.

The Bhugad reservoir lies in the Deccan Volcanics. The rock assemblage exposed is classified as Salher formation, which comprises of group Pahoehoe flows successions. No major fault or shear zone was noticed in the area, the reservoir area appears to be tight with no perceptible shear or fault zone criss-crossing the area. Neither minerals of economic importance nor monuments of archaeological importance will come under the submergence of the Bhugad reservoir. The rock type encountered is moderate to highly amygdular basalt, which is generally non-porphyrific in nature with occasional thin bands of massive basalt occurring in it.

The Khargihill reservoir area is made of Pahoehoe and flows of Deccan volcanics belonging to lower part of Salher Formation. The rocks encountered are massive basalt and amygdular basalt and are devoid of any fault or shear zones while the joints are mostly tight and as such there will be no problem of reservoir leakage. Neither minerals of economic importance nor monuments of archaeological importance will come under the submergence of the reservoir.

The entire length of the tunnels from Bhugad to Khargihill and Khargihill to Pinjal reservoir pass through the lowermost compound pahoehoe flow of the Salher formation cutting across various massive and amygdular units which is considered to be good rock for the tunneling media.

Presence of bole bed is recorded only on the left bank of Damanganga River adjacent to Bhugad-Khargihill tunnel inlet area in the total area of the project. The bole bed is green in colour and the thickness varies from 30cm to 50cm. Projection of this bed indicated that it is extending to the sill area of the tunnel and will not pose any major problem. At some locations along the tunnel corridor secondary cavities of dimensions as large as 5 m are reported. Such types of secondary cavities of larger dimensions are also anticipated during tunneling. These should be taken care of/ treated depending on dimensions of the cavities and composition of the filled cavities.

ii Sub-surface Geology and Foundation Investigations

Bhugad dam: During preparation of Feasibility Report (FR) 5 drill holes and 5 exploratory pits/trenches (max. depth 10 m) were carried out at Bhugad dam site to find out foundation grade levels and water tightness of bed rock as well as to ascertain the soil structure and its permeability characteristics so as to determine the depth of cut off trench. The interpretation of surface and subsurface data revealed that the rock encountered is massive basalt and amygdular basalt. Permeability tests carried out in all the bore holes reveal that the permeability values have not exceeded 1-12 lugeons.

Khargihill dam: During preparation of Feasibility Report (FR) 4 drill holes carried out at Khargihill dam site and its saddle dam site. The interpretation of surface and subsurface data revealed that the rock encountered is massive basalt and amygdular basalt and is exposed in the right bank. Overburden upto 30 m depth has been encountered in one hump on the left bank.

Tunnels: In order to assess the exact depth of overburden/scree materials, bedrock profile, discontinuities characters, to pickup adverse geological features, if any and to check the presence of red/green boles, sub-surface

exploration was carried out. Total twelve boreholes with cumulative depth of 1016.50m were drilled along the tunnels and edit portals. Logging and assessment of all these boreholes have been carried out by GSI indicates that massive basalt, amygdular basalt, fragmentary porphyritic basalt and massive porphyritic basalt are the rock types encountered in the boreholes.

The Rock Quality Designation (RQD) varies from 50 to 100% and the rock mass in general is categorized as fair to very good categories (Deere's classification). Based on the logging and assessment of the borehole cores, tunneling media for both the links was fairly established. It is inferred that, for most of the part at Bhugad-Khargihill link tunnel, tunneling media will be massive basalt. For the Khargihill – Pinjal link tunnel, massive Basalt (<10% amygdules) and amygdular Basalt (10-75 % amygdules) will be the tunneling media. Massive porphyritic basalt and fragmentary porphyritic basalt will be the tunneling media in the initial reaches of the Adit – I of Khargihill – Pinjal link tunnel.

Analysis of the water pressure tests carried out at top levels and at tunnel grade levels indicates laminar type of flow in all the test depths. The water loss varies from 0.2 lugeon to 0.6 lugeon which is negligible. From this, it can be inferred that the tunnelling medium in general may be dry or at the most wet.

As the most predominant flow bedding joints are disposed sub-horizontally, the tunnel profile is anticipated to be stepped. Smooth planar nature and very close spacing of the flow bedding joints intersected by other sub vertical joints indicate that systematic rock bolting support may be necessary for the majority of the reaches of the tunnel and adits.

