



# Draft Feasibility Report On Pinjal Dam

November 2011

Municipal Corporation of Brihan Mumbai



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# Content

<b>Chapter</b>	<b>Title</b>	<b>Page</b>
1		
<b>1</b>	<b>Introduction</b>	<b>1</b>
1.1	General	1
1.2	Present water supply	1
1.3	Recommendations of Dr.Chitale committee	2
1.4	Population and water demand projections	2
<b>2</b>	<b>Basin Characteristics</b>	<b>1</b>
2.1	General	1
2.2	Topography of the region	1
2.3	Geology	1
2.4	Rainfall	2
2.5	Temperature	2
2.6	Relative Humidity	2
2.7	Wind speed	2
<b>3</b>	<b>Hydrology</b>	<b>3</b>
3.1	Precipitation	3
3.2	Runoff	1
3.3	Yield Studies	1
3.4	Sedimentation	1
3.5	Evaporation	2
3.6	Flood Studies	2
<b>4</b>	<b>Previous Studies</b>	<b>3</b>
4.1	Population studies	3
4.2	Recommendations of Dr. Chitale Committee	3
4.3	NWDA Report – Releases from Damanganga to Pinjal	3
<b>5</b>	<b>Dam Studies</b>	<b>5</b>
5.1	Site selection	5
5.2	Location of the Dam	6
5.3	Geotechnical investigation	6
5.3.1	Subsurface Soil Profile	6
5.3.2	Bed rock	7
5.3.3	Dam foundation considerations	7
5.4	Type of Dam	7
5.5	Storage Planning	8
5.6	Free board	8
5.7	Location of spillway	8
5.8	Spillway Capacity and Gate Dimensions	9
5.9	Control Levels	10

5.10	Layout of the dam location _____	10
5.11	Overflow section _____	10
5.11.1	Design of Ogee Spillway _____	10
5.11.2	Energy Dissipation Arrangement (EDA) _____	11
5.11.3	Protection Works _____	11
5.12	Non-Overflow section _____	11
5.13	Stability Analysis of OF & NOF sections _____	11
5.13.1	Various Forces _____	12
5.13.2	Load combinations _____	12
5.14	Galleries _____	13
5.15	Grouting _____	13
5.16	Construction Joints _____	14
5.17	Instrumentation in Concrete gravity dams _____	14
5.17.1	Obligatory Measurements _____	14
5.17.2	Optional Measurements _____	14
5.18	River Diversion _____	14
5.19	Infrastructural works _____	15

## 6 Cost Estimates 16

## Appendices I

### Appendix A. II

A.1.	Monthly & Annual River Flows at Andhari River Gauge Station _____	II
A.2.	Dependable Yield - Pinjal River Basin _____	II

### Appendix B. III

B.1.	Capacity – Elevation Curve _____	III
B.2.	Area – Elevation Curve _____	III
B.3.	Free Board Calculations _____	III
B.4.	Design of Ogee Spillway and Energy Dissipation Arrangement _____	III
B.5.	Stability Analysis for Overflow Section _____	III
B.6.	Stability Analysis for Non-Overflow Section – Main Gorge _____	III
B.7.	Stability Analysis for Non-Overflow Section – Shallow Gorge _____	III

### Appendix C. IV

C.1.	Cost Estimates _____	IV
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## Tables

Table 1.1:	Present Demand _____	1
Table 1.2:	Present Available Water _____	2
Table 1.3:	Available Source _____	2
Table 1.4:	Population Projection by Arithmetic Average Method _____	3
Table 1.5:	Water Demand projections for the year 2021 and 2041 _____	3
Table 3.1:	Precipitation at different rain gauge stations Recorded from 1976 to 2005 _____	3
Table 3.2:	Estimated Sediment loads for proposed pinjal Reservoir in MCM _____	2
Table 4.1:	Sources of Supply to Mumbai city _____	3
Table 5.1:	Rock properties _____	6
Table 5.2:	Characteristic Strength of rock specimen _____	7
Table 5.3:	Spillway Gate Dimensions _____	9
Table 5.4:	Control levels of Pinjal Dam _____	10
Table 5.5:	Parameters considered in design of Pinjal Dam _____	12

# 1 Introduction

## 1.1 General

Mumbai is among the ten mega cities of the world and financial hub of India with the present population of about 14.5 million. The population of the city is increasing ever since the independence, due to available infrastructure for the rapid development and business opportunities. The city has grown beyond its limits and a large population lives in the suburbs from where they travel to work place located in city. Basic infrastructure like assured water supply is one of the major factors, which leads to the development of a city. The total water demand of a city mainly depends on the climatic conditions, lifestyle of the major population, type and number of industries in the city.

Municipal Corporation of Greater Mumbai had taken initiatives to timely augmentation of sources to keep pace with development and to deliver continuous water at nodal points. This issue forced MCGM to explore the water supply sources for augmentation of water supply on top priority in addition to the water conservation measures. This will meet the ever growing demand for water supply of the Mumbai city.

## 1.2 Present water supply

The present estimated population of Mumbai is about 14.5 Million. About 40% of this total population resides in slum and remaining 60% in planned development. Slum population is eligible for availing the water supply of 45 lpcd where as water supply to population in planned development is 135 lpcd. Due to ongoing slum rehabilitation programme, cluster developments in the city, redevelopment of old houses and development of land due to closure of textile mills with Floor Space Index(FSI) incentive, increase in water demand is at very rapid rate. The national norm as per CPHEEO manual is 150lpcd. The present demand with existing residential consumption pattern, industrial and commercial requirement of about 500 MLD available supplies is tabulated below:

Table 1.1: Present Demand

Description	Population (million)	Supply Norms (lpcd)	Total Demand in MLD
Population	14.5		
Slum 40%	5.8	100	580
Planned Development 60%	8.7	200	1740
Industrial and commercial Demand			500
Leakages in distribution system at 30%			1208
Losses at WTP @ 0.25%			10
Transmission losses @2%			80
Add Enroute supply			120
			4238
Total			Say 4240

Table 1.2: Present Available Water

Source	Yield at source in MLD
Tulsi	18
Vehar	90
Tansa	410 + 90 Enroute
Modak sagar	455
upper vaiarna	635
Bhatsa I+II+III+IIIA+IIIB	1820
	3518
Total	Say 3520

Above tables indicates a deficit of about 17% in available water supply against the demand and overall satisfaction level of about 83%. Present water supply is intermittent supply hours ranging from 2hrs to more than 12hrs depending upon the location of the water supply zone, drawal facility and the water distribution network.

### 1.3 Recommendations of Dr.Chitale committee

The expert committee was appointed by Govt of Maharashtra in the year 1993, under the chairmanship of Dr. Chitale (Ex-Secretary, Irrigation Dept) for advice on the long term planning for augmentation of water supply to Mumbai. The committee recommended water supply norms for the city at 240 lpcd considering the climate in Mumbai city, habits, and requirements for good health and to prevail good environmental conditions. Based on the surveys carried by the committee, considering the subtropical climate and modern gadgets, the planned development requirement is worked out as 240lpcd and that of slum at 150lpcd, considering the continuous water supply system. The committee also recommended development of following sources in phases.

Table 1.3: Available Source

Sr. No.	Source	Basin	Yield [MLD]
1	Middle Vaitarna	Vaitarna	455
2	Gargai	Vaitarna	455
3	Pinjal	Vaitarna	865

The GoM has accepted Dr. Chitale Committee recommendations and approved the above mentioned sources. MCGM has therefore taken up the Middle Vaitarna Project as an immediate additional source of water supply. Simultaneously feasibility studies of Gargai and Pinjal Projects are under process.

### 1.4 Population and water demand projections

Mumbai City is the Financial Capital of India and has recorded highest rate of influx of migrants from all parts of the country for past many years and will continue to attract people from all parts of India in future too. The city has good infrastructure to cater the needs of the residents. Population growth pattern of Mumbai is continuously rising and according to report of M/s Lee Associates, the consultants appointed by Mumbai Metropolitan Region Development Authority (MMRDA) in the year 2007 for infrastructural development of Mumbai Metropolitan region (MMR), the population growth pattern of past will continue till the year 2031. Population projection from the year 2031 to 2041 is projected based on arithmetic average method which is adopted for old cities and small towns.

Table 1.4: Population Projection by Arithmetic Average Method

Years	Population (millions)	Increase in Population (millions)	Average increase in Population (1951-2031) (millions)	Projected population till 2041 (millions)
1951	3.00	0.00		
1961	4.20	1.20		
1971	6.00	1.80		
1981	8.30	2.30		
1991	9.90	1.60		
2001	11.98	2.08	1.82	21.21
2011	14.52	2.54		
2021	17.15	2.63		
2031	19.39	2.24		
2041	21.21	1.82		

The population growth till the year 2031 is linear projection of census population available from the year 1951 to 2001. Further projection is done by arithmetic average of increase from the year 1951 to 2031 i.e. 1.82 million per decade. The population for the year 2041 with the above average, adopted for old cities works out to 21.21Million.

The water demand projections for the year 2041 are based on following assumptions made by Dr Chitale committee.

- Population in slums are supplied at the rate of 150 lpcd (24X7 scenarios).
- The consumers in the planned developments will continue to draw water at the rate of 240 lpcd.

Table 1.5: Water Demand projections for the year 2021 and 2041

Description	Supply Norms in lpcd	Total demand in MLD (2021)	Total Demand in MLD (2041)
Total population in Million 17.15(2021) 21.21(2041)			
Slum (30%): 5.145 million(2021) 6.363 million(2041)	150	772	954
Planned Development (70%) 12.005 Millions (2021) 14.847 million (2041)	240	2881	3563
Industrial & Commercial Demand		550	550
Leakages in Distribution System	@ 20%	930	1268
loses in at water treatment plant	@ 0.25%	12	16
loses in transit & transmission	@ 2%	94	128
Add enroute supply		150	200
Total		5389	6680

Thus at source the demand will be about 5389 MLD in the year 2021 and 6680 MLD in the year 2041. Present available quantity at source is 3520 MLD against water demand of 4240MLD. The augmentation will not only improve the satisfaction level but also facilitate continuous water supply and to take the effective leak control measures.

## 2 Basin Characteristics

### 2.1 General

The proposed dam on Pinjal River is located near Village Khidse, Jawahar taluka of Thane district of Maharashtra state. The catchment area up to proposed dam site is 317 square kilometers.

River Pinjal originates on the rocky slopes of Utwad Dongar located on the northern side of the ridge separating the Upper Vaitarna Lake, at an elevation higher than 980 m. Pinjal river in its initial course is formed by two streams, a major one originating from the Utwad dongar at a higher elevation of 980m and the other branch near Shirghat to the south, at a much lower elevation of about 600m datum. The Utwad dongar branch flows generally westward and after confluence with a local nalla-Kalakapri nadi, takes a more southward course. At village Bhurteki another nalla Devbandh nadi which is the southern branch of the river confluences with Pinjal thereafter river takes a well defined westward course flowing in characteristic loops, near Dakchapada village, a major tributary flowing down from the north Jawhar nadi joins Pinjal from where it takes a southwesterly course till its confluence with Gargai. Pinjal continues in the same course and joins Vaitarna near the villages of Alman / Pingepada situated about 35 km downstream of Modaksagar dam along the course of Vaitarna River. The ground elevation at its confluence with Vaitarna River is about 30 m. Total length and catchment area of the Pinjal River up to its confluence with Vaitarna is 85 km and 654.3 Sq km respectively

### 2.2 Topography of the region

The topographical information pertaining to Pinjal basin is available with Survey of India topo sheets to scale 1:50,000. These are covered in topo sheet No's 47E/1 and 47E/2. The coordinates of proposed dam site are 19°47'0"N and 73°13'0"E. The elevations referred to in this study are with respect to the Mean Sea Level (MSL) datum unless otherwise specified

The Sahyadri Range which runs north to south form an unbroken boundary and has number of off shoots besides many spurs, isolated peaks, such as Kalsubai Harischandra Ghat and Matheran. The general topography of the region is very undulating and crossed by various ranges which are generally lower in height as one travels west towards Arabian Sea from main continental divide. The river has steep slopes deep with narrow valleys; most of the flow takes place on rock beds in their initial reaches, while the valleys opens wide in its lower reaches. The lower reaches of the river mainly consists of alluvial plains. River flows are interrupted by a large number of dykes of varying thickness. The climatic condition in this region is tropical, very humid and warm. The proposed dam site is encountered by nine lava flows of Deccan basalt, varying in thickness from 7m to 25m

### 2.3 Geology

The area is extensively covered by 766 m thick pile of basaltic lava flows of Deccan trap of upper cretaceous to Palaeogene age. The basalt flows are typically quartz and hypersthene normative with minor amounts of olivine theolites. The lava flows are classified under sahyadri group which divisible into eight formations. The oldest salher formations represented by a megacryst flow constituting the top of this formation. This is overlain by lower Ratangarh formation comprising of mainly compound pahoehoe flows exposed in the area.

## **2.4 Rainfall**

Pinjal river basin receives most of its rainfall from South-West monsoon during June to September. 95% of the annual rainfall occurs during monsoon season and rest of the rainfall is mainly due to orographic and conventional rains. July is the wettest month with a rainfall nearly about 40% of the annual rainfall. Annual maximum and minimum recorded rainfalls are 4455 mm and 2076 mm. The average annual rainfall is 2429mm

## **2.5 Temperature**

The average maximum daily temperature in summer is 32.9°C during April month. The average daily Minimum temperature in winter is 16.8°C during January month.

## **2.6 Relative Humidity**

The relative humidity is high during monsoon and low during March. The relative humidity varies from 32% during March to 89% during August.

## **2.7 Wind speed**

The basin falls in wind zone II as per Indian standards (IS: 875) with normal wind speed of 39.0 m/sec.

## 3 Hydrology

### 3.1 Precipitation

Precipitation data for Pinjal basin is obtained from the State Data Storage Centre (SDSC) of Maharashtra Government located at Nasik. SDSC are repositories of all hydrological and Meteorological data related to major river basins in Maharashtra state under the Hydrology (I & II) project. The precipitation data obtained from SDSC in the form of daily recorded depth in mm of self recording gauges (SRG). There are about 13 rain gauge stations located in and around Pinjal catchment

Daily values of precipitation is available for all days of monsoon months viz; from June to October and up to November in some years. Beyond November for the non - monsoon months, the data is non existent and / or very sparse. It is observed from the data spread in Table: 3.1 precipitation data is not concurrent. Daily values at Khodala are available from 1976 to 2005 and is the longest record for 30 years while that at Khidse is for 10 years only (1989-1998) and is the shortest record. Daily rainfall values at different stations obtained are processed to obtain mean monthly and annual rainfall values.



### 3.2 Runoff

Pinjal is large river and a gauging station on the river is in existence since 1976. The gauging station on Pinjal River is self recording gauge and is located near village Andhari, Jawahar taluka of Thane district of Maharashtra. The flow data available for the studies are the daily average values recorded in Cumec at gauge discharge station. Pinjal records go from 1976 to 2004 (29 years). The data covers the monsoon season fully, extending beyond October in certain years. Observed data suggests that recessed low flows prevail in Pinjal till December. The daily flow values have been processed to generate monthly and annual flows. Compiled monthly and annual flows at Andhari gauge discharge station are shown in Appendix A.1. The annual mean flows of Pinjal at Andhari are calculated as 869 MCM and maximum flows occur in July month.

### 3.3 Yield Studies

Catchment area contributing up to the Andhari gauge station is 335.3 Sq km. Yield studies have been carried out from the runoff data available at Andhari station. Analysis was carried out for available 30 years recorded data from 1976 to 2004 to arrive annual dependable flows. 100%, 95% and 75% dependable annual yield are worked out as 508MCM, 530MCM and 631MCM at gauge discharge station. Proposed Pinjal dam site is located upstream of the Andhari gauge discharge station, with a catchment area of 317 Sq km up to the proposed dam location. The proportionate 100%, 95% and 75% annual dependable yield at dam site are 480MCM, 501MCM and 596MCM respectively. Calculations are attached in the Appendix A.2.

### 3.4 Sedimentation

All reservoirs built on rivers are subjected to the sediment deposition. Sufficient provision of space should therefore be made in the reservoir for the accumulation of the silt load so that their functioning does not get impaired during useful life of the reservoir. This necessitates the estimation of the silt load likely to accumulate in the reservoir.

To estimate annual quantity of sediment deposition, sediment rating curves based on periodic sampling data is necessary, which is not available for Pinjal Basin. Silt storage required at proposed reservoir on Pinjal River could not be estimated as per standard procedures; in this background recourse is made to regional analyses and synthesis. The estimated silt storage for the proposed reservoirs has been arrived at by the following assessment:

Dr. Khosla's guidelines for estimating annual rates of siltation for catchment areas less than 1000sq.km specifies 3.57 Ha-m / 100 sq. km / year. However systematic reservoir sedimentation studies carried out for a number of reservoirs in Maharashtra up to 1994 have showed higher rates of sedimentation than what Khosla's guidelines suggest. In the light of actual hydrographic surveys carried out, a higher rate varying from 3.84 to 8.35 Ha-m per 100 sq. km per year has been recommended for preliminary planning purposes. Pinjal basin is situated in the west flowing Tapti basin. For typical Tapti basin reservoirs like Girna (CA= 4729 sq. km) and Nalganga (315.98 sq. km) observed rates of siltation for is 7.49 Ha-m per 100 sq. km per year and 6.24 Ha-m /100 sq. km / year respectively. It may be noted here that Girna has been in existence for 14 years and Nalganga for 22 years.

Central Water Commission (CWC) has suggested an enveloping value of 1.1 acre- feet per year per sq. mile of catchment area for estimation of average annual silt deposit (5.28 ha-m/ 100 sq km per year).

In detailed feasibility studies carried out for the Middle Vaitarna storage (1988), an acceptable rate of annual siltation is considered as 75 acre- feet per 100 sq. miles per year (3.6 ha-m / 100 sq km per year)

Systematic capacity surveys carried out have brought to light that sediment gets deposited not only in the dead storage but also in the spread of live storage encroaching upon the live storage. Tansa reservoir situated in the neighboring valley has been in existence for more than 100 years. Municipal Corporation of Greater Mumbai (MCGM) in 1993 carried out a sedimentation study based on remote sensing data. According to this study the volume of silt accumulated in the live storage between reservoir levels prevailing during 1991-1992 of 120.42m and 127.68 m (both to THD) was about 11.92 Mm<sup>3</sup>. During 1992-1993 silt accumulation between levels 121.03 m and 127.68 m (THD) worked out to 8.33 Mm<sup>3</sup>. The measured siltation rates translate to an annual rate of 0.00063 Mm<sup>3</sup> / Sq.km / year. Loss of capacity in a reservoir depends on the content of sediment in the inflow as well as capacities provided. In the light of above a comparison of sediment volumes in Mm<sup>3</sup> derived has been presented in Table: 3.2 below:

Table 3.2: Estimated Sediment loads for proposed pinjal Reservoir in MCM

Active life of reservoir assumed	Based on Khoslas guidelines'	Based on CWC	Feasibility studies of Middle Vitarna	Hydro-graphic surveys		Tansa
				Girna	Nalganga	
Rate of sedimentation (ha-m / 100 sq km per year)	3.57	5.28	3.60	7.49	6.24	6.30
50	5.66	8.37	5.71	11.87	9.89	9.99
100	11.32	16.74	11.41	23.74	19.78	19.97

In view of its location and similarity with Middle Vaitarna basin, the sedimentation rate for Pinjal catchment is considered as 3.60ha-m per 100 sq km per year and the silt deposit in 50 years would be 5.71 MCM. From the capacity-elevation the dead storage level / new zero elevation works out to 88.9m.

### 3.5 Evaporation

Daily recorded data of pan evaporation at Suksale station for the years during 1994 to 2006 are considered for this study. Suksale is situated in a plain area at an elevation of 100 m (datum) outside the catchment boundary of Pinjal basin. 13 years of Suksale data have been processed to generate mean monthly depths of evaporation. The annual mean evaporation depth is 1602 mm. The mean evaporation depth recorded for the month of August viz; 56mm, which is the lowest and that of May, 237mm, is the highest in a year. Following the practice of the Irrigation Department, Pan Constants to be applied for different seasons have been assumed as below:

From 1st July to 14th October = 0.7

From 15th October to 28th February = 0.6

From 1st March to 30th June = 0.8

On the basis of the above, average Pan Constant over the whole year works out to 0.7

### 3.6 Flood Studies

A detailed flood study report has been submitted to MCBM for Pinjal. The estimated design flood for Pinjal works out to be 5870 cumec. These are based on the design storm values for two day duration with respect to Bhatsa Project

## 4 Previous Studies

### 4.1 Population studies

According to the population studies carried out by M/s Lee Associates, The population growth till the year 2031 is linear projection of census population available from the year 1951 to 2001, further projection is done based on arithmetic average method which is adopted for old and saturated cities. The increase from the year 1951 to 2031 based on arithmetic average method is 1.82 Million per decade. Population for the year 2041 with population increment rate of 1.82 million per decade was worked out as 21.21 Million.

### 4.2 Recommendations of Dr. Chitale Committee

In the year 1993, the Govt. of Maharashtra has appointed an expert committee under the chairmanship of Dr M A Chitale (Ex-Secretary, Irrigation Dept) for advice on the long term planning for augmentation of water supply to Mumbai for the above mentioned population projections by considering 240 lpcd for planned areas and 150 lpcd for slum areas. The committee has recommended the development of following water sources in different phases.

Table 4.1: Sources of Supply to Mumbai city

Sr. No.	Source	Basin	Yield [MLD]
1	Middle Vaitarna	Vaitarna	455
2	Gargai	Vaitarna	455
3	Pinjal	Vaitarna	865

The government of Maharashtra (GoM) has accepted Dr.Chitale Committee recommendations and has approved allotment of these sources for augmentation of water supply to Mumbai city. From the above studies it is observed that a minimum supply rate of 865MLD should be drawn from the Pinjal River to meet the futuristic domestic demand of Mumbai city and its suburbs.

### 4.3 NWDA Report – Releases from Damanganga to Pinjal

As per the Municipal Corporation of Greater Mumbai (MCGM) the projected water demand for Greater Mumbai by 2021 AD is 1789 MCM equivalent to 4900 Million Liters per day (MLD) whereas the present water supply from different sources viz.Vaitarna, Tansa, Bhatsa, Vehar and Tulsan rivers are 1075 MCM (2945 MLD) only. As such, there will be a shortage of 714 MCM (1955 MLD) by 2021 AD. In order to cope up with above requirement, it is proposed to divert surplus available water from Damanganga basin to Greater Mumbai through Pinjal reservoir. Feasibility studies were carried out by National Water Development Agency for Damanganga-Pinjal Link Project which is the part of Peninsular Rivers Component envisaging Interlinking of West Flowing Rivers North of Mumbai and South of Tapi. Damanganga-Pinjal Link project in the western part of India envisages transferring the surplus water at the proposed Bhugad reservoir across Damanganga River and Khargihill reservoir across Vagh River, a tributary of Damanganga River in Damanganga basin for augmentation of water supply to Greater Mumbai to meet its domestic and industrial water requirements in the near future.

The following are some of the key lines of the project.

- The FRL, of the Bhugad reservoir is fixed at 163.87 m based on detailed Surveys & Investigations. The gross and live storage capacities of the storages are 426.39 MCM and 400.00 MCM respectively.
- The total catchment area of Damanganga basin up to Bhugad dam site is 729 sq km, out of which 141sq km falls in Gujarat State and 588 sq km falls in Maharashtra State.
- 287 MCM of water at 100% dependability is proposed to be diverted from Bhugad reservoir to Khargihill reservoir through Bhugad-Khargihill link tunnel (5.0m dia & 16.85 Km length) during non-monsoon period at supply rate of 1181 MLD. However, NWDA in a meeting held in Nov 2011 has informed MCBM that the releases into Pinjal reservoir shall be on a continuous basis through out the year
- A 572.80 m long composite dam across river Vagh at Khargihill site near village Behadpada in Mokhada Taluka of Thane district of Maharashtra State is proposed.
- The FRL of the Kargihill dam fixed on the basis of detailed Surveys & Investigations is 154.52 m. The gross and live storage capacities have been fixed as 460.79 MCM & 420.50 MCM respectively.
- The maximum height of dam would be 75.62m. The total catchment area up to this dam site is 710sq km which entirely lies in Maharashtra State.
- The divertible water yield at Khargihill dam which is proposed to be diverted at 100% dependability is 290 MCM during non-monsoon period at supply rate of 1193 MLD. Thus, a combined release of 577 MCM (287 + 290 MCM) of water i.e. 2374 MLD will be diverted through Khargihill-Pinjal link tunnel (5.25m dia of 25.7 Km length) in to Pinjal reservoir which would be drawn for downstream demands.

NWDA report has also included the following considerations of Government of Maharashtra regarding Pinjal dam:

- A 681 m long Pinjal dam on river Pinjal (tributary of Vaitarna River) near village Khidse in Jawhar taluka of Thane district has been proposed by Government of Maharashtra.
- The FRL have been fixed on the basis of detailed Surveys & Investigations carried out by Government of Maharashtra as 141.00 m. The gross and live storage capacities have been fixed as 413.57 MCM and 401.55 MCM respectively.
- The total catchment area of Pinjal sub-basin up to this dam site is 317sq km which entirely lies in Maharashtra State. The divertible water to Mumbai city at Pinjal dam site at 75% dependability (as fixed by Government of Maharashtra) is 332 MCM. Thus, a combined release of 43.84 cumecs of water i.e. 3741 MLD will be diverted through Pinjal reservoir as envisaged by Government of Maharashtra.

## 5 Dam Studies

Municipal Corporation of Greater Mumbai (MCGM) has engaged Mott MacDonald Pvt Ltd to undertake a pre feasibility study for constructing a storage reservoir on Pinjal River near village Khidse, Jawahar taluka of thane district of Maharashtra state. The purpose of this storage reservoir is to supplement the existing water supply to meet future water demands of Mumbai city and its suburbs.

### 5.1 Site selection

The selected site for storage reservoir needs to facilitate required storage reliably and to safely take up the construction without causing greater environmental setbacks and involving minimal relocation and rehabilitation of project affected people. Water resources development projects are designed to perform certain functions and to serve a particular area. Three important objectives in selecting the dam sites are

- The site must be adequate enough to support the dam and its appurtenant structures.
- The area for a reservoir dam need to be in a straight and narrow river reach with sufficient area on upstream to hold the planned storage.
- The foundation of the dam should be relatively free of major faults and shears.

To finalize the location of the storage reservoir along the Pinjal River, four alternative locations are studied and presented at pre-feasibility stage. These are shown in Drawing No. MMD-224604-C-DR-PIN-XX-0002 for the alternative locations

#### Alternative 1

It was proposed to locate the dam to store a catchment driven yield of about 185 Million cubic meters at 75 % reliability covering the drainage of about 120 square kilometres. Typical location is just down stream of the confluence of the two tributaries, the Pinjal River wide opens thus increasing the length between stable banks. The river bed level at this reach is about MSL 200.00 m. This location may be useful to serve as upstream balancing reservoir than a feeder because of the forest lands. The location of dam and its submergence is with in the forest area and thus environmental issues will crop up in building many storage reservoirs across the Pinjal River like one as balancing reservoir and the other for feeder. As the availability of yield is also less than 50 % of contemplated river yield which necessitates for one more storage reservoir to utilize the contemplated river yield. Hence the location of the dam site is not preferred.

#### Alternative 2

In this alternative location of the dam was shifted towards further down stream to cover about 193 square kilometers of drainage area. The river bed level at this location is about 140 m. The improvement in storage capacity is not appreciable (about 250 million cubic meters) in comparison to the increase in height of the dam and cost. The meandering course of the river prior and after the proposed dam location is also not favorable to take up the storage dam at this location and hence the same is considered as not a preferred option

#### Alternative 3

This location is on upstream of the confluence with Gargai River. The yield of the river at this location is sufficient to meet the required storage. It is observed that no major advantage is gained in locating the storage reservoir either on up stream side or on down stream side of the location as per this alternative.

## Alternative 4

One of the major set back in locating the dam after the confluence of Gargai River with Pinjal is that the area falls nearer to Thansa wild life sanctuary. The yield of the river at this location as compared to Alternative 3 would be about 20% higher. As the river Pinjal regime beyond the confluence with Gargai River opens wide, the length of the dam between stable banks also increases in effect the cost per unit of storage increases.

The location finally adopted which also satisfies the following:

- The shape of the river Valley at the proposed dam site is nearly narrow which minimize the dam length by economizing the cost per unit storage. The dam site is open to large drainage area on up stream to tap the desired inflows to fulfill the storage facility
- The storage dam and it submergence is not in the purview of reserved wild life area
- The rim of the proposed storage shall be water tight and stable
- The submergence due to water spread proposed storage is minimum
- The sites selected minimize the cost of connectivity like roads, housing colonies etc
- The alignment of dam is along a straight reach of channel perpendicular to the direction of flow
- Avoids meandering of river locations immediately on u/s and d/s of proposed dam site

Alternative-3 is satisfying above considerations; hence this alternative is chosen carrying out further investigations, feasibility study including preliminary design and broad cost estimates

## 5.2 Location of the Dam

After studying various alternative locations for storage sites alternative-3 is adopted. The dam site is situated at Latitude: 19<sup>0</sup> 47' 0" N, Longitude: 73<sup>0</sup> 13' 0" E. The Pinjal dam location and alignment has been fixed based on the latest survey data which would provide economical section of the gravity structure as the good foundation grade rock along the alignment is found to exist at a shallow depth. This has been verified through representative bore log data. The index map of Pinjal is shown in Drawing: MMD-224604-C-DR-PIN-XX-0001

## 5.3 Geotechnical investigation

This section describes the geotechnical fieldwork and laboratory testing carried out as part of this investigation. Geotechnical investigations were undertaken at the Pinjal dam site in July 2009 as part of the foundation assessment for Pinjal storage dam. Field work consists of twelve test bore holes at stipulated locations representing key locations of dam structure; collecting disturbed, undisturbed soil samples and rock samples. The laboratory analysis of the soil, rock and ground water samples were carried out. The results of the investigations are discussed in the following sections.

### 5.3.1 Subsurface Soil Profile

The subsurface soil profile shows yellowish brown silty clay followed by weathered rock. The grain size analysis shows gravel content 7.43%, sand 54.16%, silt 15.97% and clay 22.44%. The Atterberg limits shows Liquid limit 43.73%, plastic limit 23.48%, shrinkage limit 17.07% and plasticity index 20.25%. The specific gravity is 2.68, natural moisture content is 15.65% and dry density is 1.62 g/cc.

Table 5.1: Rock properties

S No	Rock Particulars	Values
1	Density	2.27g/cc
2	Water absorption	2.07 %
3	Specific gravity	2.3

S No	Rock Particulars	Values
4	Porosity	1.38%
5	UCS	116.02 Kg/cm <sup>2</sup>
6	Young's Modulus	132000 Kg/cm <sup>2</sup>
7	Poisson ratio	0.24
8	Abrasion value	24.4%

### 5.3.2 Bed rock

Bed rock is encountered at the shallow depth of 3m to 5m with core recovery and RQD as high as 77% and 71% respectively. The bed rocks show very good unconfined compressive strength's and point load index with and without saturation of 7days. RMR values are obtained from the laboratory test results and field observations. Based on the RMR values, the bed rock is classified as class I and Class II. The bed rock encountered in the area is generally due to flows of compact basalt and amygdaloidal basalt.

### 5.3.3 Dam foundation considerations

The rocks when fresh and free from structural defects have high compressive strengths. The induced stress due to the weight component and other lateral loads at this site is about 150-200 t/m<sup>2</sup>. The characteristic strength of rocks of different types encountered at dam site.

Table 5.2: Characteristic Strength of rock specimen

S No	Location	Greyish Amygdaloidal basalt (Kg / cm <sup>2</sup> )	Compact basalt (Kg / cm <sup>2</sup> )
1	Dam Alignment Right bank	1079-1523	1139-2278
2	Dam Alignment Left bank	997-1467	
3	Spillway		1383-2440
4	Gorge		

## 5.4 Type of Dam

The topography and catchment properties of the river will provide quantitative information regarding the availability of water. This parameter will have influence on the dam type and design the type of dam and has linkages with the ground profile/ topography.

If river valley is narrow, a gravity dam is preferred. The availability of construction materials and cost of the dam has a considerable influence on the type of dam. As the impervious hearting material is not available in the vicinity of the proposed dam site, provision of concrete core with concrete faced slab is necessary.

Looking in to the functional aspects, Rock fill dam is not suitable for this location hence the same is not considered.

The pinjal dam location and alignment has been fixed based on the latest survey data which would provide economical section of the gravity structure as the good foundation grade rock along the alignment is present at shallow depth with good percentage of core recovery. The site is located in heavy rainfall zone

and such a site roller compacted concrete gravity dam is most suitable. One of the most impressive aspects of Roller Compacted Concrete (RCC) dams have been their ability to be designed and constructed rapidly as well as economically. The RCC dam technology is based on highly mechanized activities of transporting RCC to the placement; its spreading and compacting as a leaner construction process. One of the keys to a fast economic and quality RCC dams is simple dam design which requires the minimization of interferences to the RCC processes of the dam by which the contractor would be able to construct the dam in a continuous and speedy manner. RCC construction sequences and their timing play a significant role for the continuous construction progress particularly during wet seasons. In Construction of RCC dam's river diversion problems can be handled with ease as after the initial portion is constructed, the spillages of water during frequent flash floods can be permitted without planning for any extra diversion.

The Pinjal Dam is designed as Roller Compacted Concrete Gravity Dam

### 5.5 Storage Planning

From the past studies carried out by Govt. Of Maharashtra, FRL of 141.00m have been fixed on the basis of detailed Surveys & Investigations. The gross and live storage capacities have been fixed as 413.57 MCM and 401.55 MCM respectively.

From the yield studies carried out in the present study and approved by CWC, the annual yield at the proposed dam site for 95% dependability is 524MCM and inflow reliability studies carried out based on the D-static analysis for 95% reliability annual flows was arrived as 387.5MCM. Allocated supply from Pinjal reservoir to Mumbai city is 865 MLD (315.73 MCM).

Since, the yield from the catchment in to Pinjal reservoir during monsoon periods exceeds the demand, additional storage could be utilised to meet the additional future demands. From capacity-elevation curve shown in Appendix B.1, the gross storage at an RL of 145m is found to be 483 MCM. The live storage after taking into account the reservoir sedimentation referred in previous section would be 477.49MCM. Submergence area at an FRL of 145.0 m is 19.6 Sq km. The area vs elevation curve is attached as Appendix B.2

### 5.6 Free board

Free board is the vertical distance between normal pool elevations to the top of dam elevation. Free board calculations are carried out as per IS: 10635 -1993, which is 2 m from FRL/MWL. However, as recommended in this code, if the dam height from deepest foundation grade is more than 60m, a freeboard of 3m has to be provided. Since, this height for Pinjal Dam is 71.5 metres, 3 metre free board has been proposed. Free board calculations are included in Appendix B.3

### 5.7 Location of spillway

The possible spillway locations are

- a) In the gorge of main dam
- b) In one of its flanks
- c) In the saddle.

The location of spillway is studied in conjunction with the Energy Dissipation Arrangements. Suitable Energy Dissipation arrangements are provided based on the following:

- a) Tail water rating curve and jump rating curve
- b) Height and length of guide walls,
- c) Provision of spray walls

The type of the energy dissipation arrangements normally provided is

- Horizontal type (USBR type I to type IV), when tail water rating curve and jump rating curve shall not differ by 10 % (BIS 4997 )
- Roller/Slotted Bucket type where jump rating curve lies below tail water rating curve.
- Trajectory bucket type where deficiency in tail water and good foundation grade rock is available

The main parameter considered for the location of the spillway is the cost and gate operational ease during floods. If the spillway is located in the gorge, the energy dissipation arrangements due to high head of water above the crest of spillway, special energy dissipation arrangements need to be looked in to based on the velocity, discharge per unit length etc. Energy dissipation arrangements need to be tested through model experiments based on BIS4997 and BIS 7365. Similarly locating the spillway in the flanks need long guide and spray walls and need to be linked with the natural river channel. Un-gated spillway is not economically viable because of increase in the height of the dam in addition to increase in the length of overflow and submergence.

Based on the above considerations, gated spillway has been proposed in the main gorge with Trajectory bucket type of energy dissipation arrangement since compact basalt bed rock is available on down stream side with moderate tail water depth.

### 5.8 Spillway Capacity and Gate Dimensions

Flood routing studies are done based on Modified Pul's method, to pass the design flood of 5870 cumecs through the spillway gates by fixing suitable spillway length and gate dimensions, The results are shown below:

Table 5.3: Spillway Gate Dimensions

Effective length of spill way , L in m	Gate Size m x m	TOD in m	MWL in m	Crest Level in m	Design Flood through gates (Cumecs)
80	8 x 11(10 Nos.)	147	145	134.0	6033.03
95	9.5 x 9.7(10 Nos.)	147	145	135.3	5932.50
100	10 x 9.5(10 Nos.)	147	145	135.5	6052.60
110	11 x 9(10 Nos.)	147	145	136.0	6139.21
120	12 x 8.5(10 Nos.)	147	145	136.5	6147.04
130	13 x 8(10 Nos.)	147	145	137.0	6080.43
140	14 x 7.5(10 Nos.)	147	145	137.5	5943.96
150	15 x 7.5(10 Nos.)	147	145	137.5	6368.53
160	16 x 7(10 Nos.)	147	145	138.0	6125.24
170	17 x 7(10 Nos.)	147	145	138.0	6508.07

From the above calculations, 10 number of radial gates of size 9.5 m x 9.7 m are selected, which would effectively discharge the design flood with minimal submergence.

## 5.9 Control Levels

Table 5.4: Control levels of Pinjal Dam

S No	Particulars	Levels in metres
1	Top of dam	147.000
2	HFL	145.000
3	FRL	144.000
4	Spillway (C.L)	135.300
5	MDDL	92.400
6	RBL	75.500

## 5.10 Layout of the dam location

The alignment is taken across nearly perpendicular to the flow direction in the main river course. Total length of the dam (including Overflow and Non overflow section) is 540 m long and the average height is 41.2 m. The spillway is proposed in the main gorge of river. The main dam consists of about 36 monolith blocks of 15m each. The natural ground profile in the main gorge portion is nearly at river bed level. Therefore the spillway is housed in negligible excavation.

From chainage 1710m to 1900m, there is a second shallower gorge/breach section whose level at deepest point is 136.6 m, creating an average height of the breach section of 6.0 m from its lowest point. At this location Roller Compacted Concrete (RCC) Gravity type Non Overflow dam section is proposed. Drawing MMD-224604-C-DR-PIN-XX-0003 & 0004

## 5.11 Overflow section

### 5.11.1 Design of Ogee Spillway

Overflow section is proposed in the main Gorge of the river from Ch.330.0 m to Ch.450.0m. Non overflow sections are proposed on both the sides up to RL.147.00 m. Good foundation grade rock is available at shallow depth and accordingly the foundation level will be kept in sound rock where anticipated core recovery is more than 90%.

The bed level of river at the spillway location varies from 75.5 m to 78.5 m across the river width. The crest level of spillway is fixed at RL 135.3 m with downstream slope of 0.8H:1V. Ogee shaped crest spillway is used. The ogee shaped spillway has a controlled weir made to conform closely to the profile of lower surface of nappe. The shape of the Ogee profile is designed to follow the jet of the water flowing over a ventilated sharp crested weir when the head over the crest is equal to the designed head. The shape of upstream and downstream profile is designed as per IS: 6934. Details of the Ogee profile are attached as Appendix B.4

Spillway is provided with 10 Nos. of radial gates of size 9.5 m X 9.7 m and 9 RCC Piers of 2.5 m width and 24 m length from upstream face of the dam is proposed. The RCC spillway piers are rested on good foundation grade rock available in the spillway location. However the structural design for piers should be

done as per IS: 13551-1993 in detailed project report. Further details like stair case and Lift Well, Road Bridge Instrumentation are proposed as per the standard practice. The gates are operated by the rope drum hoists located on Hoist Bridge. Reinforced cement concrete (RCC) Road Bridge of 12.0 m width is also proposed. Cross sectional details of the overflow section are shown in Drawing No. MMD-224604-C-DR-PIN-XX-0005

### 5.11.2 Energy Dissipation Arrangement (EDA)

The spillway has been designed as Ogee structure and trajectory bucket type of energy dissipation arrangements are proposed in accordance with the provisions of IS: 6934 (Reaffirmed 2003) & IS: 7365 (Reaffirmed 2003) respectively. The bucket is provided with a radius of 19.5m with an angle of 40° from centre of the bucket. The elevation of the bucket lip is kept at RL 82.95 m with the provision of minimum submergence of 1.05 m below TWL of 84.0 m. The flow coming down the spillway is thrown away from toe of the dam to a considerable distance of 99 m to down stream as a free discharging upturn jet which falls in to the river directly thereby avoiding excessive scour immediately down stream of the spill way. Detailed calculations are attached in Appendix B.4. Energy Dissipation Arrangements are shown in Drawing No. MMD-224604-C-DR-PIN-XX-0005

### 5.11.3 Protection Works

As good foundation rock is available on down stream and it is not necessary to provide aprons. However, the provision of a concrete apron of about 10 to 15 m length downstream is recommended to prevent the scour near the bucket lip. Training walls extending beyond the end of the buckets generally serve to guide the flow into the river channel to protect the wrap-rounds of the adjacent river banks.

## 5.12 Non-Overflow section

Non over flow section is provided between Ch.160m to Ch.330m and Ch.450m to Ch.705m along the axis of the dam. The length of NOF section is 425m with a proposed top width of 12m. Downstream slope of NOF is provided with a slope of 0.8H:1V. The average height of the non overflow section on left side and right side of spillway are 34 m and 44 m respectively.

A shallow gorge/breach section is located between Ch.1710m and Ch.1900m, whose level at deepest point is 136.6 m, creating an average height of the breach section of 6.0 m from its lowest point. Maximum height of the non overflow section of this gorge is 10.4 m @ Ch.1800.0 m. Proposed top width of this section is 4.0m with a slope of 1 in 0.5 at down stream face of the section At this location Roller Compacted Concrete (RCC) Gravity type Non Overflow dam section is proposed. Cross sectional details of the NOF section have shown in MMD-224604-C-DR-PIN-XX-0006 & 0007

## 5.13 Stability Analysis of OF & NOF sections

The sections of Over flow and Non Overflow are calculated based on BIS Codes (IS: 6512, IS: 6934 BIS 1893) and to withstand likely seismic forces. The stability analysis of the Non Overflow section is carried as single block without considering the lateral anchorage due to abutments.

The following requirements and assumptions have been considered in design criteria according to IS 6512 (Reaffirmed 1998).

- The overflow section should be adequate enough to carry the design flood without causing any destruction to the dam structure and its components
- Stress transfer from body structure to the foundation should follow elastic laws and they are in-separable and act as a monolithic structure

- Unit length of dam as a slice between two vertical planes normal to the base has been considered without lateral stress transfers to the abutments
- The governing criteria for stability are the factor of safety against over turning and sliding
- No lateral stress transfers to the abutments and no movement of foundation due to load transfer
- The concrete body of OF/NOF structures are homogeneous, isotropic and uniform elastic material
- No differential moment takes place either at foundation or in the body of dam
- All loads are carried by gravity action. The normal stress variation from U/S to D/S or vice versa is uniform and linear

Table 5.5: Parameters considered in design of Pinjal Dam

Sr no.	Material	Values adopted for the design
1	Roller compacted concrete	24 KN/m <sup>3</sup>
2	Water	9.81 KN/m <sup>3</sup>
3	Silt	3.6 KN/m <sup>3</sup>
4	Earth quake coefficient	0.04
5	Uplift	100%
6	Angle of internal friction over rock	42°
7	Wind velocity at FRL	122.4 km/hr
	Wind velocity at HFL	138.3 km/hr
8	Seismic coefficient	Zone III
9	Importance factor	3
10	Cohesion over rock	0.24 N/mm <sup>2</sup>

### 5.13.1 Various Forces

Various forces considered for the design as per IS: 6512-1984(Reaffirmed 1998).

- Self weight of dam
- Horizontal water pressure
- Weight of water on upstream inclined face of the dam
- Uplift force at the base of the dam section
- Wave pressure
- Weight due to piers and bridge for over flow section design
- Wind forces
- Seismic forces as per IS: 1893-1984

### 5.13.2 Load combinations

Stability is checked for the following combination of loads as per IS: 6512 1984 Para 4.1 page 5.

- i. Load combination B:  
Normal Operating Condition – Full reservoir elevation, Normal dry weather tail water, normal uplift, ice and silt (if applicable).
- ii. Load combination C  
Flood discharge condition Reservoir at MWL, All gates open, Normal uplift, and Silt.
- iii. Load combination E:  
Combination 'B' with Earth quake but no ice
- iv. Load combination F  
Load combination C but with extreme uplift (Drains inoperative)

#### v. Load Combination G

Load combination E + Extreme uplift (Drains inoperative)

Load combination of G is considered for the Non overflow section and F is considered for Overflow section in the current design. Based on these adverse load combinations using an appropriate safety factors stability analysis has been carried out. The permissible stresses are adopted as per the provision in IS code for concrete construction. The stability analysis of NOF and OF section is carried out on the basis of provisions contained in IS: 6512-1984 and suitable dimensions are adopted which safeguards the dam. Detailed calculation of stability analysis are attached as Appendices B.5, B.6 and B.7

### 5.14 Galleries

The height of the dam is 76.50 m over the foundation grade rock. On the basis of prevailing practice as per Indian Standards, it is obligatory to provide a drainage gallery when the dam height exceeds 20 metres above foundation grade rock as per IS 10135. The foundation gallery is so located so that it will be as close as possible to the foundation grade rock line. The drainage gallery is located such that it follows the profile of foundation. The minimum cover over the foundation grade rock to the bottom of the foundation gallery is about 1.5 m. Foundation gallery is proposed to collect seepage water from the body of the dam and to reduce uplift. It will also facilitate easy inspection of dam and to monitor structural behaviour of the dam. A rectangular shape foundation gallery of size 2.0 m X 2.5 m has been proposed in the body of the both overflow and non overflow sections. The provision of 2.3 metre is to facilitate the re-drilling of the drainage holes and to grout the curtain grout holes. The upstream face of foundation gallery is kept in line with the vertical u/s face of the dam. It also fulfils the criteria for the distance from the face of dam that is 5% hydrostatic head or 3 metres whichever is higher. Hence the galleries have been provided at a distance of 3.5 m from the U/S vertical face of the dam. The floor of the drainage gallery is given a longitudinal slope which is to be decided as per the location of the sump well.