In addition to the tunneling problems while negotiating the above weak zones, minor problems of over/side breaks may occur due the intersection of smooth planar, shear and filled joints, etc., and high water flow/ water seepage near the intrusive dykes.

Sub-surface rock mass classification was also attempted based on the data collected by logging and assessment of borehole cores, which is also worked out to be 'Good' for massive & amygdular basalt.

iii Seismicity

The studies for site specific design ground motion parameters for the various components of Damanganga-Pinjal Link Project have been carried out by Central Water & Power Research Station (CW&PRS), Pune during the year, 2011. As per these studies the deterministic estimate is found to be governed by a maximum credible earthquake magnitude of 6.3 at a closest distance of 18.0 km to the fault rupture plane. The values of peak ground acceleration for horizontal and vertical components are found to be 0.280 g and 0.223 g for maximum credible earthquake (MCE) conditions and 0.140 g and 0.112 g for design basis earthquake (DBE) conditions. This report has been approved by the National Committee on Seismic Design Parameters in its 23rd meeting held on 20th November 2012. The dam wise summarised seismic design parameters have been communicated by FE&SA Directorate of CWC vide their letter No. 2/2/2012 (vol-I)/FE&SA/17 dated 4th January, 2013.

10.0 Hydrology and Water Assessment

The hydrological studies of Damanganga basin as a whole and also upto the proposed Bhugad and Khargihill dam sites were carried out by CWC in consultation with NWDA and Gujarat and Maharashtra States to assess the water balance position at the ultimate stage of development (by the year 2050 AD). As per the study the 100% dependable gross annual yield of Damanganga basin at proposed Bhugad dam site and Khargihill dam sites has been assessed to be 372 Mm³ and 477 Mm³ and the 75 % dependable gross yield has been assessed to be 517 Mm³ and 748 Mm³ respectively.

After considering the upstream utilizations planned by the States for irrigation through existing, ongoing and proposed projects, hydropower project's reservoir evaporation losses, domestic & Industrial requirement, down-stream committed releases and environmental and ecological needs

about 284 Mm³ and 401 Mm³ of surplus waters at 100% dependability are available at proposed Bhugad and Khargihill dam sites respectively for transfer to proposed Pinjal reservoir for augmentation of domestic water supply to Mumbai City. To work out the quantity that can be diverted from Bhugad and Khargihill reservoirs to Pinjal dam for augmentation of drinking water supply to Mumbai city, simulation analysis considering the inflows, local demands, committed down-stream release, environmental flow requirement and capacity of the reservoirs has been carried out for the period from 1975 to 2004. Simulation analysis indicates that about 210 Mm³ of water from Bhugad reservoir and about 369 Mm³ of Water from Khargihill reservoir at 100% success rate (total 579 Mm³ from Damanganga basin) can be transferred to Pinjal reservoir. The waters available at Pinjal dam for diversion to Mumbai for augmentation of domestic water supply is 316 Mm³. The combined waters of Bhugad and Khargihill reservoirs of Damanganga basin and Pinjal reservoir of Vaitarna basin for transfer to Mumbai city is assessed to be 895 Mm³.

11.0 Flood Control and Drainage

No flood storage is earmarked in any of the reservoirs proposed under Damanganga – Pinjal link project. However, due to storage in the reservoirs and release into the tunnels for augmentation of domestic water supply to Mumbai city, there will be incidental flood moderation in the areas down-stream of Bhugad and Khargihill dam sites.

12.0 Reservoir and Power

Two reservoirs i.e. Bhugad and Khargihill reservoirs are planned to be utilized for diversion of surplus Damanganga water at these two dam sites to Pinjal reservoir for augmentation of domestic water supply to Mumbai city. The Bhugad reservoir will have gross storage capacity of 427.07 Mm³ at FRL 163.87 m and dead storage of 28.496 Mm³ an MDDL of 124.83 m. The Khargihill reservoir will have gross storage capacity of 460.896 Mm³ at FRL 154.52 m and dead storage of 40.850 Mm³ an MDDL of 109.75 m.

Two power houses; one each in the down-stream of Bhugad and Khargihill reservoirs are proposed. The power house at Bhugad dam will be with 2 units each of 1.0 MW installed capacity each. The annual energy generation in the 90% dependable year and at 95 % plant availability will be 9.09 Million Units (MU). Power house at Khargihill dam will be with 2 units each of 1.5 MW installed capacity. The annual energy generation in the 90% dependable year and at 95 % plant availability will be 16.20 MU.