As the dam height is more than 60 metres inspection gallery are proposed at every 30 metres interval above the roof of drainage gallery. The size of inspection gallery is also proposed as 1.5 m X 2.25 m. This gallery would facilitate to monitor the behaviour of the dam by installing instruments.

Drainage holes are proposed at 3 metres centre to centre to relieve the uplift at the dam foundation. Normally depth of hole is about two third of the curtain grout i.e., 75 mm diameter. Drainage holes are drilled after foundation grouting activity completed. A safe distance of about 30 metre may be kept if two activities are simultaneously tackled. Water stop joints are proposed for overflow and non overflow sections. The positioning of the PVC water stops for overflow sections will be as per standard practice.

Ventilation pipes of 300 mm are proposed at 50 metre c/c. The ventilation pipes are taken from the roof of the gallery and emerge on down stream face of NOF section.

### 5.15 Grouting

Grouting is proposed to reduce the deformability of jointed or shattered rock and to reduce the permeability of the foundation rock. The consolidation grouting is provided one third of the base width from the U/S face of the dam. The foundation grade rock is amygdaloidal compact basalt which is light in nature and may not require elaborate treatment. However some dykes are present, which must have linked with small cracks in the foundation grade rock. Therefore it is necessary to seal any rock crevices and plug the seepage water by undertaking consolidation grouting with in the upstream 1/3rd of base. Grouting is done until required Lugeon values are achieved if not secondary and further tertiary grouting is done till the required Lugeon value is achieved (IS: 6066).

As per the geotechnical report curtain grouting is required for the foundation rock available at the dam site. The Curtain grouting is proposed through single line grout curtains with primary spacing of 12 metres. Further it can be reduced to 6 metres and 3 metres. Curtain grouting is proposed through the foundation gallery with 75 mm dia holes up to a depth equal to 75 % hydrostatic head. The depth of the grout curtain depends upon the type and conditions of the rock mass with respect to its permeability. As per IS: 11293-part II -1993, the empirical formula,  $D = 2/3 H + 8$  is used to calculate the depth of curtain grout (D) where H is the Height of reservoir water. Therefore, the depth of the curtain grout is arrived as 57 m below drainage gallery.

### 5.16 Construction Joints

Usually monolith joints are provided at 20m Interval for concrete structure Standard copper water seal is proposed on upstream side. PVC water stop is proposed on down stream side between dam blocks.

### 5.17 Instrumentation in Concrete gravity dams

Normally, instruments are installed in a concrete gravity dam to measure the various parameters that indicate the structural health of the dam and the state of the foundation. These instruments have been classified into two types: obligatory and optional measurements, by Bureau of Indian Standards IS 7436(part2)-1997.

#### 5.17.1 Obligatory Measurements

- Uplift pressure at the base of the dam at a sufficient number of transverse sections
- Seepage into the dam and appearing downstream there-from;
- Temperature of the interior of the dam; and
- Displacement measurements.
  - Those determined by suspended plumb lines;
  - Those determined by geodetic measurements where warranted by the importance of the structure;
  - Those determined by embedded resistance joint meters at contraction joints where grouting is required to be done

#### 5.17.2 Optional Measurements

The following measurements are optional and may be undertaken where warranted by special circumstances of project. These would be beneficial for high dams, for structures of unusual design, for structures where unusual or doubtful foundations exist, for the verification of design criteria and for effecting improvement in future designs:

- a) Stress
- b) Strain
- c) Pore pressure (as distinct from uplift pressure), and
- d) Seismicity of the area and dynamic characteristic of the structure.

Surveillance of seismic environment of the project site needs special attention in case of large dams to know about the seismicity of the region before taking up construction. Creation of a reservoir generates additional load on the surrounding area and underlying geological strata. Thus, it becomes essential to know the change in the seismicity pattern, if any, due to creation of large reservoir. The behavior of dam during an earthquake also needs to be assessed. For these purposes, a seismological laboratory may be established near the project site.

### 5.18 River Diversion

Regardless of the type of dam, whether concrete or embankment types, it is necessary to de-water the site for final geological inspection, foundation improvement and for the construction of the first stage of the dam.

In order to carry out the above works the river has to be diverted temporarily. For concrete dams, it may be necessary to divert the river during the first phase of the construction of the dam. Diversion channels are often classified according to the type of diversion namely, single stage or multiple stage diversion scheme. In the former which is more suitable for narrow valleys, the same set of diversion channel and coffer dams is utilized throughout the period of construction. The channels and coffer dams are shifted from place to place in accordance with phasing of the work. River diversion can be done by constructing diversion tunnels to divert water from upstream of the river to down stream of the river without causing damage to the storage structure since good grade of rock is available at dam site.

A concrete or masonry dams is allowed to get overtopped during floods when construction activity is not in progress. The resulting damage is either negligible or could be tolerated without much concern. Therefore, it is customary to adopt diversion flood which is just adequate to be handled during non monsoon season, when construction activity of the dam is continued. Generally the largest observed non-monsoon flood or non-monsoon flood of 100 year return period is adopted as a diversion flood.

### **5.19 Infrastructural works**

A 12 m wide road way is proposed along the dam axis for entire length of 545 m which connects nearby access roads. RCC Road Bridge of 12 m wide of length 120 m above overflow section is proposed. All other infrastructural works like access roads, Colonies, Recreational arrangements as a part of tourism & other construction areas of the project could be further explored during the detailed design phase.

## 6 Cost Estimates

Broad cost estimates have been worked out using the quantities of various elements of dam and associated infrastructure using regional schedule of rates. The quantities are based on the preliminary design carried out as per relevant IS codes. These estimates, however, do not involve environmental costs and social costs associated with displacement.

The overall broad cost of Pinjal Dam is: INR 309.03 Crores

The abstract sheet is included in Appendix C.1

# Appendices

- Appendix A. II
- Appendix B. III
- Appendix C. IV

# Appendix A.

## **A.1. Monthly & Annual River Flows at Andhari River Gauge Station**


## **A.2. Dependable Yield - Pinjal River Basin**


## Appendix B.

- B.1. Capacity – Elevation Curve**
- B.2. Area – Elevation Curve**
- B.3. Free Board Calculations**
- B.4. Design of Ogee Spillway and Energy Dissipation Arrangement**
- B.5. Stability Analysis for Overflow Section**
- B.6. Stability Analysis for Non-Overflow Section – Main Gorge**
- B.7. Stability Analysis for Non-Overflow Section – Shallow Gorge**


# Appendix C.

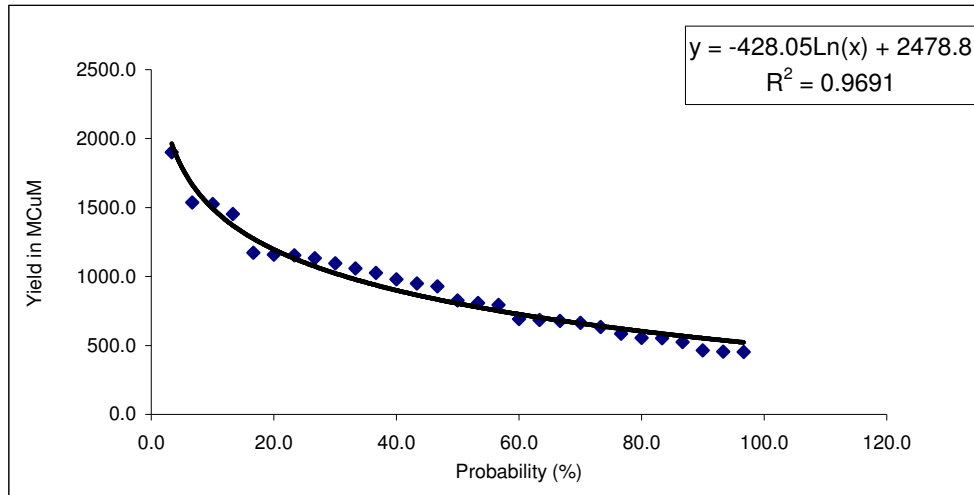
## **C.1. Cost Estimates**

Project name		Mumbai IV Water Supply					
Calculation for		Monthly & Annual River Flows at Andhari River Gauge Station					
		Discipline	IWU	File No.	224604		
		Calc by	SHA	Date	10.11.2011		
		Checked by	NR	Date	10.11.2011		
Year	June	July	August	September	October	Annual	
	MCM	MCM	MCM	MCM	MCM	MCM	
1976	165.00	642.00	438.00	203.00	15.00	1463.00	
1977	71.00	400.39	223.97	196.00	12.02	903.38	
1978	91.00	220.67	186.07	97.47	7.90	603.11	
1979	4.00	126.00	465.16	45.00	19.00	659.16	
1980	103.37	314.00	367.57	137.92	9.00	931.86	
1981	11.19	649.00	268.38	132.85	37.37	1098.79	
1982	24.00	117.37	329.01	44.16	12.00	526.54	
1983	7.53	246.44	291.34	156.00	55.51	756.82	
1984	58.52	331.00	297.00	69.74	30.00	786.26	
1985	5.94	164.31	265.57	51.00	12.89	499.71	
1986	58.57	240.22	211.23	17.00	2.00	529.02	
1987	0.00	180.31	200.00	44.37	8.00	432.68	
1988	0.00	544.65	248.81	184.00	65.59	1043.05	
1989	0.00	272.33	258.00	78.00	38.28	646.61	
1990	46.84	414.74	447.00	141.00	54.41	1103.99	
1991	144.25	493.51	265.02	68.77	6.00	977.55	
1992	8.77	135.48	306.60	182.86	19.00	652.71	
1993	31.00	271.89	131.50	133.00	64.25	631.64	
1994	105.67	432.04	280.02	161.44	29.00	1008.17	
1995	0.00	205.13	95.59	88.14	53.00	441.86	
1996	16.56	159.00	153.00	79.47	23.00	431.03	
1997	59.55	376.82	442.53	160.94	38.18	1078.02	
1998	0.00	303.37	474.00	539.51	66.18	1383.06	
1999	11.80	333.36	101.90	45.63	64.964	557.66	
2000	22.29	513.99	129.96	55.948	48.00	770.18	
2001	216.70	399.21	213.00	31.00	25.00	884.91	
2002	923.24	383.98	71.00	67.00	7.00	1452.22	
2003	337.96	850.74	327.63	256.00	37.172	1809.50	
2004	46.13	174.76	780.00	78.00	38.00	1116.89	


Project name		Mumbai IV Water Supply			
Calculation for		Dependable Yield - Pinjal River Basin			<b>Mott MacDonald</b>
		Discipline	IWU	File No.	224604
		Calc by	SHA	Date	10.11.2011
		Checked by	NR	Date	10.11.2011
YEAR	Annual Monsoon Flows (MCM)	Probability of Exceedence(%)	Annual Monsoon Flows (Descending) MCM	Annual Flows (Descending) MCM	
1976	1463.00	3.33	1809.50	1899.98	
1977	903.38	6.67	1463.00	1536.15	
1978	603.11	10.00	1452.22	1524.83	
1979	659.16	13.33	1383.06	1452.21	
1980	931.86	16.67	1116.89	1172.73	
1981	1098.79	20.00	1103.99	1159.19	
1982	526.54	23.33	1098.79	1153.73	
1983	756.82	26.67	1078.02	1131.92	
1984	786.26	30.00	1043.05	1095.20	
1985	499.71	33.33	1008.17	1058.58	
1986	529.02	36.67	977.55	1026.43	
1987	432.68	40.00	931.86	978.45	
1988	1043.05	43.33	903.38	948.55	
1989	646.61	46.67	884.91	929.16	
1990	1103.99	50.00	786.26	825.57	
1991	977.55	53.33	770.18	808.69	
1992	652.71	56.67	756.82	794.66	
1993	631.64	60.00	659.16	692.12	
1994	1008.17	63.33	652.71	685.35	
1995	441.86	66.67	646.61	678.94	
1996	431.03	70.00	631.64	663.22	
1997	1078.02	73.33	603.11	633.27	
1998	1383.06	76.67	557.66	585.54	
1999	557.66	80.00	529.02	555.47	
2000	770.18	83.33	526.54	552.87	
2001	884.91	86.67	499.71	524.70	
2002	1452.22	90.00	441.86	463.95	
2003	1809.50	93.33	432.68	454.31	
2004	1116.89	96.67	431.03	452.58	


Note: Non monsoon flows @ 5% of Monsoon Flows


Project name	Mumbai IV Water Supply			
Calculation for	Dependable Yield - Pinjal River Basin			<b>Mott MacDonald</b>
	Discipline	IWU	File No.	224604
	Calc by	SHA	Date	10.11.2011
	Checked by	NR	Date	10.11.2011

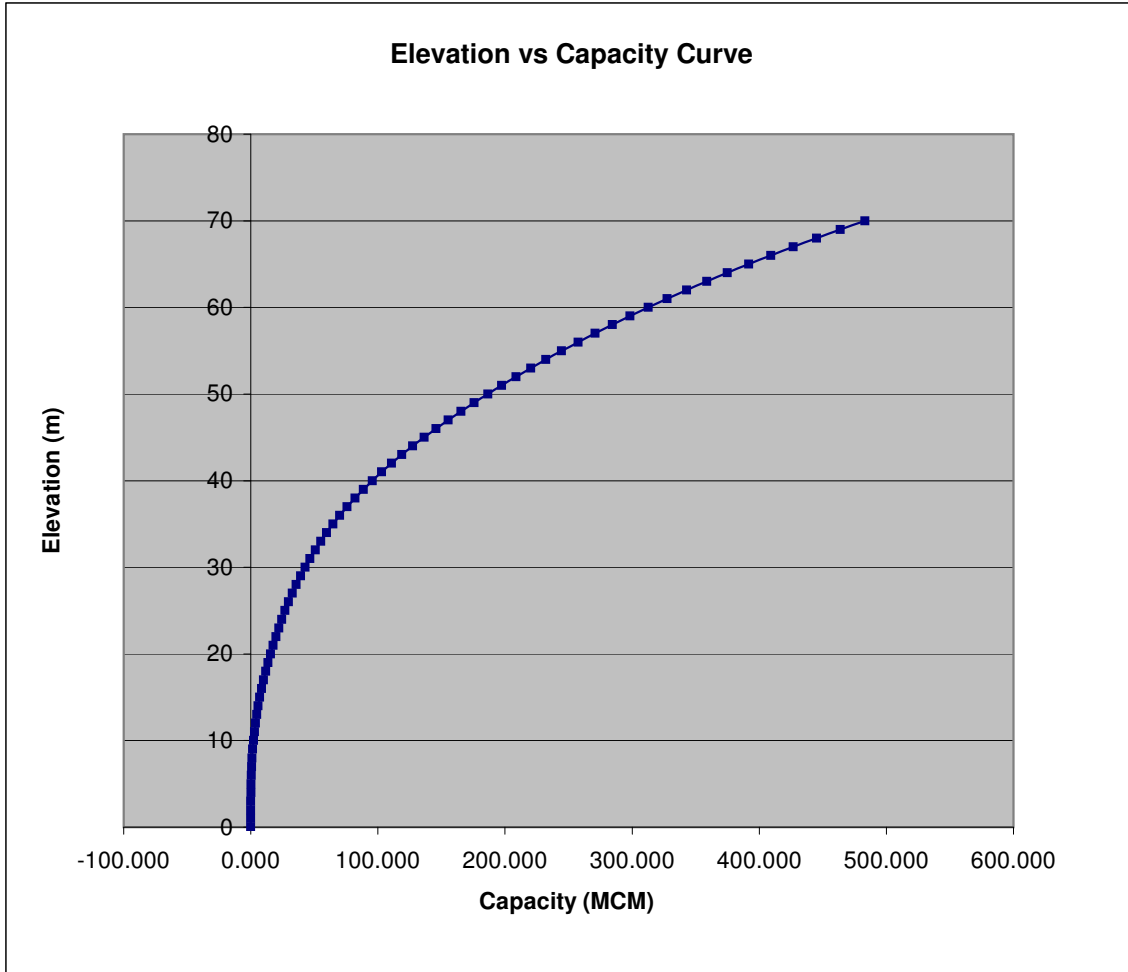



Probability (%)	Yield at Andhari MCM	Annual Yield at Dam Site MCM
75.0	631	596
95.0	530	501
100.0	508	480

Project name		Mumbai IV Water Supply				
Calculation for		Pinjal: Capacity - Elevation Curve			<b>Moti MacDonald</b>	
		Discipline	IWU	File No.	224604	
		Calc by	SHA	Date	10.11.2011	
		Checked by	RC	Date	10.11.2011	
Elevation (m)	Incremental Ht of Dam (H)	Surveyed area in m <sup>2</sup>	Area in Sq.Km <sup>2</sup>	Cumulative Area in Sq.Km <sup>2</sup>	Storage b/w Two successive contours MCM	Q, incremental Storage Capacity MCM
75	0	0.00	0.00000	0	0.000	0.000
76	1	2760.52	0.00276	0.003	0.001	0.001
77	2	43639.39	0.04364	0.046	0.023	0.025
78	3	73921.00	0.07392	0.120	0.059	0.083
79	4	94507.49	0.09451	0.215	0.084	0.168
80	5	154098.31	0.15410	0.369	0.124	0.292
81	6	200700.90	0.20070	0.570	0.177	0.469
82	7	274430.68	0.27443	0.844	0.238	0.707
83	8	390830.30	0.39083	1.235	0.333	1.039
84	9	533281.09	0.53328	1.768	0.462	1.502
85	10	694237.38	0.69424	2.462	0.614	2.115
86	11	806856.70	0.80686	3.269	0.751	2.866
87	12	924360.16	0.92436	4.194	0.866	3.731
88	13	1039718.28	1.03972	5.233	0.982	4.713
89	14	1164598.05	1.16460	6.398	1.102	5.816
90	15	1363834.00	1.36383	7.762	1.264	7.080
91	16	1486552.85	1.48655	9.248	1.425	8.505
92	17	1624742.97	1.62474	10.873	1.556	10.061
93	18	1759264.57	1.75926	12.632	1.692	11.753
94	19	1879109.85	1.87911	14.511	1.819	13.572
95	20	2016286.59	2.01629	16.528	1.948	15.520
96	21	2114455.93	2.11446	18.642	2.065	17.585
97	22	2216408.52	2.21641	20.859	2.165	19.750
98	23	2342763.48	2.34276	23.201	2.280	22.030
99	24	2479735.58	2.47974	25.681	2.411	24.441
100	25	2663817.33	2.66382	28.345	2.572	27.013
101	26	2844002.09	2.84400	31.189	2.754	29.767
102	27	3026466.83	3.02647	34.215	2.935	32.702
103	28	3211606.34	3.21161	37.427	3.119	35.821
104	29	3522219.01	3.52222	40.949	3.367	39.188
105	30	3739982.96	3.73998	44.689	3.631	42.819
106	31	3953449.65	3.95345	48.643	3.847	46.666
107	32	4200639.35	4.20064	52.843	4.077	50.743
108	33	4465088.28	4.46509	57.308	4.333	55.076
109	34	4780042.49	4.78004	62.088	4.623	59.698
110	35	5194856.62	5.19486	67.283	4.987	64.686
111	36	5569942.17	5.56994	72.853	5.382	70.068
112	37	5939648.35	5.93965	78.793	5.755	75.823
113	38	6353738.24	6.35374	85.147	6.147	81.970
114	39	6779960.80	6.77996	91.927	6.567	88.537
115	40	7269574.41	7.26957	99.196	7.025	95.561
116	41	7582930.47	7.58293	106.779	7.426	102.988
117	42	7925265.66	7.92527	114.704	7.754	110.742
118	43	8308422.92	8.30842	123.013	8.117	118.859
119	44	8714516.61	8.71452	131.727	8.511	127.370
120	45	9205636.00	9.20564	140.933	8.960	136.330

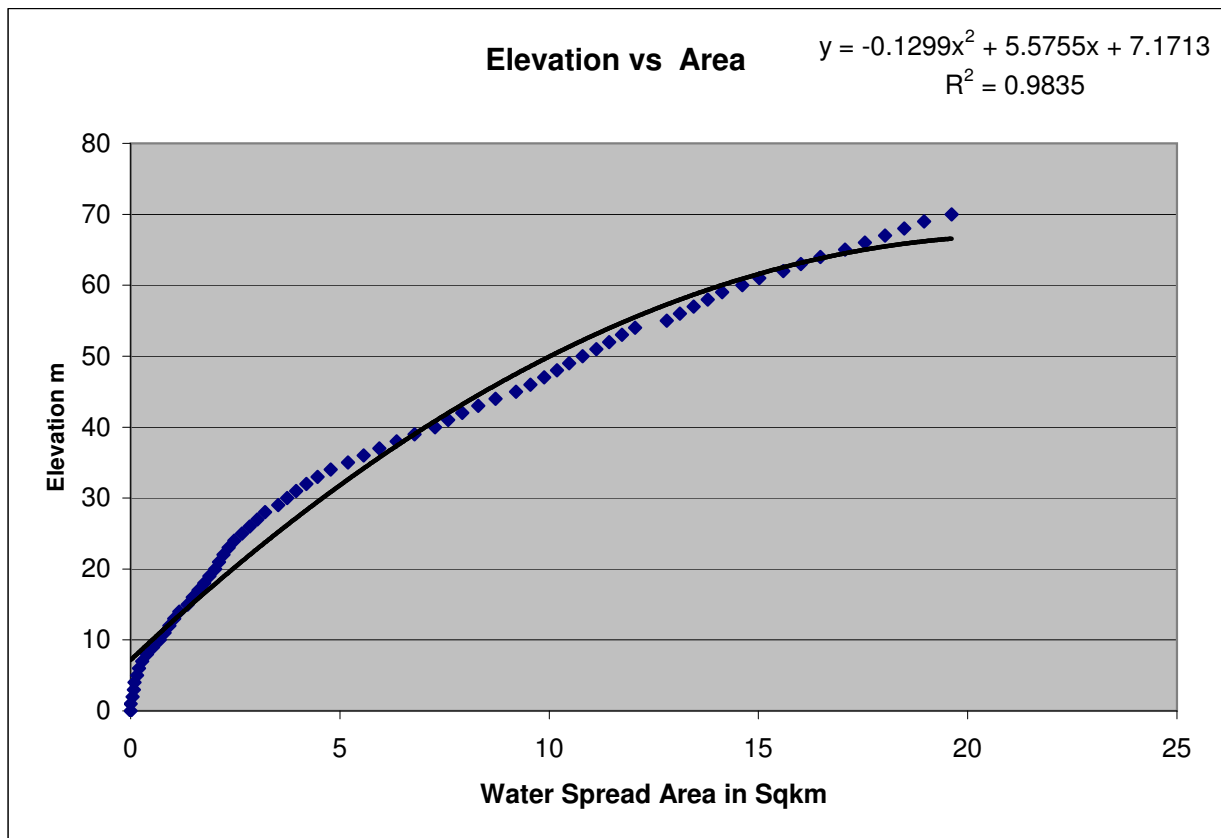
Project name		Mumbai IV Water Supply				
Calculation for		Pinjal: Capacity - Elevation Curve			<b>Moti MacDonald</b>	
		Discipline	IWU	File No.	224604	
		Calc by	SHA	Date	10.11.2011	
		Checked by	RC	Date	10.11.2011	
121	46	9549794.92	9.54979	150.483	9.378	145.708
122	47	9882694.58	9.88269	160.365	9.716	155.424
123	48	10190169.13	10.19017	170.556	10.036	165.460
124	49	10476134.92	10.47613	181.032	10.333	175.794
125	50	10797790.17	10.79779	191.829	10.637	186.431
126	51	11125164.16	11.12516	202.955	10.961	197.392
127	52	11432312.30	11.43231	214.387	11.279	208.671
128	53	11738040.37	11.73804	226.125	11.585	220.256
129	54	12053706.15	12.05371	238.179	11.896	232.152
130	55	12813228.57	12.81323	250.992	12.433	244.585
131	56	13124382.94	13.12438	264.116	12.969	257.554
132	57	13455556.21	13.45556	277.572	13.290	270.844
133	58	13787479.53	13.78748	291.359	13.622	284.466
134	59	14131079.98	14.13108	305.490	13.959	298.425
135	60	14616151.33	14.61615	320.107	14.374	312.799
136	61	15018139.46	15.01814	335.125	14.817	327.616
137	62	15596405.56	15.59641	350.721	15.307	342.923
138	63	16012649.80	16.01265	366.734	15.805	358.727
139	64	16476867.83	16.47687	383.211	16.245	374.972
140	65	17072017.84	17.07202	400.283	16.774	391.747
141	66	17544830.10	17.54483	417.827	17.308	409.055
142	67	18022368.40	18.02237	435.850	17.784	426.839
143	68	18485990.18	18.48599	454.336	18.254	445.093
144	69	18961844.32	18.96184	473.298	18.724	463.817
145	70	19613436.40	19.61344	492.911	19.288	483.104


Project name	Mumbai IV Water Supply			
Calculation for	Pinjal: Capacity - Elevation Curve			
	Discipline	IWU	File No.	224604
	Calc by	SHA	Date	10.11.2011
	Checked by	RC	Date	10.11.2011



Project name		Mumbai IV Water Supply				
Calculation for		Pinjal: Lake Level - Area Details				
		Discipline	IWU	File No.	224604	
		Calc by	SHA	Date	10.11.2011	
		Checked by	NR	Date	10.11.2011	
Elev in m	H, Incremental Ht of Dam	Surveyed area in m <sup>2</sup>	Area in Sq.Km <sup>2</sup>	Cumulative Area in Sq.Km <sup>2</sup>	Storage b/w Two successive contours Mm <sup>3</sup>	Q, incremental Storage Capacity Mm <sup>3</sup>
75	0	0	0.00000	0	0.000	0.000
76	1	2760.518	0.00276	0.003	0.001	0.001
77	2	43639.393	0.04364	0.046	0.023	0.025
78	3	73921.001	0.07392	0.120	0.059	0.083
79	4	94507.492	0.09451	0.215	0.084	0.168
80	5	154098.305	0.15410	0.369	0.124	0.292
81	6	200700.900	0.20070	0.570	0.177	0.469
82	7	274430.682	0.27443	0.844	0.238	0.707
83	8	390830.296	0.39083	1.235	0.333	1.039
84	9	533281.089	0.53328	1.768	0.462	1.502
85	10	694237.379	0.69424	2.462	0.614	2.115
86	11	806856.698	0.80686	3.269	0.751	2.866
87	12	924360.164	0.92436	4.194	0.866	3.731
88	13	1039718.277	1.03972	5.233	0.982	4.713
89	14	1164598.053	1.16460	6.398	1.102	5.816
90	15	1363834.002	1.36383	7.762	1.264	7.080
91	16	1486552.850	1.48655	9.248	1.425	8.505
92	17	1624742.965	1.62474	10.873	1.556	10.061
93	18	1759264.567	1.75926	12.632	1.692	11.753
94	19	1879109.847	1.87911	14.511	1.819	13.572
95	20	2016286.590	2.01629	16.528	1.948	15.520
96	21	2114455.927	2.11446	18.642	2.065	17.585
97	22	2216408.515	2.21641	20.859	2.165	19.750
98	23	2342763.482	2.34276	23.201	2.280	22.030
99	24	2479735.579	2.47974	25.681	2.411	24.441
100	25	2663817.326	2.66382	28.345	2.572	27.013
101	26	2844002.092	2.84400	31.189	2.754	29.767
102	27	3026466.827	3.02647	34.215	2.935	32.702
103	28	3211606.343	3.21161	37.427	3.119	35.821
104	29	3522219.014	3.52222	40.949	3.367	39.188
105	30	3739982.957	3.73998	44.689	3.631	42.819
106	31	3953449.651	3.95345	48.643	3.847	46.666
107	32	4200639.354	4.20064	52.843	4.077	50.743
108	33	4465088.277	4.46509	57.308	4.333	55.076
109	34	4780042.487	4.78004	62.088	4.623	59.698
110	35	5194856.619	5.19486	67.283	4.987	64.686
111	36	5569942.171	5.56994	72.853	5.382	70.068
112	37	5939648.354	5.93965	78.793	5.755	75.823
113	38	6353738.237	6.35374	85.147	6.147	81.970
114	39	6779960.799	6.77996	91.927	6.567	88.537
115	40	7269574.410	7.26957	99.196	7.025	95.561
116	41	7582930.466	7.58293	106.779	7.426	102.988
117	42	7925265.660	7.92527	114.704	7.754	110.742
118	43	8308422.919	8.30842	123.013	8.117	118.859
119	44	8714516.611	8.71452	131.727	8.511	127.370
120	45	9205636.004	9.20564	140.933	8.960	136.330
121	46	9549794.921	9.54979	150.483	9.378	145.708
122	47	9882694.577	9.88269	160.365	9.716	155.424
123	48	10190169.125	10.19017	170.556	10.036	165.460

			Calc by	SHA	Date	10.11.2011
			Checked by	NR	Date	10.11.2011
124	49	10476134.923	10.47613	181.032	10.333	175.794
125	50	10797790.166	10.79779	191.829	10.637	186.431
126	51	11125164.163	11.12516	202.955	10.961	197.392
127	52	11432312.303	11.43231	214.387	11.279	208.671
128	53	11738040.373	11.73804	226.125	11.585	220.256
129	54	12053706.152	12.05371	238.179	11.896	232.152
130	55	12813228.571	12.81323	250.992	12.433	244.585
131	56	13124382.936	13.12438	264.116	12.969	257.554
132	57	13455556.208	13.45556	277.572	13.290	270.844
133	58	13787479.526	13.78748	291.359	13.622	284.466
134	59	14131079.984	14.13108	305.490	13.959	298.425
135	60	14616151.330	14.61615	320.107	14.374	312.799
136	61	15018139.457	15.01814	335.125	14.817	327.616
137	62	15596405.563	15.59641	350.721	15.307	342.923
138	63	16012649.797	16.01265	366.734	15.805	358.727
139	64	16476867.828	16.47687	383.211	16.245	374.972
140	65	17072017.841	17.07202	400.283	16.774	391.747
141	66	17544830.100	17.54483	417.827	17.308	409.055
142	67	18022368.399	18.02237	435.850	17.784	426.839
143	68	18485990.178	18.48599	454.336	18.254	445.093
144	69	18961844.316	18.96184	473.298	18.724	463.817
145	70	19613436.396	19.61344	492.911	19.288	483.104



Project name	Mumbai IV Water Supply				
Calculation for	Free Board Calculations				
	Discipline	IWU	File No.	224604	
	Calc by	SHA	Date	10.11.11	
	Checked by	NR	Date	11.11.11	

$\alpha$	Radian	Cos $\alpha$	Xi (km)	Xi Cos $\alpha$	Xi Cos $\alpha$ * Cos $\alpha$
42	0.733038	0.7431448	0.48	0.35670952	0.265086831
36	0.628319	0.809017	0.49	0.39641833	0.320709164
30	0.523599	0.8660254	3.7	3.20429399	2.775
24	0.418879	0.9135455	4.1	3.74553638	3.421717743
18	0.314159	0.9510565	5	4.75528258	4.522542486
12	0.20944	0.9781476	1.7	1.66285092	1.626513639
6	0.10472	0.9945219	1.5	1.49178284	1.483610701
0	0	1	1.5	1.5	1.5
6	0.10472	0.9945219	1.4	1.39233065	1.384703321
12	0.20944	0.9781476	1.4	1.36940664	1.33948182
18	0.314159	0.9510565	0.83	0.78937691	0.750742053
24	0.418879	0.9135455	0.68	0.62121091	0.567504406
30	0.523599	0.8660254	0.5	0.4330127	0.375
36	0.628319	0.809017	0.5	0.4045085	0.327254249
42	0.733038	0.7431448	0.5	0.37157241	0.276132116
		<b>13.510917</b>			<b>20.93599853</b>

Effective fetch, Fe = 1.55 km  
 50 year return period land Wind velocity, U = 34 m/s

Coefficient for effective fetch, Q = 1.13  
 Wind velocity on water, V = 38.55 m/s  
 Wave height, Hs = 1.175 m  
 Wave Period, Ts = 3.162 Sec  
 Wave length, Ls = 15.60 m  
 Design wave height, Ho = 1.962 m  
 Steepness ratio, Ho/Ls = 0.126  
 Embankment slopes = 1 : 3


With the help of curves given in graph in Fig. 4 of IS:10635, between different values of steepness ratio and the embankment slopes read R / Ho ratio, and compute wave run up on smooth surface (R).

R/Ho = 1.35 Ref. IS: 10635, pg.5, Fig.4  
 Wave Runup on smooth surface, R = 2.65 m  
 Roughness coefficient = 0.75 Ref. IS: 10635, pg.5, Tab.2  
 (Laid flat)  
 wave runup on rough surface, Ra =

Hence, Consider Ra as equal to Designed wave height, i.e., Ra = 1.99 m

Fetch length, F = 1.5 km  
 River bed gradient = 1 in 750  
 River Bed level @ centreline of dam = 75.5 m  
 River bed level @ max fetch length = 77.5 m  
 Average reservoir depth along fetch, D = 69.8 m

Wind set-up, S =  $V^2F/62000 D$   
 S = 0.007  
 Normal Free Board = 2.0 m  
 FRL = 144 m  
 TBL = 146.0 m  
 Minimum Free Board = 1.0 m  
 MWL = 145 m  
 TBL = 146.0 m  
 2/3 rd wind velocity = 92.5 kmph  
 Wind set-up, S =  $V^2F/62000 D$   
 S = 0.003 m  
 Free Board = 2.0 m  
 MWL = 145 m  
 TBL = 147.0 m  
 Adopted TBL = 147.0 m

Project name	Mumbai IV Water Supply			
Calculation for	Design of Ogee Spillway @ Ch.420.0m			
	Discipline	IWU	File No.	224604
	Calc by	SHA	Date	10.11.2011
	Checked by	NR	Date	10.11.2011

### Design of Ogee Spillway @ Ch.420.0m

River bed level, RBL =	75.5 m
Crest level of Spillway =	135.3 m
Depth of flow over spillway, H =	9.7 m
Maximum Water Level (MWL) =	145 M
Net Clear water way considered, L =	95 m
Length of each span =	9.5 m
No. of spans =	10 Nos.
Design flood, Q =	5870 cumecs
Coefficient of discharge, C =	2.07
U/S slope of spill way =	vertical
D/S slope of spill way =	0.8 :1
Foundation depth from bed level =	3.5 m
Tail Water depth	8.5 m
No. of Piers = N =	9
Thickness of pier =	2.50 m

$$Q = C.L_e.He^{(3/2)}$$

$$He^{(3/2)} = 29.850 \quad \therefore L_e \approx L$$

$$He = 9.7 \text{ m}$$

$$\text{Velocity approach, } V_a = 0.719 \text{ m/s}$$

$$H_a = 0.026 \text{ m}$$

This is very small and neglected in He calculations. Therefore, He = Hd

Where, He is total head above spillway crest including velocity head and Hd is designed head over crest.

Height of spillway above river bed, h = 59.80 m

$$h/H_d = 6 > 1.33$$

Effective length of ogee spillway crest,  $L_e = L - 2*He(N*K_p + K_a)$

Where, N= No of piers  
 Kp= Pier contraction coefficient  
 Ka= Abutment contraction coefficient  
 L = Net clear water way

Assumed, 90° cut water nose piers and rounded abutments shall be provided,

$$K_p = 0.010$$

$$K_a = 0.100$$

$$L_e = 91 \text{ m}$$

#### D/S Spillway Profile :

With the reference of U.S.Army Corps of engineers at their WES, the following equation is used to fix the D/S profile of the Ogee Spillway.

$$X^{1.85} = 2 (H_d)^{0.85} Y \quad (\text{when U/S slope is vertical})$$

Where x,y are the co - ordinates from origin C and Hd is the Designed head over the crest.

$$Y = \frac{X^{1.85}}{2(H_d)^{0.85}}$$

$$Y = \frac{X^{1.85}}{13.797}$$

#### Tangent point :


D/S slope of spill way = 0.8 :1  
 Total base width at river bed level = 47.8 m

$$X = 13.8 \text{ m}$$

$$Y = 9.31 \text{ m}$$

Tangent point is available at (x,y) = (13.8,9.31)

The co-ordinates from x = 0 to x = 13.8 m are tabulated below :

Project name	Mumbai IV Water Supply			
Calculation for	Design of Ogee Spillway @ Ch.420.0m			
	Discipline	IWU	File No.	224604
	Calc by	SHA	Date	10.11.2011
	Checked by	NR	Date	10.11.2011

X in m	Y in m
0.5	0.02
1.0	0.07
1.5	0.15
2.0	0.26
2.5	0.39
3.0	0.55
3.5	0.74
4.0	0.94
4.5	1.17
5.0	1.42
5.5	1.70
6.0	1.99
6.5	2.31
7.0	2.65
7.5	3.01
8.0	3.40
8.5	3.80
9.0	4.22
9.5	4.67
10.0	5.13
10.5	5.62
11.0	6.12
11.5	6.65
12.0	7.19
12.5	7.75
13.0	8.34
13.1	8.46
13.2	8.58
13.3	8.70
13.4	8.82
13.5	8.94
13.6	9.06
13.7	9.19
13.8	9.31

**U/S Spillway Profile :**

According to latest studies of US Army Corps, the U/S curve of the Ogee spillway having a vertical U/S face, U/S profile should follow the equation, i.e.,

$$y = [0.724(X+0.27Hd)^{1.85} / Hd^{0.85}] + 0.126Hd - 0.4315Hd^{0.375}(X+0.27Hd)^{0.625}$$

$$= [0.201(X+1.215)^{1.85}] + 0.567 - [0.758(X+1.215)^{0.625}]$$


U/S profile extends up to,  $x = 0.27 Hd = 2.619 \text{ m}$

$$Y = 1.23 \text{ m}$$

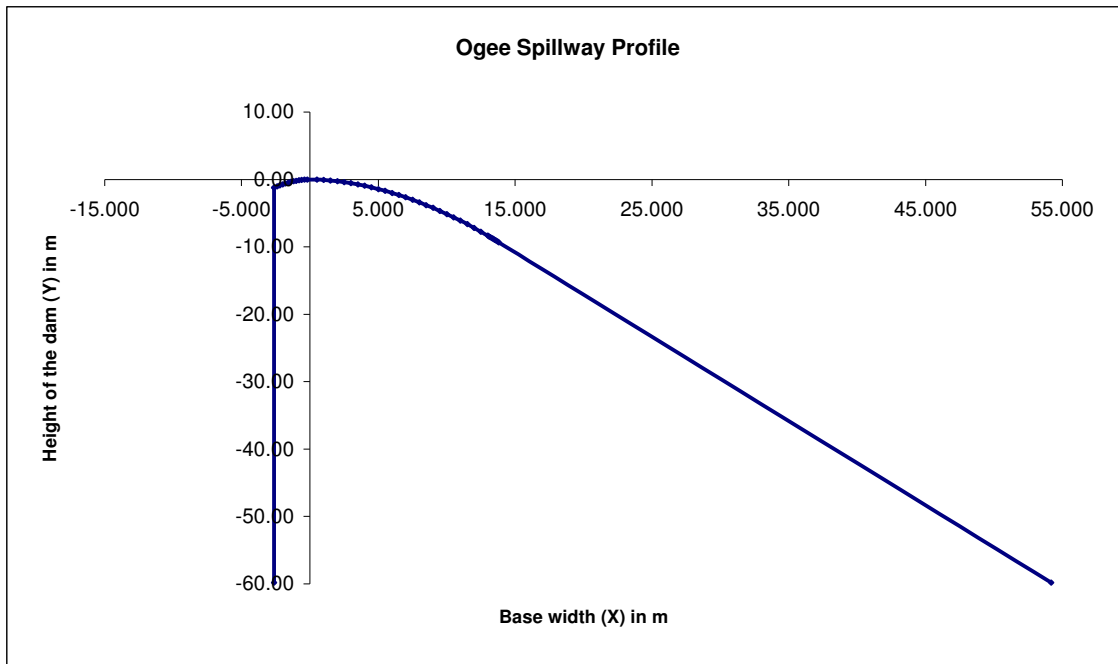
U/S profile touches vertical surface of spillway at the co-ordinate (x,y) = (2.619,1.230)

The co-ordinates from x = -0.1 to x = - 2.619 m are tabulated below :

X in m	Y in m
0.000	0.000
0.200	0.010
0.400	0.030
0.600	0.070
0.800	0.130
1.000	0.200
1.200	0.280
1.400	0.370
1.600	0.480
1.800	0.600

Project name	Mumbai IV Water Supply			
Calculation for	Design of Ogee Spillway @ Ch.420.0m			
	Discipline	IWU	File No.	224604
	Calc by	SHA	Date	10.11.2011
	Checked by	NR	Date	10.11.2011
	2.000	0.740		
	2.200	0.880		
	2.400	1.040		
	2.600	1.210		
	2.619	1.230		

With the above arrived co-ordinates, Ogee spillway profile will be formed as drawn below:



**Hydraulic Design of Trajectory Bucket Type Energy Dissipator  
Lip Angle / Lip elevation and Radius of the Bucket curve**

As per IS:7365, Pg.No.29, Assume the angle,  $\theta = 40^\circ$   
 Bucket Invert level = 78.5 m  
 Foundation level = 70.5 m  
 Tail Water level = 84 m

As per IS:7365, Pg.No.29, Radius of bucket =  $R = 0.8 \sqrt{H_1 H_5}$

Where H is Depth of overflow over spillway in m  
 $H_5$  is Reservoir Pool Elevation - Jet Surface Elevation on Bucket

MWL = EL. 145.00 m  
 H = 9.7 m  
 $H_5 = 61$  m  
 R = 19.5 m

Radius, R = 14.95 m (As per SK garg)

Consider the Radius, R = 19.5 m


With the Radius of 19.5 m and Lip Angle of 40 degrees, RL of Tangent point at Toe and RL of Lip are read from Drawing with trial and error basis by keeping lip level should be at minimum submergence level based on Tail Water Level.

RL of Tangent point at Toe = 82.95 m  
 RL of Lip = EL. 82.95 m

Bucket curve at the toe with a radius, R = 19.50m with an angle of 40 degrees and it starts from the tangent point above bed level and extends till the RL of Lip i.e EL.82.95 m

**Trajectory Length**

$$\frac{X}{H_v} = \frac{\sin 2\theta + 2 \cos \theta \sin^2 \theta + \gamma}{H_v}$$

Project name	Mumbai IV Water Supply			
Calculation for	Design of Ogee Spillway @ Ch.420.0m		<b>Mott MacDonald</b>	
	Discipline	IWU	File No.	224604
	Calc by	SHA	Date	10.11.2011
	Checked by	NR	Date	10.11.2011

Where,  $X =$  Horizontal throw distance from bucket lip  
 $\gamma =$  Difference between the lip level and tailwater level = **1.05 m**  
 $H_v =$  Velocity head of jet at the bucket lip in m  
 $\emptyset =$  Bucket lip angle = 40  
 $H_v = \frac{V_a^2}{2g}$   
 $= \frac{q^2}{d_1^2 * 2 * g}$

Theoretical velocity entering the bucket,  
 $v_t = \sqrt{2g * H_3}$  Where, Diff.between MWL and TWL,  $H_3 =$  **61 m**  
 $=$  34.6 m/s

$H =$  9.7 m

$H_3 =$  61 m

From the Fig.7 of IS:7365, Pg.No.19, Read the value of  $v_a/v_t$ .

$v_a/v_t =$  0.9

$v_a =$  31.14 m/s

Depth of water entering the Bucket,  $d_1 =$  2.06 m

$H_v =$  49.5 m

Horizontal throw,  **$X =$  99 m**

**Vertical distance of throw above the lip level**

$$a = \frac{v_a^2 \sin^2 \emptyset}{2g}$$

$a =$  Vertical distance from the lip level to the highest point of the centre of jet in m,

$v_a =$  Actual velocity of flow entering the bucket in m/s,

$\emptyset =$  Bucket lip angle in degrees

$g =$  Acceleration due to gravity in  $m/s^2$

**$a =$  20.5 m**

**Estimation of Erosion at the point of Impact**

$$d_s = m (q H_4)^{0.5}$$

Where,  $d_s =$  Depth of scour in metre.,

$m =$  Constant for ultimate stabilized scour


Ref: IS 7365, Pg.No.30

$=$  0.54

$q =$  Discharge intensity per metre, = 50.0  $m^2/s$ .