13.0 Irrigation and Command Area Development

Damanganga – Pinjal link has been planned as a drinking water supply project for augmentation of domestic water supplies of Mumbai city, as such no irrigation is proposed under the project.

14.0 Navigation and Tourism

Navigation is not proposed under this project. Regarding tourism development, the tourist/picnic spots are proposed to be developed on the periphery of Bhugad and Khargihill reservoirs.

15.0 Design Features

Bhugad Dam: The height of the Bhugad dam has been designed as 69.42 m with top width as 16 m. The FRL of the Bhugad dam has been kept as 163.87 m. The concrete portion of the dam will be 324 m long whereas concrete faced rock fill portion will be 527.5 m. The spillway will have 9 bays of 13.5 m long each. The power house at dam toe is proposed with 2 units of 1.0 MW each.

Khargihill Dam: The height of the Khargihill dam has been designed as 77.92 m with top width as 10 m. The concrete portion of the dam will be 277.20 m long whereas concrete faced rock fill portion will be 341.00 m. The FRL of the Khargihill dam has been kept as 154.52 m. The spillway will have 6 bays of 14.0 m long each. The power house at dam toe is proposed with 2

units of 1.5 MW each. The height of Khargihill saddle dam has been designed as 25.92 m with a top width as 8.0 m. The length of the saddle dam is 400 m.

Total length of Bhugad – Khargihill tunnel will be 17.488 Km with diameter of 3.2 m and bed slope as 1:1342. The tunnel will be of D - shape.

Total length of Khargihill - Pinjal tunnel will be 25.224 Km with diameter of 4.0 m and bed slope as 1:1717. The tunnel will be of D – shape.

16.0 Construction Materials

The construction materials required for the project i.e. rock and aggregates, sand, soil etc. can be met from the nearby quarries located in the project area. The laboratory testing of various materials has been carried out through CSMRS. These materials have been found suitable for use as construction material. Damanganga river with its steep gradient does not have sand in the vicinity except for small quantity. Crushed sand made of the rock is proposed to be utilized as replacement to natural sand. The link project envisages construction of 2 tunnels of about 42 Km long. The muck to be generated from these tunnels can be used as construction material for concrete face rockfill dams and also for producing sand by crushing the rocks for use in concrete.

The nearest cement factory for the dam sites is the Narmada cement factory which is located at Surat about 100 km from the project area. Cement can be transported upto Valsad/ Vapi and Dahanu rail head by railway and further upto project/colony sites by road.

Friends Ispat Plant is located at Ahmadabad. Shree Sai Krupa Ispat plant is located at Khopoli, Raigad District in Maharashtra state. The steel required for project construction can be procured from these plants and transported to Valsad, Vapi, and Dahanu rail heads by rail and further upto project/colony sites by road.

17.0 Accessibility & Infrastructure

The link Project is located in Valsad district of Gujarat State and Nasik and Thane districts of Maharashtra State. The Bhugad dam across Damanganga river is located near village Bhugad of Trimbak taluka of Nasik district in Maharashtra State. The nearest railway station for this dam site is Valsad on Mumbai – Delhi route of western railway. The Bhugad dam is approachable from Valsad (Gujarat State) through Valsad - Dharampur – Nasik State Highway upto Statebari village which is about 70 km away from Valsad and thereafter about 25 km bituminous road upto village Modushi of Kaprada taluka of Valsad district on right bank of Damanganga river. The Bhugad dam site lies 1 km upstream of Modushi village and is approachable by foot track. While the bituminous road from Statebari to Modushi village may have to be widened and a new road is required to be constructed from Modushi village to transport heavy machinery and construction materials to Bhugad dam site. The Bhugad dam is also approachable from Nasik side through Nasik – Harsul – Baphanvahir – Ranapada – Bhugad village (80 Km). The nearest airport in the vicinity of the Bhugad dam site is located at Surat (170 km).

Khargihill dam is proposed across river Vagh near village Behadpada in Jawhar taluka of Thane district in Maharashtra state. The nearest railway stations for this dam site are Umargaon and Sanjan on Mumbai – Delhi route of western railway. The nearest town is Jawhar, which is a taluka headquarter in Thane district. The dam site is approachable from Vapi – Bhilad (24 km) (NH-8) then Bhilad – Silvassa – Chalatwar – Behadpada State Highway (83 km). The site is also approachable from Nasik side through Nasik – Harsul – Ozarkhed – Behadpada road (85 km). The airport in the vicinity of proposed Khargihill dam site is located at Mumbai (170 km).

The Bhugad - Khargihill tunnel alignment is approachable through Nasik – Harsul -Ozarkhed road. The Khargihill – Pinjal tunnel alignment is approachable through Nasik – Jawhar and further major district roads and village roads in the project area. However the approach roads upto adits of both the tunnels are to be constructed as per requirement.

18.0 Construction and Equipment Planning

The schedule of construction of the link project is planned for a period of seven years. The infra-structural development like project colonies, approach roads, workshop, haul roads, stores, office buildings, etc, pre-construction surveys and investigations, preparation of design/specifications and tender documents are planned to be completed during first two years. The construction of all civil structures has been planned to be completed within 3rd quarter of 7th year. The erection, commissioning and testing of units would be required to be planned so that full benefits could be accrued at the end of the proposed construction period. The requirement of important construction equipments as assessed by Construction Management Organisation, CWC is furnished below. Suitable provisions for these construction equipments have been kept in the estimate.

S. No.	Name of Equipment	Capacity	Quantity
1	Hydraulic excavator	2 m ³	14
2	Front End loader	2.5 m ³	14
3	Front End loader	1.5 m ³	5
4	Loader-cum-Excavator	1.0/0.24 m ³	10
5	Crawler dozer	180 Hp	33
6	Heavy duty rock hammer /Jack hammer	120 cfm	38
7	Wagon drill/Crawler Drill	600 cfm	10
8	Hydraulic Drill Jumbo (single Boom)		10
9	Rock Bolting Jumbo		6
10	Rear dumper	18/20 t	97
11	Tipper	4.5 m ³	99
12	Vibratory compactor (pad foot)	10 t	2
13	Vibratory compactor (smooth drum)	10 t	6
14	Water sprinkler	8000 L	16
15	Transit mixer truck mounted	4.5 m ³	68
16	Filter processing plant	750 tph	1
17	Filter processing plant	500 tph	3

18	Filter processing plant	300 tph	1
19	Filter processing plant	250 tph	1

20	Aggregate processing plant	250 tph	1
21	Aggregate processing plant	300 tph	1
22	Aggregate processing plant	70 tph	10
23	Batching and mixing plant	120 m ³ /hr	1
24	Batching and mixing plant	90 m ³ /hr	1
25	Batching and mixing plant	30 m ³ /hr	10
26	Mobile batching and mixing plant	18 m ³ /hr	4
27	Concrete Mixer	14/10 cft	10
28	Concrete pump with boom	38 m ³ /hr	6
29	Concrete pump	25 m ³ /hr	10
30	Concrete pump with boom	15 m ³ /hr	2
31	Shotcrete Machine	4/6 m ³ /hr	10
32	Shotcrete Machine with robot arm	10 m ³ /hr	10
33	Collapsible Shutter Form with Traveler	3.2x10 m	6
34	Collapsible Shutter Form with Traveler	4.0x10 m	8
35	Grout pump	20 kg/m ²	24
36	Tower crane	6t@40m	4
37	Tower crane	10t@50m	3
38	Dewatering pump	LS	LS
39	Compressed air	cfm	8100
40	Air Compressor Diesel		10
41	Mobile crane	16 t	4
42	Truck	8/10 t	24
43	Concrete vibrator (electrical/ pneumatic)		21
44	Hydraulic rock breaker	10 t	2
45	Hydraulic rock loader, Railed	50 m ³ /hr	4
46	Hydraulic rock loader, Railed	80 m ³ /hr	6

47	Muck Car	6 m ³	24
48	Muck Car	9 m ³	42
49	Wheel loader	1 m ³	10

19.0 Environmental and Ecological Aspects of the Project

The water resources projects when built increase the water availability leading to various developmental activities and prosperity in the area, but some adverse impacts on the environment are also seen. As such it is necessary to identify the adverse impacts of the project and suggest the measures to mitigate or ameliorate the anticipated adverse impacts on the environment. To identify the possible environmental impacts, both positive and adverse due to the proposed Damanganga-Pinjal Link Project and to suggest measures to mitigate or ameliorate the anticipated adverse impacts on the environment, the Environmental Impact Study of Damanganga – Pinjal Link project has been carried out through WAPCOS Limited.