$H_4 =$  Reservoir pool elevation - bucket lip elevation in m = 62.05

**$d_s =$  31.00 m**

Project name	Mumbai IV Water Supply		
Calculation for	Design of Non-Overflow Section of Dam (Main Gorge)		
IS- 6512-1984 Reaffirmed 1998	Discipline	IWU	File No.
	Calc by	SHA	Date
	Checked by	NR	Date
			224604
			10.11.2011
			11.11.2011

**Design of Gravity Dam as per IS- 6512- 1984 Reaffirmed 1998****Load Case (G): Reservoir full with all forces including upliftacting on entire area of the dam****Input Data**

Top width of dam		12 m	
Crest Level of adjacent overflow section		135.3 m	(Ref: Spill Way Calc)
FRL		144 m	
MWL		145 m	
RBL		75.5 m	
Free board		3 m	
Top of dam		147 m	
Ht of dam H upto water surface/MWL <b>H</b>		69.5 m	
Total Ht of dam		71.5 m	
Tailwater ht <b>H'</b>		8.5 m	
Tail water level		84 m	
Providing batter from base of the foundation ( <b>y</b> )	25%	17.38 m	
U/s slope of the dam for battered portion		0.1H:1V	
base width of the u/s triangular portion		1.75 m	
Ht up to rectangular portion at d/s face TOD-CL		11.7 m	
Depth of silt deposited <b>h</b>		18.5 m	Ref: Silt Calc
Assumed Depth of foundation below RBL		3.5 m	Ref: Geotech Report
D/s slope		0.8H : 1V.	
Base width of the dam <b>B</b>		61.6 m	
Unit wt of water <b>g<sub>w</sub></b>		9.81 KN/m <sup>3</sup>	
Cohesion of material at the plane considered	0.24 N/mm <sup>2</sup>	240 KN/m <sup>2</sup>	Ref: For Basalt
Unit wt of silt considered ( <b>γ<sub>sat</sub></b> )		19 KN/m <sup>3</sup>	
Unit wt of concrete <b>g<sub>c</sub></b>		24 KN/m <sup>3</sup>	
Drainage gallery is at a distance from u/s face		3.48 m	Ref: IS 10135-1985
Wave height <b>h<sub>w</sub></b>		1.175 m	Ref: Free Board Calc
coefficient of internal friction over rock <b>φ</b>		42 Degrees	
Angle of u/s face with horizontal ( <b>θ</b> )		84.29 Degrees	
Angle made by d/s face with vertical ( <b>α</b> )		38.66 Degrees	
Angle of u/s face with vertical ( <b>θ1</b> )		5.71 Degrees	
Grade of concrete <b>fc</b> N/mm <sup>2</sup>	20	20000 KN/m <sup>2</sup>	M30 Considered
Coefficient of friction b/w dam and foundation material <b>μ (assu</b>		0.75	μ value varies from 0.65 to 0.75 14kg/cm <sup>2</sup> for poor rocks to
Average shear strength of the joint <b>q (Assumed)</b>		2500 KN/m <sup>2</sup>	
Type of siesmic zone where the dam is to be built ( <b>Zone</b> )		III	
Allowable compressive stress in concrete		7000 KN/m <sup>2</sup>	IS 6512
Permissible max Tensile stress under worst loadings is		800 KN/m <sup>2</sup>	As Per IS-6512 1984
Forces/Pressure acting on Gravity Dam			
water pressureat u/s face p=γ <sub>w</sub> *H		681.80 KN/m <sup>2</sup>	
1 Acting at a distance of 1/3*H		23.17 m	
<b>water pressureat d/s face p'=γ<sub>w</sub>*H'</b>		83.39 KN/m <sup>2</sup>	
1.a Acts at a distance of 1/3*H'		2.83 m	
<b>2 Uplift pressure</b>			
pressure acting at Heel= γ <sub>w</sub> *H		681.80 KN/m <sup>2</sup>	
pressure acting at toe= γ <sub>w</sub> *H' (U1)		83.39 KN/m <sup>2</sup>	
<b>3 Silt pressure</b>			
<b>As per USBR recommendations</b>			
Horizontal force due to silt =3.6*h*h/2		616.05 KN	As Per IS-6512 1984

Project name	Mumbai IV Water Supply		
Calculation for	Design of Non-Overflow Section of Dam (Main Gorge)		
IS- 6512-1984 Reaffirmed 1998	Discipline	IWU	File No. 224604
	Calc by	SHA	Date 10.11.2011
	Checked by	NR	Date 11.11.2011

Vertical force due to silt =  $9.2 \cdot h^2/2$  1574.35 KN  
 Acts at a distance of  $h/3$  from base 6.17 m

**4 Wave pressure**

$h_w = 0.032 \cdot \sqrt{V \cdot F} + 0.763 - 0.271 \cdot F^{3/4}$  1.175 m

hw= ht of water from the top of crest to bottom of trough in m

V= wind velocity in Km/hr

F= Fetch or straight length of water expanse in km

**Wave Pressure =  $2.4 \cdot \gamma_w \cdot h_w$**  27.66 KN/m<sup>2</sup> **As Per IS-6512 1984**

Horizontal force due to wave action =  $0.5 \cdot (2.4 \cdot \gamma_w \cdot h_w) \cdot h_w \cdot 5/3$  27.09 KN

Force acts at a distance of  $3 \cdot h_w/8$  0.44 m

**5 wt of the Dam**

V1= wt of rectangular portion =top width \* Total Ht\* $\gamma_c$  20592 KN

V2 = wt of triangular portion (d/s) = $0.5 \cdot \text{base} \cdot \text{ht}$  34330 KN

V3= wt of triangular portion on u/s side of dam 365 KN

V= wt of the dam 55287 KN

**Wt of water supported on u/s slope & d/s slope**

W1 wt of water supported on u/s face rectangular portion 894.77 KN

W2 wt of water supported on u/s face triangular portion 149.19 KN

W = total wt of water u/s of dam 1043.96 KN

W3 wt of water supported on d/s face 283.51 KN

**6 Earth quake forces**

Effect of Horizontal acceleration  $\alpha_h = \beta \alpha_o$  **Ref IS-1893-1984 page no-16**

$\beta$  1

l 3

$\alpha_o$  0.04 **Ref IS-1893-1984 page no-16**

Horizontal acceleration  $\alpha_h$  0.12

**Hydro dynamic pressure using zanger formulae**

Hydrodynamic pressure  $p_e = C_s \cdot \alpha_h \cdot \gamma_w \cdot H$  (u/s)

Pressure coefficient  $C_m = 0.736 \cdot (1 - \theta_y/90)$  0.7360

and depth  $(C_m/2 \cdot (y/h(2-y/h) + \sqrt{y/h(2-y/h)}))$  0.736

$\alpha_h$  0.12

$p_e$  60.2 KN/m<sup>2</sup>

Hydro Dynamic force acting on dam  $P_e = 0.726 \cdot p_e \cdot H$  3038.33 KN

Moment due to this force is =  $0.299 \cdot P_e \cdot H$  63138.02 KN-m **Ref IS-1893-1984 page no-41**

Hydrodynamic pressure  $p'e = C_s \cdot \alpha_h \cdot \gamma_w \cdot H$  (d/s)

Pressure coefficient  $C_m = 0.736 \cdot (1 - \theta_y/90)$  0.736

and depth  $(C_m/2 \cdot (y/h(2-y/h) + \sqrt{y/h(2-y/h)}))$  0.736

$\alpha_h$  0.12

$p'e$  7.4 KN/m<sup>2</sup>

Hydro Dynamic force acting on dam  $P'e = 0.726 \cdot p'e \cdot H$  45.45 KN

Moment due to this force is =  $0.299 \cdot P'e \cdot H$  115.51 KN-m

**Inertia force due to earth quake**


$1.5 \cdot \alpha_h$  considering value of horizontal seismic coefficient 0.18

Inertia force Pw1 3706.56 KN

Inertia force Pw2 6179.4 KN

Inertia force Pw3 65.7 KN

$W \cdot a_v/g$

Project name	Mumbai IV Water Supply				
Calculation for	Design of Non-Overflow Section of Dam (Main Gorge)				
IS- 6512-1984 Reaffirmed 1998	Discipline	IWU	File No.	224604	
	Calc by	SHA	Date	10.11.2011	
	Checked by	NR	Date	11.11.2011	


$\alpha_v=0.75\alpha_{fh}$  Vertical acceleration due to gravity 0.09 As per IS-1893-1984 page no -44

reduce in wt due to effect of vertical acceleration Pv1 1853.3 KN

reduce in wt due to effect of vertical acceleration Pv2 3089.7 KN

reduce in wt due to effect of vertical acceleration Pv3 32.85 KN

S.N	Name of force	Description	Magnitude of force in KN		Leverarm	Moments about the toe anti-clockwise in KN-M		
			Vertical	Horizontal				
1	Downward wt of dam (+ve)	V1	20592		53.84		1108673.28	
		V2	34330		31.89		1094783.70	
		V3	365		60.42		22053.30	
	wt of water supported at d/s face (+ve)	W1	894.77		60.72		54325.97	
		W2	149.19		61.01		9101.81	
	W3	283.51		2.27			642.62	
		<b>ΣV</b>	<b>56614.4647</b>				<b>ΣM</b> <b>2289580.68</b>	
2	Uplift forces (-ve)	U1	5135.68215		30.80		158153.33	
		U2	18428.04		41.06		756655.16	
		<b>ΣV</b>	<b>23563.72</b>				<b>ΣM</b> <b>914808.49</b>	
3	Vertical forces due to earth quake (-ve)	Pv1	1853.3				99780.60	
		Pv2	3089.7				98530.53	
		Pv3	32.85				1984.80	
		<b>ΣV</b>	<b>4975.8</b>				<b>ΣM</b> <b>200295.93</b>	
4	Horizontal forces	Hydro static forces						
			u/s face (+ve)		23692.38	23.17		548873.47
			d/s face (-ve)		354.38625	2.83		1004.09
			<b>ΣH</b>	<b>23337.994</b>			<b>ΣM</b> <b>547869.38</b>	
5	Silt pressure	Horizontal force		616.05	6.17		3801.03	
			<b>ΣH</b>	<b>616.05</b>			<b>ΣM</b> <b>3801.03</b>	
		Vertical force		1574.35	61.01		96045.85	
			<b>ΣV</b>	<b>1574.35</b>			<b>ΣM</b> <b>96045.85</b>	
6	Wave pressure	Ws		27.09	69.94		1894.54	
		<b>ΣH</b>	<b>27.09</b>			<b>ΣM</b> <b>1894.54</b>		
7	Hydrodynamic Forces	Upstream face			3038.33		63138.02	
			Downstream face (tail water)			45.45	115.51	
		<b>ΣH</b>	<b>2992.88</b>			<b>ΣM</b> <b>63022.51</b>		
		Horizontal inertia force due to earth quake	Pw1		3706.6	35.75		132509.52
Pw2			6179.4	19.93		123155.44		
Pw3			65.7	5.79		380.62		
		<b>ΣH</b>	<b>9951.7</b>			<b>ΣM</b> <b>256045.58</b>		

Project name	Mumbai IV Water Supply									
Calculation for	Design of Non - Overflow section of Dam at Main Gorge									
IS 6512 - 1984 reaffirmed 1998							Discipline	IWU	File No.	224604
							Calc by	SHA	Date	10.11.2011
							Checked by	NR	Date	11.11.2011

**Load combinations as per IS 6512-1984 page no 5**

Allowable working stress in dam material 9333.33 KN/m2 Ref: IS 1893-1984 page no-12

Max allowable tensile stress for worst case 800 KN/m2 As per IS 6512-1984

**Load Case (G) I Reservoir full with all forces including upliftacting on entire area of the dam**

Various forces acting on the dam in the above case	Force		Moment (KN-M)
	Vertical (KN)	Horizontal (KN)	
1 Hydrostatic Forces			
On u/s Face		-23692.38	-548873.47
On d/s Face		354.39	1004.09
2 Hydrodynamic Force		-2992.88	-63022.51
3 Uplift Force	-23563.72		-914808.49
4 Weight of the dam	56614.46		2289580.68
Horizontal earthquake moving towards the reservoir causing			
u/s acceleration and producing Horizontal forces towards		-9951.66	-256045.58
Vertical earthquake moving downward producing upward			
forces	-4975.83		-200295.93
7 Silt Force vertical	1574.35		96045.85
Silt Force (Horizontal)		-616.05	-3801.03
8 Wave Pressure		-27.09	-1894.54
<b>Forces acting on the dam (Vertical)</b>	$\Sigma V$	<b>29649.3</b>	
<b>Forces acting on the dam (Horizontal)</b>	$\Sigma H$		<b>-36925.7</b>
<b>Resisting moment due to the above forces</b>			$\Sigma M$ <b>397889.07</b>

**Structural Stability of Concrete Gravity Dam**

FOS against overturning =( resisting moments/overturning moments)

Resisting Moments 2386631

Overturning Moments 1988742

FOS 1.20 safe

FOS against sliding  $\{((w-u)*\tan\phi/F_f+C*A/F_c)/P\}$  FOS 1.14 safe Ref IS : 65

FOS against Shear Friction  $\{(\mu*\Sigma V+B*q)/(SH)\}$  4.77 safe

Distance at which the resultant acts from the centre of the dam  $X=\Sigma M/\Sigma V$  13.42 m

Eccentricity  $e=B/2-X$  17.38 m

**Calculation of Average Stresses in the body of Dam**

Average vertical stress  $\Sigma V/B$  481.4 KN/m<sup>2</sup>

vertical stress at Toe  $P_{vt}=\Sigma V/B(1+6e/B)$  1296.47 KN/m<sup>2</sup> Safe in compression

vertical stress at Heel  $P_{vh}=\Sigma V/B(1-6e/B)$  -333.67 KN/m<sup>2</sup> Safe

**Calculation of principal stress**

Principal stress at toe of the dam  $\sigma = P_v \sec^2 \alpha - (p' \cdot p' e) \tan^2 \alpha$  2077.57 KN/m<sup>2</sup> Safe in compression


Principal stress at Heel of the dam  $\sigma_1 = P_{vh} \sec^2 \theta_1 - (P + p_e) \tan^2 \theta_1$  -344.42 KN/m<sup>2</sup> Safe

**Check for Tension crack** No Tension Crack

**Calculation of Shear stress**


Shear stress at toe  $T_o=(P_v \cdot p') \cdot \tan \alpha$  970.47 KN/m<sup>2</sup>

Shear stress at heel  $T_h=[-(P_{vh} \cdot (p+p_e))] \cdot \tan \theta_1$  107.56 KN/m<sup>2</sup> ok

Project name	Mumbai IV Water Supply			
Calculation for	Design of Non-Overflow Section of Dam (Shallow Gorge)	Mott MacDonald		
IS- 6512-1984 Reaffirmed 1998	Discipline	IWU	File No.	224604
	Calc by	SHA	Date	10.11.2011
	Checked by	NR	Date	11.11.2011

**Design of Gravity Dam as per IS- 6512- 1984 Reaffirmed 1998****Load Case (G): Reservoir full with all forces including uplifting on entire area of the dam****Input Data**

Top width of dam	4 m	
FRL	144 m	
MWL	145 m	
RBL	136.6 m	
Free board	2 m	
Top of dam	147 m	
Ht of dam H upto water surface/MWL <b>H</b>	8.4 m	
Total Ht of dam	10.4 m	
Ht up to rectangular portion at d/s face TOD-CL	2 m	
Depth of silt deposited <b>h</b>	0 m	Ref: Silt Calc
Assumed Depth of foundation below RBL	5 m	Ref: Geotech Report
D/s slope	0.5H : 1V.	
Base width of the dam <b>B</b>	8.2 m	
Unit wt of water <b>g<sub>w</sub></b>	9.81 KN/m <sup>3</sup>	
Cohesion of material at the plane consider 0.24 N/mm <sup>2</sup>	240 KN/m <sup>2</sup>	Ref: For Basalt
Unit wt of silt considered (γ <sub>sat</sub> )	19 KN/m <sup>3</sup>	
Unit wt of concrete <b>g<sub>c</sub></b>	24 KN/m <sup>3</sup>	
Drainage gallery is at a distance from u/s face	3 m	Ref: IS 10135-1985
Wave height <b>h<sub>w</sub></b>	1.175 m	Ref: Free Board Calc
coefficient of internal friction over rock <b>φ</b>	42 Degrees	
Angle of u/s face with horizontal ( <b>θ</b> )	90 Degrees	
Angle made by d/s face with vertical ( <b>α</b> )	26.57 Degrees	
Angle of u/s face with vertical ( <b>θ1</b> )	0.00 Degrees	
Grade of concrete <b>fc</b> N/mm <sup>2</sup>	20	M20 Considered
Coefficient of friction b/w dam and foundation material	0.75	μ value varies from 0.65 to 0.75 q varies from 14kg/cm <sup>2</sup> for poor rocks to 40kg/cm <sup>2</sup> for
Average shear strength of the joint <b>q (Assumed)</b>	2500 KN/m <sup>2</sup>	
Type of seismic zone where the dam is to be built ( <b>Z</b> )	III	
Allowable compressive stress in concrete	7000 KN/m <sup>2</sup>	IS 6512
Permissible max Tensile stress under worst loadings is	800 KN/m <sup>2</sup>	As Per IS-6512 1984
<b>Forces/Pressure acting on Gravity Dam</b>		
<b>water pressure at u/s face p=γ<sub>w</sub>*H</b>	82.40 KN/m <sup>2</sup>	
1 Acting at a distance of 1/3*H	2.80 m	
<b>water pressure at d/s face p'=γ<sub>w</sub>*H'</b>	0.00 KN/m <sup>2</sup>	
1.a Acts at a distance of 1/3*H'	0.00 m	
<b>2 Uplift pressure</b>		
pressure acting at Heel= γ <sub>w</sub> *H	82.40 KN/m <sup>2</sup>	
pressure acting at toe= γ <sub>w</sub> *H' (U1)	0.00 KN/m <sup>2</sup>	
<b>3 Silt pressure</b>		
<b>As per USBR recommendations</b>		
Horizontal force due to silt =3.6*h*h/2	0 KN	As Per IS-6512 1984
Vertical force due to silt = 9.2*h*h/2	0 KN	
Acts at a distance of h/3 from base	0 m	
<b>4 Wave pressure</b>		
h <sub>w</sub> =0.032*sqrt(V*F)+0.763-0.271*F^(3/4)	1.175 m	
hw= ht of water from the top of crest to bottom of trough in m		

Project name	Mumbai IV Water Supply				
Calculation for	Design of Non-Overflow Section of Dam (Shallow Gorge)	<b>Mott MacDonald</b>			
IS- 6512-1984 Reaffirmed 1998	Discipline	IWU	File No.	224604	
	Calc by	SHA	Date	10.11.2011	
	Checked by	NR	Date	11.11.2011	

V= wind velocity in Km/hr

F= Fetch or straight length of water expanse in km

**Wave Pressure** =  $2.4 \cdot \gamma_w \cdot h_w$  27.66 KN/m<sup>2</sup> **As Per IS-6512 1984**

Horizontal force due to wave action =  $0.5 \cdot (2.4 \cdot \gamma_w \cdot h_w) \cdot h$  27.09 KN

Force acts at a distance of  $3 \cdot h_w / 8$  0.44 m

#### 5 wt of the Dam

V1= wt of rectangular portion =top width \* Total Ht\* $\gamma_c$  998.4 KN

V2 = wt of triangular portion (d/s) = $0.5 \cdot \text{base} \cdot \text{ht}$  423 KN

V3= wt of triangular portion on u/s side of dam 0 KN

V= wt of the dam 1421 KN

#### Wt of water supported on u/s slope & d/s slope

W1 wt of water supported on u/s face rectangular porti 0.00 KN

W2 wt of water supported on u/s face triangular portior 0.00 KN

W = total wt of water u/s of dam 0.00 KN

W3 wt of water supported on d/s face 0.00 KN

#### 6 Earth quake forces

Effect of Horizontal acceleration  $\alpha_n = \beta I \alpha_o$  **Ref IS-1893-1984 page no-16**

$\beta$  1

I 3

$\alpha_o$  0.04 **Ref IS-1893-1984 page no-16**

Horizontal acceleration  $\alpha_n$  0.12

#### Hydro dynamic pressure using zanger formulae

Hydrodynamic pressure  $p_e = C_s \cdot \alpha_n \cdot \gamma_w \cdot H$  (u/s)

Pressure coefficient  $C_m = 0.736 \cdot (1 - \theta_1 / 90)$  0.7360

shape and depth ( $C_m / 2 \cdot (y/h)^2$ ) 0.736

$\alpha_n$  0.12

$p_e$  7.3 KN/m<sup>2</sup>

Hydro Dynamic force acting on dam  $P_e = 0.726 \cdot p_e \cdot H$  44.38 KN

Moment due to this force is =  $0.299 \cdot P_e \cdot H$  111.46 KN-m **Ref IS-1893-1984 page no-41**

Hydrodynamic pressure  $p'_e = C_s \cdot \alpha_n \cdot \gamma_w \cdot H$  (d/s)

Pressure coefficient  $C_m = 0.736 \cdot (1 - \theta_1 / 90)$  0.736

shape and depth ( $C_m / 2 \cdot (y/h)^2$ ) 0.736

$\alpha_n$  0.12

$p'_e$  0.0 KN/m<sup>2</sup>

Hydro Dynamic force acting on dam  $P'_e = 0.726 \cdot p'_e \cdot H$  0 KN

Moment due to this force is =  $0.299 \cdot P'_e \cdot H$  0 KN-m

#### Inertia force due to earth quake

$1.5 \cdot \alpha_n$  considering value of horizontal seismic coefficient 0.18

**Inertia force Pw1** 179.712 KN

**Inertia force Pw2** 76.14 KN

**Inertia force Pw3** 0 KN

$W \cdot a_v / g$


$\alpha_v = 0.75 \cdot \alpha_n$  Vertical acceleration due to gravity 0.09


**As per IS-1893-1984 page no -44**

reduce in wt due to effect of vertical acceleration Pv1 89.9 KN

reduce in wt due to effect of vertical acceleration Pv2 38.1 KN

reduce in wt due to effect of vertical acceleration Pv3 0 KN

Project name		Mumbai IV Water Supply						
Calculation for		Design of Non-Overflow Section of Dam (Shallow Gorge)			Mott MacDonald			
IS- 6512-1984 Reaffirmed 1998				Discipline	IWU	File No.	224604	
				Calc by	SHA	Date	10.11.2011	
				Checked by	NR	Date	11.11.2011	
S.N	Name of force	Descriptio	Magnitude of force in KN		Leverarm	Moments about the toe anti clockwise in KN-M		
			Vertical	Horizontal				
1	Downward wt of dam (+ve)	V1	998.4		6.2		6190.08	
		V2	423		2.8		1184.40	
		V3	0		8.2		0.00	
		W1	0.00		8.20		0.00	
		W2	0.00		8.2		0.00	
		W3	0.00		0.00		0.00	
	wt of water supported at d/s face (+ve)	W3	0.00		0.00		0.00	
		<b>ΣV</b>	<b>1421.4</b>			<b>ΣM</b>	<b>7374.48</b>	
2	Uplift forces (-ve)	U1	0		4.10		0.00	
		U2	337.86		5.47		1846.95	
		<b>ΣV</b>	<b>337.86</b>			<b>ΣM</b>	<b>1846.95</b>	
3	Vertical forces due to earth quake (-ve)	Pv1	89.9				557.11	
		Pv2	38.1				106.60	
		Pv3	0				0.00	
		<b>ΣV</b>	<b>127.9</b>			<b>ΣM</b>	<b>663.70</b>	
4	Horizontal forces	Hydro static forces						
			u/s face (+ve)	P		346.1	2.80	969.08
			d/s face (-ve)	P'		0	0.00	0.00
			<b>ΣH</b>	<b>346.1</b>		<b>ΣM</b>	<b>969.08</b>	
5	Silt pressure	Horizontal force	P <sub>sh</sub>		0	0	0.00	
			<b>ΣH</b>	<b>0</b>		<b>ΣM</b>	<b>0.00</b>	
			Vertical force	P <sub>sv</sub>		0	8.20	0.00
				<b>ΣV</b>	<b>0</b>		<b>ΣM</b>	<b>0.00</b>
6	Wave pressure	W <sub>s</sub>		27.09	8.84	239.47		
		<b>ΣH</b>	<b>27.09</b>		<b>ΣM</b>	<b>239.47</b>		
7	Hydrodynamic Forces	Upstream face	P <sub>e</sub>		44.38		111.46	
			Downstream face (tail water)	P' <sub>e</sub>		0	0.00	
			<b>ΣH</b>	<b>44.38</b>		<b>ΣM</b>	<b>111.46</b>	
8	quake		Pw1		179.7	5.2	934.50	
			Pw2		76.1	2.8	213.19	
			Pw3		0	0.00	0.00	
			<b>ΣH</b>	<b>255.9</b>		<b>ΣM</b>	<b>1147.69</b>	