(i) Base line study and EIA study

The baseline levels of environmental parameters which could be significantly affected by the implementation of the project are essential to be ascertained before implementation of the project. The baseline status shall involve both field work and review of data collected from secondary sources. The baseline survey planning commenced with the short listing of impacts and identification of parameters for which the data needs to be collected. Baseline status has been ascertained for air environment, water environment, land environment, public health and biological (terrestrial and aquatic) environment. The likely impacts due to the project during construction and operation phases have been studied on the aspects like land, water and air environments, aquatic and terrestrial ecology, socio-economic, impact on public health, risk on failure of dam structures etc.

(ii) Flora and Fauna

The impacts on forest cover; rare, endangered and threatened species and impacts on wildlife such as impact due to habitat change having effect like corridor loss and loss of migratory path for wildlife including birds, impact on breeding grounds of species, impacts on access of animals to food and shelter have been studied. The study indicates that rare, endangered and threatened

species are not reported in the study area. The impacts due to acquisition of forest land shall be mitigated through compensatory afforestation measures and implementation of biodiversity conservation measures suggested in the EMP Volume. The proposed reservoir does not lie on migratory path of any wildlife. Thus, no major adverse impact of corridor loss is anticipated. The impact on aquatic ecology due to: increase in the turbidity levels; spawning areas of fishes; damming of river and impacts on migratory fish species etc were also studied.

(iii) Land use pattern

Majority of the environmental impacts during construction phase are temporary in nature, lasting mainly during the construction phase and for small duration beyond the construction period. The major impacts anticipated on land environment during construction phase are: environmental degradation due to immigration of labour population; operation of construction equipment; soil erosion; and solid waste management. Remedial measures have been suggested to mitigate/ameliorate these impacts. During operation phase the impact is mainly due to submergence of land by the Bhugad and Khargihill reservoirs. These two reservoirs will submerge about 3461 ha land (Bhugad reservoir – 1903 ha and Khargihill reservoir – 1558 ha) of which 966 ha (28 %) if the forest land, 1422 ha (41 %) is agricultural land and 1073 ha (31 ha) land is under river portion including other land. Damanganga-Pinjral link has been planned as drinking water supply project to augment the domestic water supply of Mumbai city and the transfer of water will be through the lined tunnels, as such, water logging is not expected due to this project.

(iv) Environmental Management Plan (EMP)

The various environmental aspects such as pollution control at construction sites; water quality management; land management plan, biodiversity conservation and management plan; green belt development plan; environmental management in labour camps; public health management;

catchment area treatment (CAT) plan, dam break analysis and disaster management programme (DMP), environmental monitoring programme etc have been considered and suitable provisions have been kept in the estimate.

Damanganga – Pinjal link when completed will provide 895 Mm³ water (579 Mm³ from Damanganga basin and 316 Mm³ from Pinjal sub-basin of Vaitarna basin) to Mumbai city for augmentation of its domestic water supply. Both the reservoirs are devoid of any mineral of economic importance and no monuments or any remains of archaeological importance were noticed in the project area of Damanganga - Pinjal Link. Ensured release of minimum quantity of water required to maintain the river ecology down-stream of dams during lean season will increase the river ecology. Due to creation of Bhugad and Khargihill reservoir the ground water level in the down-stream areas will rise. The water samples tests indicate that organic and heavy metal components in the water are within permissible limits. The rocks in the reservoirs area are hard, massive and devoid of any major fault or shear zones while the joints are mostly tight and as such there will be no problem of reservoir leakage. The total estimated cost for implementation of Environmental Management Plan (EMP) is Rs. 12142 lakh (excluding the cost of R&R Plan).

20.0 Socio-economic aspects & Resettlement and Rehabilitation

About 3461 ha land area will come under submergence of proposed Bhugad and Khargihill reservoirs: Bhugad reservoir 1903 ha; and Khargihill reservoir 1558 ha. Out of total 3461 ha land 1421.85 ha will be agriculture land, and 965.75 ha will be forest land. Total number of affected families would be 2302 of which 1098 families would be affected due to creation of Bhugad reservoir spread over 14 villages and 1204 families would be affected due to Khargihill reservoir spread over 16 villages in Kaprada taluka of Valsad district of Gujarat and Trimbak and Peint talukas of Nasik district and Jawhar and Mokhada talukas of Thane district of Maharashtra. The affected families may lose their lands or houses or both in the submergence when the reservoirs are created. All the affected families would be compensated for the loss of their lands and houses. The families whose houses are coming under submergence

would be resettled in the new habitations and would be assisted to take up some alternative occupation in the new surroundings.