Project name	Mumbai IV Water Supply								
Calculation for	Design of Non - Overflow section of Dam at Shallow Gorge								
	IS 6512 - 1984 reaffirmed 1998								
					Discipline	IWU	File No.	224604	
					Calc by	SHA	Date	10.11.2011	
					Checked by	NR	Date	11.11.2011	


**Load combinations as per IS 6512-1984 page no 5 Load case G**Allowable working stress in dam material 9333.33 KN/m<sup>2</sup> Ref: IS 1893-1984 page no-12Max allowable tensile stress for worst case 800 KN/m<sup>2</sup> As per IS 6512-1984**Load Case (G) I Reservoir full with all forces including upliftacting on entire area of the dam**


	Force	Force		Moment (KN-M)
		Vertical (KN)	Horizontal (KN)	
1 Hydrostatic Forces				
On u/s Face			-346.10	-969.08
On d/s Face			0.00	0.00
2 Hydrodynamic Force			-44.38	-111.46
3 Uplift Force	-337.86			-1846.95
4 Weight of the dam	1421.40			7374.48
Horizontal earthquake moving towards the reservoir				
5 causing u/s acceleration and producing Horizontal			-255.85	-1147.69
Vertical earthquake moving downward producing upward				
6 forces		-127.93		-663.70
7 Silt Force vertical	0.00			0.00
Silt Force (Horizontal)			0.00	0.00
8 Wave Pressure			-27.09	-239.47
<b>Forces acting on the dam (Vertical)</b>	$\Sigma V$	<b>955.6</b>		
<b>Forces acting on the dam (Horizontal)</b>	$\Sigma H$		<b>-673.4</b>	
<b>Resisting moment due to the above forces</b>			$\Sigma M$	<b>2396.12</b>


**Structural Stability of Concrete Gravity Dam**


FOS against overturning =( resisting moments/overturning moments)


<b>Resisting Moments</b>		7374.5	
<b>Overturning Moments</b>		4978.4	
	FOS	<b>1.50</b>	safe
<b>FOS against sliding</b> $\{((w-u) \cdot \tan \phi / F_f + C \cdot A / F_c) / P\}$	FOS	<b>3.88</b>	safe Ref IS : 651
<b>FOS against Shear Friction</b> $\{(\mu \cdot \Sigma V + B \cdot q) / (\Sigma H)\}$		<b>31.51</b>	safe
Distance at which the resultant acts from the centre of the dam $X = \Sigma M / \Sigma V$		2.51 m	
Eccentricity $e = B / 2 - X$		1.59 m	
<b>Calculation of Average Stresses in the body of Dam</b>			
Average vertical stress $\Sigma V / B$		116.54 KN/m <sup>2</sup>	
vertical stress at Toe $P_{vt} = \Sigma V / B (1 + 6e / B)$		252.12 KN/m <sup>2</sup>	Safe in compression
vertical stress at Heel $P_{vh} = \Sigma V / B (1 - 6e / B)$		-19.04 KN/m <sup>2</sup>	Safe
<b>Calculation of principal stress</b>			
Principal stress at toe of the dam $\sigma = P_v \sec^2 \alpha - (p' \cdot p' e) \tan^2 \alpha$		315.18 KN/m <sup>2</sup>	Safe in compression
Principal stress at Heel of the dam $\sigma_1 = P_v \sec^2 \theta_1 - (P + p_e) \tan^2 \theta_1$		-19.04 KN/m <sup>2</sup>	Safe
<b>Check for Tension crack</b>		<b>No Tension Crack</b>	
<b>Calculation of Shear stress</b>			
Shear stress at toe $T_o = (P_v \cdot p') \cdot \tan \alpha$		126.09 KN/m <sup>2</sup>	
Shear stress at heel $T_h = [(P_v \cdot h - (p + p_e))] \cdot \tan \theta_1$		0 KN/m <sup>2</sup>	ok

Project name		Mumbai IV Water Supply							
Calculation for		Estimates of Pinjal Dam							
				Discipline	IWU	File No.	224604		
				Calc by	SHA	Date	10.11.2011		
				Checked by	NR	Date	11.11.2011		
Sl.No.	Description of item of work	Units	Nos	L	B	D	Qty	Total Qty	
<b>1</b>	<b>Excavation</b>								
<b>a</b>	Below overflow section	Cu.M	1	120.00	61.58	5.00	36948.00		
<b>b</b>	Below Non overflow section								
	<b>LHS of the dam</b>								
	Ch160to165	Cu.M	1	5.00	12.00	5.00	300.00		
	Ch165to180	Cu.M	1	15.00	12.00	5.00	900.00		
	Ch180to195	Cu.M	1	15.00	17.78	5.00	1333.50		
	Ch195to210	Cu.M	1	15.00	24.63	5.00	1847.40		
	Ch210to225	Cu.M	1	15.00	30.22	5.00	2266.80		
	Ch225to240	Cu.M	1	15.00	35.16	5.00	2637.00		
	Ch240to255	Cu.M	1	15.00	39.62	5.00	2971.20		
	Ch255to270	Cu.M	1	15.00	42.81	5.00	3210.60		
	Ch270to285	Cu.M	1	15.00	44.80	5.00	3360.30		
	Ch285to300	Cu.M	1	15.00	47.73	5.00	3579.60		
	Ch300to315	Cu.M	1	15.00	52.27	5.00	3920.10		
	Ch315to330	Cu.M	1	15.00	57.03	5.00	4277.40		
	<b>RHS of the dam</b>								
	Ch450to465	Cu.M	1	15.00	60.26	5.00	4519.80		
	Ch465to480	Cu.M	1	15.00	59.07	5.00	4430.00		
	Ch480to495	Cu.M	1	15.00	58.07	5.00	4355.40		
	Ch495to510	Cu.M	1	15.00	57.12	5.00	4283.80		
	Ch510to525	Cu.M	1	15.00	55.79	5.00	4184.00		
	Ch525to540	Cu.M	1	15.00	53.50	5.00	4012.20		
	Ch540to555	Cu.M	1	15.00	50.51	5.00	3788.00		
	Ch555to570	Cu.M	1	15.00	47.29	5.00	3546.40		
	Ch570to585	Cu.M	1	15.00	44.25	5.00	3318.40		
	Ch585to600	Cu.M	1	15.00	41.12	5.00	3084.00		
	Ch600to615	Cu.M	1	15.00	37.78	5.00	2833.40		
	Ch615to630	Cu.M	1	15.00	33.44	5.00	2507.80		
	Ch630to645	Cu.M	1	15.00	28.02	5.00	2101.80		
	Ch645to660	Cu.M	1	15.00	23.38	5.00	1753.40		
	Ch660to675	Cu.M	1	15.00	18.31	5.00	1373.20		
	Ch675to690	Cu.M	1	15.00	13.07	5.00	980.20		
	Ch690to705	Cu.M	1	15.00	12.00	5.00	900.00		
	Below Non overflow section (shallow Gorge)								
	Ch1710to1725	Cu.M	1	15.00	5.65	5.00	423.38		
	Ch1725to1740	Cu.M	1	15.00	6.72	5.00	503.63		
	Ch1740to1755	Cu.M	1	15.00	7.22	5.00	541.13		
	Ch1755to1770	Cu.M	1	15.00	8.05	5.00	603.56		
	Ch1770to1785	Cu.M	1	15.00	9.48	5.00	711.19		
	Ch1785to1800	Cu.M	1	15.00	10.37	5.00	777.94		
	Ch1800to1815	Cu.M	1	15.00	10.42	5.00	781.31		
	Ch1815to1830	Cu.M	1	15.00	10.13	5.00	759.38		
	Ch1830to1845	Cu.M	1	15.00	9.92	5.00	744.00		
	Ch1845to1860	Cu.M	1	15.00	9.35	5.00	701.44		
	Ch1860to1875	Cu.M	1	15.00	8.06	5.00	604.69		
	Ch1875to1890	Cu.M	1	15.00	7.26	5.00	544.50		
	Ch1890to1900	Cu.M	1	10.00	7.26	5.00	363.00		
	<b>Total Quantity</b>	<b>Cu.M</b>					<b>127582.83</b>	<b>127582.83</b>	
<b>2</b>	<b>PCC M15 as levelling course of thickness 100mm</b>								
<b>a</b>	Below Overflow section	Cu.M	1	120.00	61.58	0.10	738.96		
<b>b</b>	Below Non overflow section								
	<b>LHS of the dam</b>								
	Ch160to165	Cu.M	1	5.00	12.00	0.10	6.00		
	Ch165to180	Cu.M	1	15.00	12.00	0.10	18.00		
	Ch180to195	Cu.M	1	15.00	17.78	0.10	26.67		
	Ch195to210	Cu.M	1	15.00	24.63	0.10	36.95		
	Ch210to225	Cu.M	1	15.00	30.22	0.10	45.34		
	Ch225to240	Cu.M	1	15.00	35.16	0.10	52.74		
	Ch240to255	Cu.M	1	15.00	39.62	0.10	59.42		
	Ch255to270	Cu.M	1	15.00	42.81	0.10	64.21		
	Ch270to285	Cu.M	1	15.00	44.80	0.10	67.21		

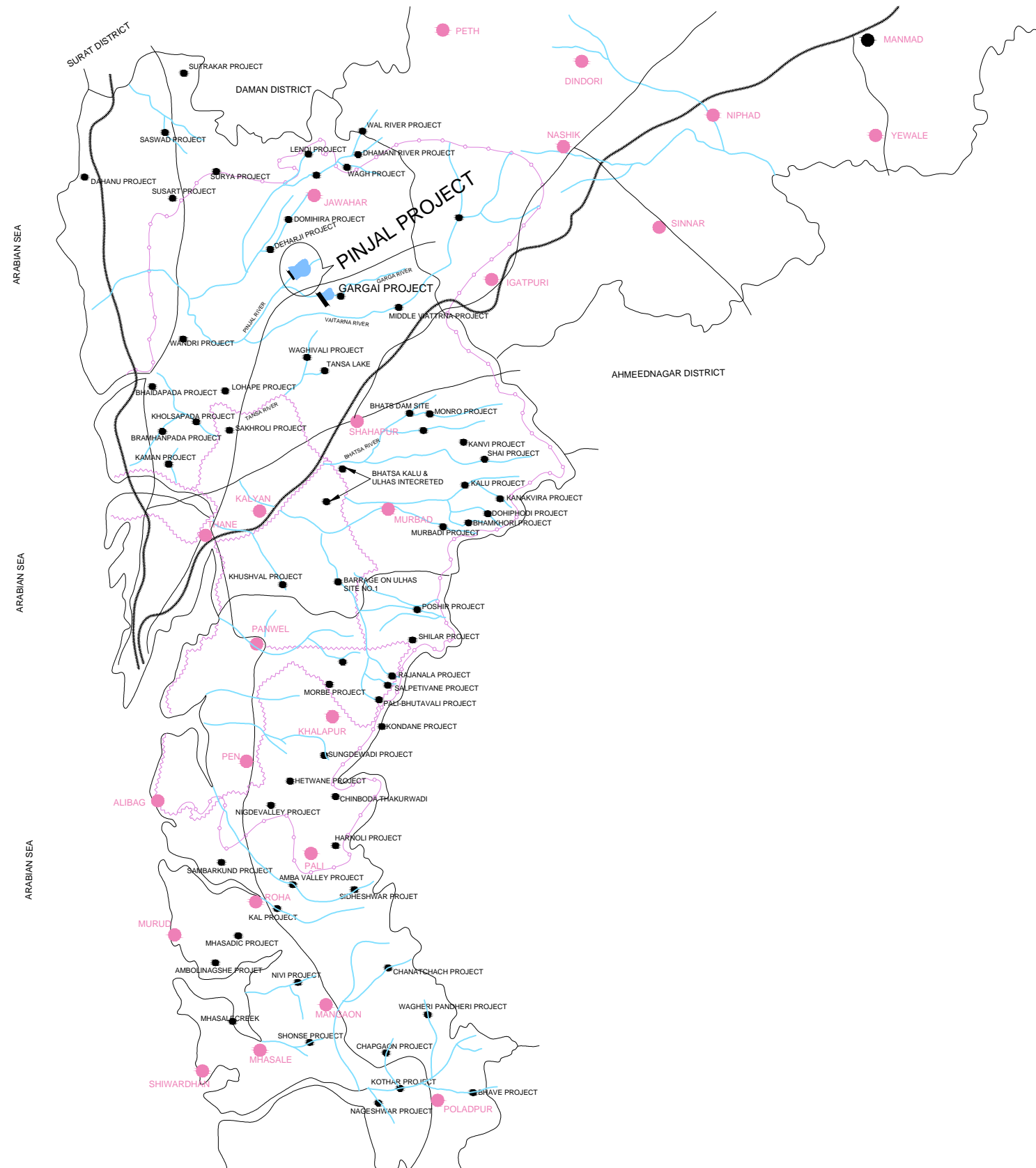
Project name		Mumbai IV Water Supply							
Calculation for		Estimates of Pinjal Dam							
				Discipline	IWU	File No.	224604		
				Calc by	SHA	Date	10.11.2011		
				Checked by	NR	Date	11.11.2011		
Sl.No.	Description of item of work	Units	Nos	L	B	D	Qty	Total Qty	
	Ch285to300	Cu.M	1	15.00	47.73	0.10	71.59		
	Ch300to315	Cu.M	1	15.00	52.27	0.10	78.40		
	Ch315to330	Cu.M	1	15.00	57.03	0.10	85.55		
	<b>RHS of the dam</b>								
	Ch450to465	Cu.M	1	15.00	60.90	0.10	91.36		
	Ch465to480	Cu.M	1	15.00	59.70	0.10	89.56		
	Ch480to495	Cu.M	1	15.00	58.39	0.10	87.58		
	Ch495to510	Cu.M	1	15.00	57.62	0.10	86.42		
	Ch510to525	Cu.M	1	15.00	56.78	0.10	85.17		
	Ch525to540	Cu.M	1	15.00	54.96	0.10	82.44		
	Ch540to555	Cu.M	1	15.00	52.18	0.10	78.28		
	Ch555to570	Cu.M	1	15.00	48.86	0.10	73.29		
	Ch570to585	Cu.M	1	15.00	45.64	0.10	68.47		
	Ch585to600	Cu.M	1	15.00	42.79	0.10	64.19		
	Ch600to615	Cu.M	1	15.00	39.61	0.10	59.42		
	Ch615to630	Cu.M	1	15.00	35.94	0.10	53.92		
	Ch630to645	Cu.M	1	15.00	31.27	0.10	46.90		
	Ch645to660	Cu.M	1	15.00	24.98	0.10	37.47		
	Ch660to675	Cu.M	1	15.00	20.86	0.10	31.28		
	Ch675to690	Cu.M	1	15.00	16.70	0.10	25.04		
	Ch690to705	Cu.M	1	15.00	12.00	0.10	18.00		
	<b>Below Non overflow section (Shallow George)</b>								
	Ch1710to1725	Cu.M	1	15.00	5.65	0.10	8.47		
	Ch1725to1740	Cu.M	1	15.00	6.72	0.10	10.07		
	Ch1740to1755	Cu.M	1	15.00	7.22	0.10	10.82		
	Ch1755to1770	Cu.M	1	15.00	8.05	0.10	12.07		
	Ch1770to1785	Cu.M	1	15.00	9.48	0.10	14.22		
	Ch1785to1800	Cu.M	1	15.00	10.37	0.10	15.56		
	Ch1800to1815	Cu.M	1	15.00	10.42	0.10	15.63		
	Ch1815to1830	Cu.M	1	15.00	10.13	0.10	15.19		
	Ch1830to1845	Cu.M	1	15.00	9.92	0.10	14.88		
	Ch1845to1860	Cu.M	1	15.00	9.35	0.10	14.03		
	Ch1860to1875	Cu.M	1	15.00	8.06	0.10	12.09		
	Ch1875to1890	Cu.M	1	15.00	7.26	0.10	10.89		
	Ch1890to1900	Cu.M	1	10.00	7.26	0.10	7.26		
	<b>Total Quantity</b>	<b>Cu.M</b>					<b>2591.00</b>	<b>2591.00</b>	
<b>3</b>	<b>RCC M20</b>								
a	Piers U/S	Cu.M	9	16.42	2.50	76.50	28262.93		
b	Piers D/S Considering 5m additional above TOD for gate opening	Cu.M	9	2.62	2.50	81.50	4804.43		
c	Wing walls from take-off parent canal to U/S floor	Cu.M							
d	Wing walls at Glacis & Crest	Cu.M							
e	Wing walls at D/S floor	Cu.M							
f	Wing walls at D/S Extra Road bottom	Cu.M							
	<b>Road Bridge</b>								
	Floor of Bridge	Cu.M	1	120.00	7.00	1.00	840.00		
	<b>Total Quantity</b>	<b>Cu.M</b>					<b>33907.35</b>	<b>33907.35</b>	
<b>4</b>	<b>PCC M20</b>								
	<b>Foundation for OF section</b>								
	R.L below 75.5 up to 72.0 m	Cu.M	1	95.00	61.58	5.00	14625.25		
	<b>Foundation for NOF section</b>								
	<b>LHS of the dam</b>								
	Ch160to165	Cu.M	1	5.00	12.00	5.00	150.00		
	Ch165to180	Cu.M	1	15.00	12.00	5.00	450.00		
	Ch180to195	Cu.M	1	15.00	17.78	5.00	666.75		
	Ch195to210	Cu.M	1	15.00	24.63	5.00	923.70		
	Ch210to225	Cu.M	1	15.00	30.22	5.00	1133.40		
	Ch225to240	Cu.M	1	15.00	35.16	5.00	1318.50		
	Ch240to255	Cu.M	1	15.00	39.62	5.00	1485.60		
	Ch255to270	Cu.M	1	15.00	42.81	5.00	1605.30		
	Ch270to285	Cu.M	1	15.00	44.80	5.00	1680.15		
	Ch285to300	Cu.M	1	15.00	47.73	5.00	1789.80		
	Ch300to315	Cu.M	1	15.00	52.27	5.00	1960.05		
	Ch315to330	Cu.M	1	15.00	57.03	5.00	2138.70		
	<b>RHS of the dam</b>								

Project name		Mumbai IV Water Supply							
Calculation for		Estimates of Pinjal Dam							
				Discipline	IWU	File No.	224604		
				Calc by	SHA	Date	10.11.2011		
				Checked by	NR	Date	11.11.2011		
Sl.No.	Description of item of work	Units	Nos	L	B	D	Qty	Total Qty	
	Ch450to465	Cu.M	1	15.00	60.90	5.00	2283.90		
	Ch465to480	Cu.M	1	15.00	59.70	5.00	2238.90		
	Ch480to495	Cu.M	1	15.00	58.39	5.00	2189.55		
	Ch495to510	Cu.M	1	15.00	57.62	5.00	2160.60		
	Ch510to525	Cu.M	1	15.00	56.78	5.00	2129.25		
	Ch525to540	Cu.M	1	15.00	54.96	5.00	2061.00		
	Ch540to555	Cu.M	1	15.00	52.18	5.00	1956.90		
	Ch555to570	Cu.M	1	15.00	48.86	5.00	1832.25		
	Ch570to585	Cu.M	1	15.00	45.64	5.00	1711.65		
	Ch585to600	Cu.M	1	15.00	42.79	5.00	1604.70		
	Ch600to615	Cu.M	1	15.00	39.61	5.00	1485.45		
	Ch615to630	Cu.M	1	15.00	35.94	5.00	1347.90		
	Ch630to645	Cu.M	1	15.00	31.27	5.00	1172.55		
	Ch645to660	Cu.M	1	15.00	24.98	5.00	936.75		
	Ch660to675	Cu.M	1	15.00	20.86	5.00	782.10		
	Ch675to690	Cu.M	1	15.00	16.70	5.00	626.10		
	Ch690to705	Cu.M	1	15.00	12.00	5.00	450.00		
	<b>Foundation for NOF section (Shallow gorge)</b>								
	Ch1710to1725	Cu.M	1	15.00	5.65	5.00	211.69		
	Ch1725to1740	Cu.M	1	15.00	6.72	5.00	251.81		
	Ch1740to1755	Cu.M	1	15.00	7.22	5.00	270.56		
	Ch1755to1770	Cu.M	1	15.00	8.05	5.00	301.78		
	Ch1770to1785	Cu.M	1	15.00	9.48	5.00	355.59		
	Ch1785to1800	Cu.M	1	15.00	10.37	5.00	388.97		
	Ch1800to1815	Cu.M	1	15.00	10.42	5.00	390.66		
	Ch1815to1830	Cu.M	1	15.00	10.13	5.00	379.69		
	Ch1830to1845	Cu.M	1	15.00	9.92	5.00	372.00		
	Ch1845to1860	Cu.M	1	15.00	9.35	5.00	350.72		
	Ch1860to1875	Cu.M	1	15.00	8.06	5.00	302.34		
	Ch1875to1890	Cu.M	1	15.00	7.26	5.00	272.25		
	Ch1890to1900	Cu.M	1	10.00	7.26	5.00	181.50		
	<b>Over flow section (Between CL &amp; FL )</b>								
	<b>Spill way</b>								
(i)	D/S profile up to tangent portion	Cu.M	9	13.80	9.50	9.31	5492.95		
(ii)	Rectangular portion below D/S profile	Cu.M	9	13.80	9.50	50.49	59572.12		
(iii)	Triangular portion from tangent point to toe	Cu.M	0.5	37.59	120.00	50.49	113877.13		
	<b>U/s batter portion from RL. 93.13 to RL. 75.5 m</b>								
	quantity of u/s batter portion in OF section	Cu.M	0.5	120.00	1.74	17.38	1814.47		
	NOF batter portion								
	LHS of the dam	Cu.M	0.5	30.00	1.22	12.25	224.92		
	RHS of the dam	Cu.M	0.5	105.00	0.89	8.91	208.35		
	<b>D/s Bucket profile</b>								
	d/s Bucket	Cu.M	1	27.23	120.00	7.45	12170.53		
	<b>Non over flow section (Between TOD &amp; FL )</b>								
	<b>LHS of the dam</b>								
	Ch160to165	Cu.M	1	5	12.00	0	0.00		
	Ch165to180	Cu.M	1	15	12.00	4.93	443.70		
	Ch180to195	Cu.M	1	15	13.78	13.92	1438.59		
	Ch195to210	Cu.M	1	15	20.63	22.49	3479.97		
	Ch210to225	Cu.M	1	15	26.22	29.48	5797.86		
	Ch225to240	Cu.M	1	15	31.16	35.65	8331.62		
	Ch240to255	Cu.M	1	15	35.62	41.22	11011.06		
	Ch255to270	Cu.M	1	15	38.81	45.21	13158.14		
	Ch270to285	Cu.M	1	15	40.80	47.7	14596.77		
	Ch285to300	Cu.M	1	15	43.73	51.36	16843.10		
	Ch300to315	Cu.M	1	15	48.27	57.03	20644.23		
	Ch315to330	Cu.M	1	15	53.03	62.99	25052.51		
	<b>RHS of the dam</b>								
	Ch450to465	Cu.M	1	15	56.90	67.83	28947.27		
	Ch465to480	Cu.M	1	15	55.70	66.33	27710.75		
	Ch480to495	Cu.M	1	15	54.39	64.68	26382.84		
	Ch495to510	Cu.M	1	15	53.61	63.72	25622.51		
	Ch510to525	Cu.M	1	15	52.78	62.68	24812.82		
	Ch525to540	Cu.M	1	15	50.96	60.4	23085.42		
	Ch540to555	Cu.M	1	15	48.18	56.93	20573.02		