(i) Resettlement & Rehabilitation Plan

The Department of Land Resources (DLR), Ministry of Rural Development, Government of India formulated a policy entitled, “National Rehabilitation & Resettlement Policy-2007”. Similarly, the State Governments of Madhya Pradesh, Gujarat and Maharashtra also developed the R&R Policies for Project Affected Peoples (PAPs) of Sardar Sarovar Project. Keeping in view these policies a R&R package has been developed to compensate the project affected families enabling them to gain at least their levels of living standards. All major sons in a joint family are to be treated as separate families and would be entitled for all R&R benefits

All the Project Affected Families will be provided Rehabilitation & Resettlement assistance. The rehabilitation assistance would include sanction of productive asset grant to each head of project affected households and also to each of the major son of such households, besides provision of subsistence allowance, annuity, mandatory employment for one member from each family or compensation, R&R relief aid, vocational training grant, etc. The costs for resettlement of displaced persons includes free residential plot, house building assistance, grant for construction of cattle shed, and civic amenities like domestic water, electricity, school, play ground and children park, health centre, resettlement centre, place of worship, community hall, sanitation, drainage, approach roads, public transport, place of funeral etc. The total cost of Resettlement and Rehabilitation of the project affected families including cost of Local Area Development Plan and monitoring & evaluation aspects works out to be Rs. 623 Crores.

Socio-economic condition of the people living in command area as well as in near vicinity of the project will improve in general. No major adverse impacts are anticipated due to the link project on the socio-economic front. Damanganga – Pinjal link envisages transfer of surplus waters of Damanganga basin at proposed Bhugad and Khargihill reservoirs to proposed Pinjal

reservoir for augmentation of domestic water supply of Mumbai city. However, before affecting the transfer of water it will be ensured that the water requirements for various purposes of the local peoples are met on priority. Tourism will develop in the project area. Enormous employment opportunities will be generated in the project area during project construction phase and also project operation phase.

21.0 Cost estimate

The cost estimate for Damanganga – Pinjal link has been prepared based on the quantities of various material and works involved in the various components worked out based on the engineering drawings. To work out the rates of various items the rate analysis has been carried out using the rates of various materials, man power etc from schedule of rates for South Gujarat region of Water Resources Department, Government of Gujarat for the year 2012-13. Rates for the items which are not available in the schedule of rates of Gujarat and Maharashtra, have been taken from schedule of rates of WRD, Government of Karnataka for the year 2012-13.

The total cost of Damanganga – Pinjal link project has been estimated to Rs. 274661 lakh. The details are in the following table:

Item	Estimated cost
Unit-I Head works	271130 lakh
Unit-III Hydro-electric installations	3531 lakh
Total	274661 lakh

22.0 Economic & Financial Evaluation

Sl. No.	Description	Rs. in lakh
1	Sale of Domestic water	72533
2	Sale of power	688
	Total	73221

3	Annual cost like interest, depreciation, operation & maintenance (O&M) charges for head works and power plants, apportioned annual cost of conveyance system beyond Pinjal dam etc.	37615
4	Benefit cost ratio	1.95
5	Internal Rate of Return	16.29%

23.0 Clearances Required

The Damanganga-Pinjal link project will require the following clearances:

S.No.	Clearance	Agencies
i.	Techno Economic Clearance	Central Water Commission and TAC of MoWR
ii.	Resettlement and Rehabilitation of Tribal Population	Ministry of Tribal Affairs

The Ministry of Environment & Forest (MOEF) vide letter No.J-12011/56/2008-IA.I dated 03-12-2008 indicated that the project being a drinking water supply project does not come under the provision of EIA Notifications,2006, as such environmental clearance is not required.

Based on the above clearances, investment clearance will be accorded by the Planning Commission.

24.0 Data Base

During preparation of DPR the data required for various studies/ design of various components were collected from field while carrying out field investigations and also from various Government agencies and data base has been prepared in the field office.