Project name		Mumbai IV Water Supply							
Calculation for		Estimates of Pinjal Dam							
				Discipline	IWU	File No.	224604		
				Calc by	SHA	Date	10.11.2011		
				Checked by	NR	Date	11.11.2011		
Sl.No.	Description of item of work	Units	Nos	L	B	D	Qty	Total Qty	
	Ch555to570	Cu.M	1	15	44.86	52.77	17754.31		
	Ch570to585	Cu.M	1	15	41.65	48.76	15229.65		
	Ch585to600	Cu.M	1	15	38.79	45.19	13147.71		
	Ch600to615	Cu.M	1	15	35.61	41.21	11006.53		
	Ch615to630	Cu.M	1	15	31.94	36.63	8775.49		
	Ch630to645	Cu.M	1	15	27.27	30.78	6294.63		
	Ch645to660	Cu.M	1	15	20.98	22.93	3608.24		
	Ch660to675	Cu.M	1	15	16.86	17.77	2246.54		
	Ch675to690	Cu.M	1	15	12.70	12.57	1196.92		
	Ch690to705	Cu.M	1	15	12.00	3.6	324.00		
	<b>Non over flow section (Between TOD &amp; FL of Shallow gorge)</b>								
	Ch1710to1725	Cu.M	1	15.00	4.00	0.29	8.76		
	Ch1725to1740	Cu.M	2	15.00	4.22	2.43	153.96		
	Ch1740to1755	Cu.M	3	15.00	4.72	3.43	364.17		
	Ch1755to1770	Cu.M	4	15.00	5.55	5.10	848.18		
	Ch1770to1785	Cu.M	5	15.00	6.98	7.97	2086.61		
	Ch1785to1800	Cu.M	6	15.00	7.87	9.75	3452.86		
	Ch1800to1815	Cu.M	7	15.00	7.92	9.83	4087.77		
	Ch1815to1830	Cu.M	8	15.00	7.63	9.25	4231.88		
	Ch1830to1845	Cu.M	9	15.00	7.42	8.84	4427.91		
	Ch1845to1860	Cu.M	10	15.00	6.85	7.71	3961.90		
	Ch1860to1875	Cu.M	11	15.00	5.56	5.13	2354.58		
	Ch1875to1890	Cu.M	12	15.00	4.76	3.52	1510.32		
	Ch1890to1900	Cu.M	13	10.00	4.76	3.52	1090.78		
	<b>Total Quantity</b>	<b>Cu.M</b>					<b>660382.66</b>	<b>660382.66</b>	
	<b>5 Grouting in the Dam foundation</b>								
	Drilling of 75mm dia grout holes at 3.0mc/c along the axis of the dam nearer to heel sloping towards u/s	rmt	57			54.33	3096.81		
		rmt	85			54.33	4618.05		
		rmt	40			54.33	2173.2		
	<b>Grouting in the Dam foundation (shallow gorge)</b>								
	Drilling of 75mm dia grout holes at 6.0mc/c along the axis of the dam nearer to heel sloping towards u/s	rmt	32			13.6	435.2		
	<b>Total Quantity</b>	<b>Rmt</b>					<b>10323.26</b>	<b>10323.26</b>	
	<b>Quantity of grout</b>								
	Assuming 75mm dia grout holes at 3.0mc/c along the axis of the dam nearer to heel sloping towards u/s								
	NOF LHS	Ton	57		0.04	54.33	178.38		
	NOF RHS	Ton	85		0.04	54.33	266		
	OF	Ton	40		0.04	54.33	125.18		
	<b>Quantity of grout (shallow gorge)</b>								
	Assuming 75mm dia grout holes at 6.0mc/c along the axis of the dam nearer to heel sloping towards u/s								
	NOF LHS	Ton	32		0.04	13.6	25.07		
	<b>Total Quantity</b>	<b>Tonnes</b>					<b>594.63</b>	<b>594.63</b>	
	<b>6 Spilway Radia gates</b>								
(i)	embedded parts								
	$W=0.0177*(L^{12}+H^4)^{0.673}$	Tonnes	10	9.80	1.00	9.70	82.19		
	<b>Total Quantity</b>						<b>82.19</b>	<b>82.19</b>	
(i)	Radial gates								
	$W=0.0710*(L^{12}+H^4)^{0.673}$	Tonnes	10	9.80	1.00	9.70	329.71		
	<b>Total Quantity</b>	<b>Tonnes</b>					<b>329.71</b>	<b>329.71</b>	
(ii)	Electrically operated rope drum Hoist								
	1.5*wt of gates and rounding it to 10tonnes	Tonnes					500.00		
	<b>Total Quantity</b>	<b>Tonnes</b>					<b>500.00</b>	<b>500.00</b>	
	<b>Spilway stoplog gates</b>								
	embedded parts								
	$W=0.0025*(L^{12}+H^4)^{0.716}$ as per (2011-2012)	Tonnes	10	10.15	1	9.7	18.14		
	<b>Total Quantity</b>						<b>18.14</b>	<b>18.14</b>	
	Vertical sliding type stoplog gates								
	$W=0.0553*(L^{12}+H^4)^{0.716}$	Tonnes	10	10.15	1	9.7	401.22		
	<b>Total Quantity</b>						<b>401.22</b>	<b>401.22</b>	

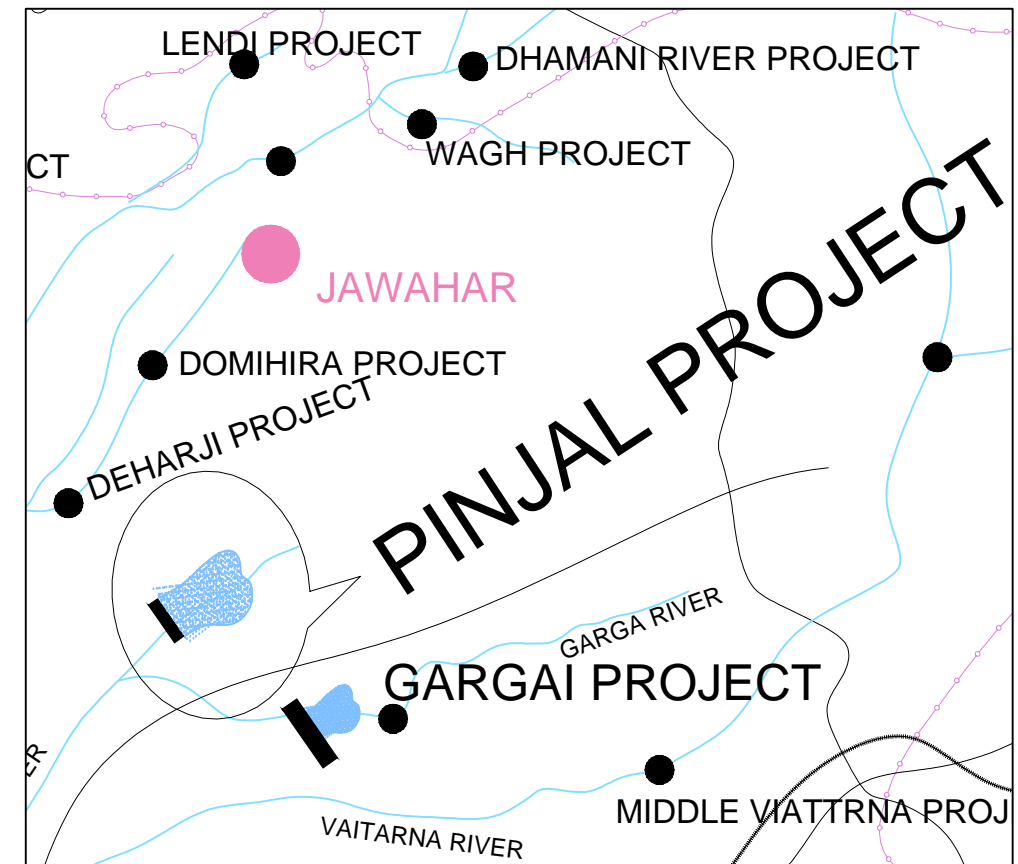
Project name		Mumbai IV Water Supply							
Calculation for		Estimates of Pinjal Dam							
				Discipline	IWU	File No.	224604		
				Calc by	SHA	Date	10.11.2011		
				Checked by	NR	Date	11.11.2011		
Sl.No.	Description of item of work	Units	Nos	L	B	D	Qty	Total Qty	
	Automatic lifting beam with all accessories								
	$W=0.02212*(L^{0.2}+H^3)^{0.716}/n$	Tonnes	10	10.15	1	9.7	80.24		
	<b>Total Quantity</b>						80.24	80.24	
	Moving gantry crane								
	2.5*wt of vertical sliding stop log gates	Tonnes					501.53		
	<b>Total Quantity</b>						501.53	501.53	
<b>8</b>	<b>Cat walk/Operating plat form</b>								
	1m wide catwalk along the dam (OF) is 300kg/m length	m	1	120	1		120		
	<b>Total Quantity</b>						120	120	
<b>9</b>	<b>Steel reinforcement</b>								
	(i) For piers and Road bridge M20 (Assume 50Kg/Cum)	MT		33907.35	X	50.00	1695367.5		
	(ii) For foundation gallery 50kg/cum	MT		2483.75	X	50.00	124187.5		
	(iii) Assumed 50% of OF is provided with reinforcement	MT		207985.72	X	50.00	5199643.04		
	<b>Total Quantity</b>	MT					7019.198	7019.20	
<b>10</b>	<b>Operating Platform</b>								
	(i) Chequered Plate Sheet	Sq.Mt	1	2.00	28.20	-	56.40		
	<b>Total Quantity</b>	Sq.Mt					56.40	56.40	
<b>11</b>	<b>Service Gate</b>								
		Sq.Mt	3	24.00	6.00	-	432		
	<b>Total Quantity</b>	Sq.Mt					432	432	
<b>12</b>	<b>Hand railing with GI Pipe</b>								
	On Operating Platform	Rmt	6	130.00	-	-	780.00		
	On Bridge	Rmt	6	130.00	-	-	780.00		
	<b>Total Quantity</b>	Rmt					1560.00	1560.00	

Summary of quantites			
Sr no	Description of Items	Units	Total Qty
1	Excavation Earth work	Cu.M	127582.83
3	PCC M15	Cu.M	2591.00
4	RCC M20	Cu.M	33907.35
5	PCC M20	Cu.M	660382.66
9	Steel reinforcement	MT	7019.198
10	Operating Platform	m	120.00
11	Radial gates of spilway		
	Embedded parts	MT	82.19
	service gates including hoist	MT	500.00
	Stoplog Gates of spilway		
	Embedded parts	MT	18.14
	Vertical sliding stoplog gates	MT	401.22
	Lifting beam	MT	80.24
	Moving Gantry crane	MT	501.53
12	Hand railing with GI Pipe	Rmt	1560.00
13	Grouting	Tonnes	594.63
14	Grout Holes	Rmt	10323.26



**LEGENT**


- 1. PROPOSED DAM SITE
- 2. SUBMERGENCE AREA
- 3. RIVER
- 4. DISTRICT BOUNDRY
- 5. METROPOLITIN REGION
- 6. HYDROMATRIC AREA
- 7. RAILWAY
- 8. CITY

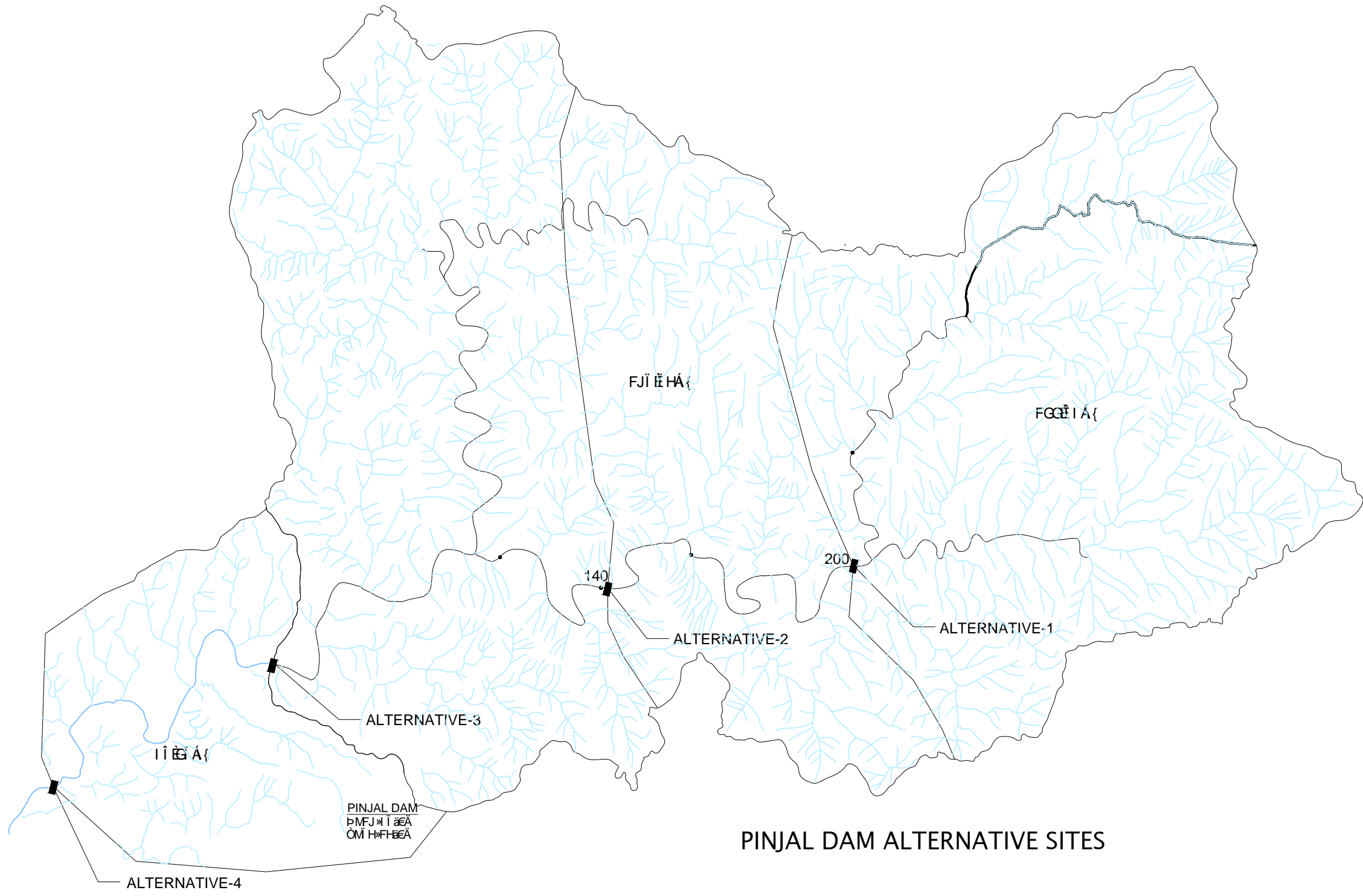


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 <p><b>Mott MacDonald</b></p> <p>7th Floor Prism Tower, Mindspace Goregaon, 400 062 India</p> <p>T +91(0) 22 39810100 F +91(0) 22 3981 0212 W www.mottmac.com</p>	<p>Client</p> <p><b>MUNICIPAL CORPORATION OF BRIHAN MUMBAI.</b></p>	Rev	Date	Drawn	Description	Ó@ç	ç]ç	Title	Drawn	RSK
		P0	11-11-11	RSK			KNR			PINJAL DAM INDEX PLAN
									Approved	
									Scale at A3 NTS	
									Drawing Number	MMD-224604-C-DR-PIN-XX-0001
									Status	PRE
									Rev	P0

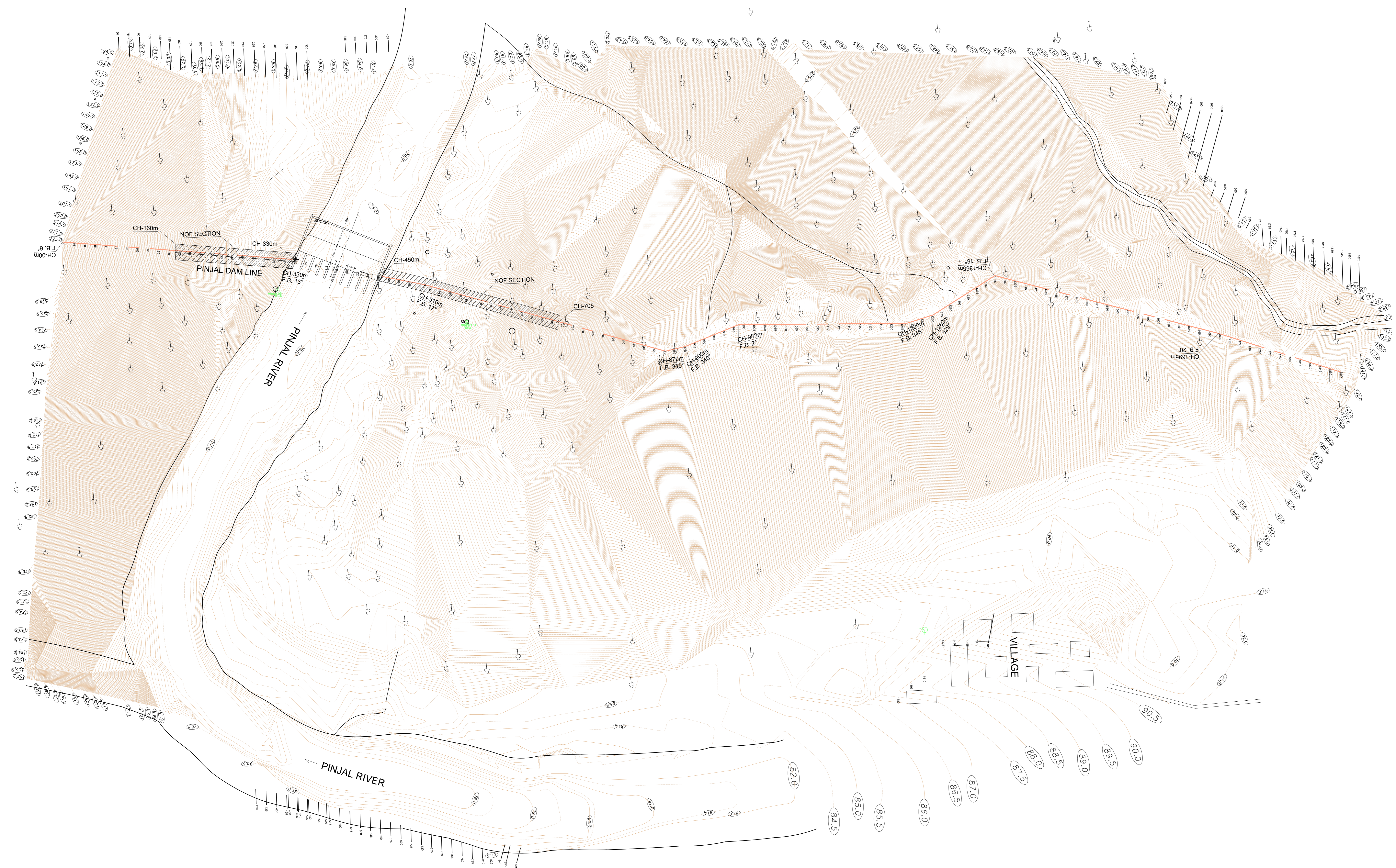


PINJAL DAM ALTERNATIVE SITES

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 7th Floor Prism Tower, Mindspace Goregaon, 400 062 India	Client <b>Municipal Corporation of Brihan Mumbai</b>	Rev 11-11-11 RSK	Date 11-11-11	Drawn RSK	Description	Title <b>Alternative Locations of Pinjal Dam</b>	Drawn Checked Approved Scale at A3	RSK GS
	Project <b>IV MUMBAI WATER SUPPLY PROJECT</b>	Drawing Number <b>MMD-224604-C-DR-PIN-XX-0002</b>	Rev Status					

- 1) ALL DIMENSIONS ARE IN METRES UNLESS OTHERWISE SPECIFIED.
- 2) ALL LEVELS AND RUNNING DISTANCES ARE IN METRES.
- 3) THE DRAWING IS PREPARED ON THE BASIS OF RECENT SURVEY DATA IN THE ABSENCE OF GEOLOGICAL INVESTIGATIONS.
- 4) DIMENSIONS SHOULD NOT BE SCALED FROM THE DRAWING.
- 5) CEMENT CONCRETE CONSTRUCTION SHOULD CONFORM TO IS 456-1988.
- 6) THE DETAILS SHOWN IN THIS DRAWING ARE LIKELY TO CHANGE AS PER GEOLOGICAL INVESTIGATIONS.
- 7) THE CONTROL LEVELS NAMED F.B.L. (M.M. CREST LEVEL OF SPILLWAY, T.B. MOD. IS BASED ON RECENT SURVEY DATA.
- 8) THIS DRAWING IS INTENDED TO INDICATE GENERAL GUIDELINES FOR THE CONSIDERATION OF FEASIBILITY REPORT.
- 9) THE STORAGE SITE LIES IN SEISMIC ZONE II AND ACCORDINGLY THE OVER FLOW AND NOT OVER FLOW SECTIONS ARE DESIGNED.
- 10) THE SPILLWAY IS TO BE FITTED IN THE MAIN GORGE PORTION WITH MINIMUM EXCAVATION.
- 11) THE SIZE OF SPILLWAY GATES CONSIDERED IN THIS DRAWING IS SUBJECT FOR CHANGE AS PER THE APPROVED DESIGN FLOOD BY THE COMPETENT AUTHORITY.
- 12) ALL THE COMPONENTS SHOWN IN THIS DRAWING ARE INDICATIVE.
- 13) THE DAM IS PROPOSED TO BE CONSTRUCTED FROM ROLLER COMPACTED CONCRETE.



### DAM LINE PLAN

PO	11-11-11	RSK		KNR
Rev	Date	Drawn	Description	

7th Floor  
Prism Tower, Mindspace  
Goregaon, 400 062  
India  
P: +91 (0)22 3981 0100  
F: +91 (0)22 3981 0212  
www.mottmac.com

Client  
**Municipal Corporation of  
Brihan Mumbai**

Title  
**GENERAL LAYOUT OF  
PINJAL DAM**

Designed	RSK	Eng check	GS/KNR
Drawn	GS	Coordination	
Dwg check	GS	Approved	
Scale at A0	Status	Rev	
NTS	PRE	PO	

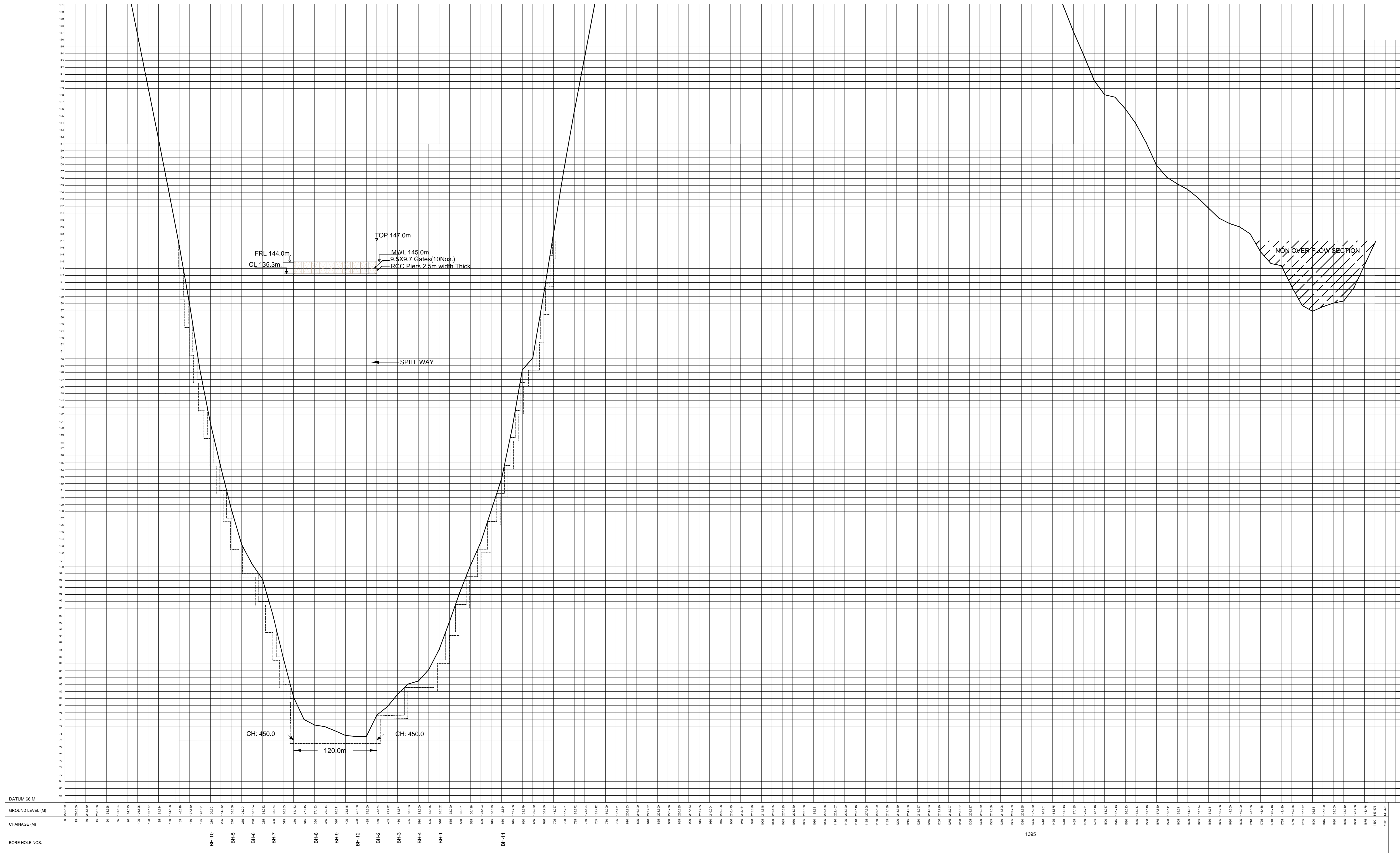
Drawing Number  
**MMD-224604-C-DR-PIN-XX-0003**

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Project: Pinjal Dam Feasibility Study  
Drawing: FALLIGNMENT & SECTION OF GARGA DAM 05-03-10\_recover.dwg  
Nov 11, 2011 5:22PM ram0500

Notes

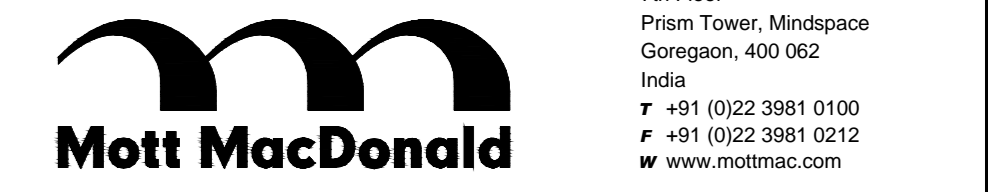
- 1) ALL DIMENSIONS ARE IN METRES UNLESS OTHERWISE SPECIFIED.
- 2) ALL LEVELS AND RUNNING DISTANCES ARE IN METRES.
- 3) THE DRAWING IS PREPARED ON THE BASIS OF RECENT SURVEY DATA IN THE ABSENCE OF GEOLOGICAL INVESTIGATIONS.
- 4) DIMENSIONS SHOULD NOT BE SCALED FROM THE DRAWING.
- 5) CEMENT CONCRETE CONSTRUCTION SHOULD CONFORM TO IS 456-1989.
- 6) THE DETAILS SHOWN IN THIS DRAWING ARE LIKELY TO CHANGE AS PER GEOLOGICAL INVESTIGATIONS.
- 7) THE CONTROL LEVELS NAMELY F.R.L., MWL, CREST LEVEL OF SPILLWAY, T.S. MOD. IS BASED ON RECENT SURVEY DATA.
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- 12) ALL THE COMPONENTS SHOWN IN THIS DRAWING ARE INDICATIVE.
- 13) THE DAM IS PROPOSED TO BE CONSTRUCTED FROM ROLLER COMPACTED CONCRETE.



DATUM 66 M	
GROUND LEVEL (M)	CHAINAGE (M)
147.00	0
146.80	10
146.60	20
146.40	30
146.20	40
146.00	50
145.80	60
145.60	70
145.40	80
145.20	90
145.00	100
144.80	110
144.60	120
144.40	130
144.20	140
144.00	150
143.80	160
143.60	170
143.40	180
143.20	190
143.00	200
142.80	210
142.60	220
142.40	230
142.20	240
142.00	250
141.80	260
141.60	270
141.40	280
141.20	290
141.00	300
140.80	310
140.60	320
140.40	330
140.20	340
140.00	350
139.80	360
139.60	370
139.40	380
139.20	390
139.00	400
138.80	410
138.60	420
138.40	430
138.20	440
138.00	450
137.80	460
137.60	470
137.40	480
137.20	490
137.00	500
136.80	510
136.60	520
136.40	530
136.20	540
136.00	550
135.80	560
135.60	570
135.40	580
135.20	590
135.00	600
134.80	610
134.60	620
134.40	630
134.20	640
134.00	650
133.80	660
133.60	670
133.40	680
133.20	690
133.00	700
132.80	710
132.60	720
132.40	730
132.20	740
132.00	750
131.80	760
131.60	770
131.40	780
131.20	790
131.00	800
130.80	810
130.60	820
130.40	830
130.20	840
130.00	850
129.80	860
129.60	870
129.40	880
129.20	890
129.00	900
128.80	910
128.60	920
128.40	930
128.20	940
128.00	950
127.80	960
127.60	970
127.40	980
127.20	990
127.00	1000
126.80	1010
126.60	1020
126.40	1030
126.20	1040
126.00	1050
125.80	1060
125.60	1070
125.40	1080
125.20	1090
125.00	1100
124.80	1110
124.60	1120
124.40	1130
124.20	1140
124.00	1150
123.80	1160
123.60	1170
123.40	1180
123.20	1190
123.00	1200
122.80	1210
122.60	1220
122.40	1230
122.20	1240
122.00	1250
121.80	1260
121.60	1270
121.40	1280
121.20	1290
121.00	1300
120.80	1310
120.60	1320
120.40	1330
120.20	1340
120.00	1350
119.80	1360
119.60	1370
119.40	1380
119.20	1390
119.00	1400
118.80	1410
118.60	1420
118.40	1430
118.20	1440
118.00	1450
117.80	1460
117.60	1470
117.40	1480
117.20	1490
117.00	1500
116.80	1510
116.60	1520
116.40	1530
116.20	1540
116.00	1550
115.80	1560
115.60	1570
115.40	1580
115.20	1590
115.00	1600
114.80	1610
114.60	1620
114.40	1630
114.20	1640
114.00	1650
113.80	1660
113.60	1670
113.40	1680
113.20	1690
113.00	1700
112.80	1710
112.60	1720
112.40	1730
112.20	1740
112.00	1750
111.80	1760
111.60	1770
111.40	1780
111.20	1790
111.00	1800
110.80	1810
110.60	1820
110.40	1830
110.20	1840
110.00	1850
109.80	1860
109.60	1870
109.40	1880
109.20	1890
109.00	1900
108.80	1910
108.60	1920
108.40	1930
108.20	1940
108.00	1950
107.80	1960
107.60	1970
107.40	1980
107.20	1990
107.00	2000
106.80	2010
106.60	2020
106.40	2030
106.20	2040
106.00	2050
105.80	2060
105.60	2070
105.40	2080
105.20	2090
105.00	2100
104.80	2110
104.60	2120
104.40	2130
104.20	2140
104.00	2150
103.80	2160
103.60	2170
103.40	2180
103.20	2190
103.00	2200
102.80	2210
102.60	2220
102.40	2230
102.20	2240
102.00	2250
101.80	2260
101.60	2270
101.40	2280
101.20	2290
101.00	2300
100.80	2310
100.60	2320
100.40	2330
100.20	2340
100.00	2350
99.80	2360
99.60	2370
99.40	2380
99.20	2390
99.00	2400
98.80	2410
98.60	2420
98.40	2430
98.20	2440
98.00	2450
97.80	2460
97.60	2470
97.40	2480
97.20	2490
97.00	2500
96.80	2510
96.60	2520
96.40	2530
96.20	2540
96.00	2550
95.80	2560
95.60	2570
95.40	2580
95.20	2590
95.00	2600
94.80	2610
94.60	2620
94.40	2630
94.20	2640
94.00	2650
93.80	2660
93.60	2670
93.40	2680
93.20	2690
93.00	2700
92.80	2710
92.60	2720
92.40	2730
92.20	2740
92.00	2750
91.80	2760
91.60	2770
91.40	2780
91.20	2790
91.00	2800
90.80	2810
90.60	2820
90.40	2830
90.20	2840
90.00	2850
89.80	2860
89.60	2870
89.40	2880
89.20	2890
89.00	2900
88.80	2910
88.60	2920
88.40	2930
88.20	2940
88.00	2950
87.80	2960
87.60	2970
87.40	2980
87.20	2990
87.00	3000
86.80	3010
86.60	3020
86.40	3030
86.20	3040
86.00	3050
85.80	3060
85.60	3070
85.40	3080
85.20	3090
85.00	3100
84.80	3110
84.60	3120
84.40	3130
84.20	3140
84.00	3150
83.80	3160
83.60	3170
83.40	3180
83.20	3190
83.00	3200
82.80	3210
82.60	3220
82.40	3230
82.20	3240
82.00	3250
81.80	3260
81.60	3270
81.40	3280
81.20	3290
81.00	3300
80.80	3310
80.60	3320
80.40	3330
80.20	3340
80.00	3350
79.80	3360
79.60	3370
79.40	3380
79.20	3390
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78.80	3410
78.60	3420
78.40	3430
78.20	3440
78.00	3450
77.80	3460
77.60	3470
77.40	3480
77.20	3490
77.00	3500
76.80	3510
76.60	3520
76.40	3530
76.20	3540
76.00	3550
75.80	3560
75.60	3570
75.40	3580
75.20	3590
75.00	3600
74.80	3610
74.60	3620
74.40	3630
74.20	3640
74.00	3650
73.80	3660
73.60	3670
73.40	3680
73.20	3690
73.00	3700
72.80	3710
72.60	3720
72.40	3730
72.20	3740
72.00	3750
71.80	3760
71.60	3770
71.40	3780
71.20	3790
71.00	3800
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69.60	3870
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67.80	3960
67.60	3970
67.40	3980
67.20	3990
67.00	4000
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66.60	4020
66.40	4030
66.20	4040
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65.20	4090
65.00	4100
64.80	4110
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64.00	4150
63.80	4160
63.60	4170
63.40	4180
63.20	4190
63.00	4200
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62.00	4250
61.80	4260
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61.40	4280
61.20	4290
61.00	4300
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59.40	4380
59.20	4390
59.00	4400
58.80	4410
58.60	4420
58.40	4430
58.20	4440
58.00	4450
57.80	4460
57.60	4470
57.40	4480
57.20	4490
57.00	4500

L-SECTION SCALE:- V = 1 : 200  
H = 1 : 2000

PO	11-11-11	RSK		KNR
Rev	Date	Drawn	Description	Óñññ

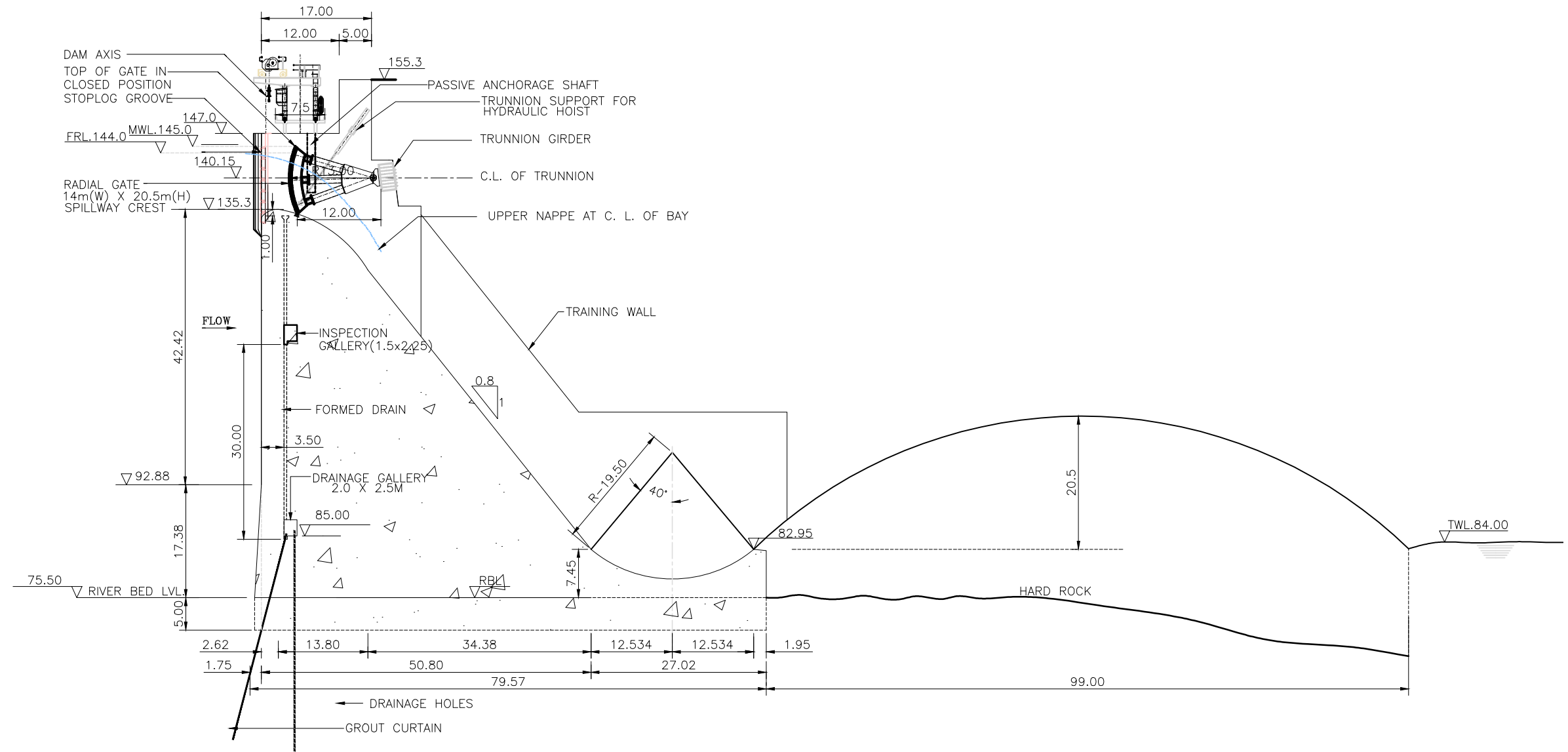


Client: Municipal Corporation of Brihan Mumbai

CROSS SECTION OF RIVER AT DAM LOCATION

Designed		Eng check	GSKNR
Drawn	RSK	Coordination	
Dwg check		Approved	
Scale at A0	NTS	Status	PRE
Drawing Number		Rev	P0

Drawing Number: MMD-224604-C-DR-PIN-XX-0004




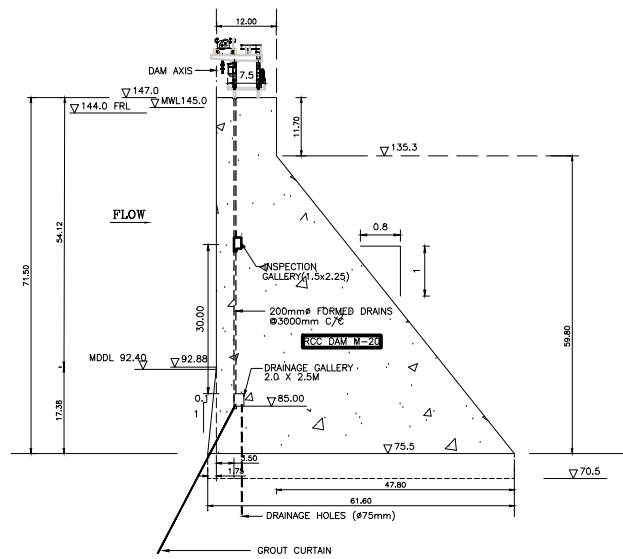
DAM-OVERFLOW SECTION

Scale 1:1

११ [ ०१ २३० ] २३

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 <p><b>Mott MacDonald</b></p> <p>7th Floor Prism Tower, Mindspace Goregaon, 400 062 India</p> <p>T +91(0) 22 39810100 F +91(0) 22 3981 0212 W www.mottmac.com</p>	Client	Rev	Date	Drawn	Description	Ó@ç	Ç]ç	Title	Drawn	RSK	
	MUNICIPAL CORPORATION OF BRIHAN MUMBAI.	P0	11-11-11	RSK			KNR		PINJAL DAM OVERFLOW SECTION WITH ENERGY DISSIPATION ARRANGEMENT	Checked	KNR.
	Project								Scale at A3	Approved	
	IV MUMBAI WATER SUPPLY PROJECT								Drawing Number	Status	Rev
								MMD-224604-C-DR-PIN-XX-0005	PRE	P0	

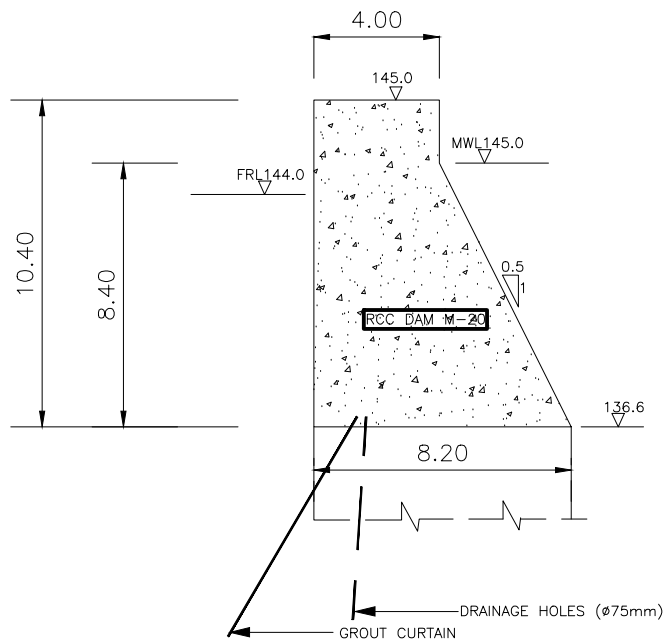


DAM-NON OVERFLOW SECTION IN MAIN DAM  
SCALE 1:1

ए [ ०४ २००८ ] २००

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Project IV MUMBAI WATER SUPPLY PROJECT							
Title PINJAL DAM NON OVER FLOW SECTION							
Date	Drawn	Checked	Approved	Scale at A4	Drawing Number	Status	Rev
11-11-11	RSK	KNR	.	1:1	MMD-224604-C-DR-PD-000 6	PRE	P0



DAM-NON OVERFLOW SECTION IN SHALLOW GORGE  
SCALE 1:5

ए [ ०११ २२०८ ] २००६

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Project IV MUMBAI WATER SUPPLY PROJECT							
Title PINJAL DAM NON OVER FLOW SECTION							
Date	Drawn	Checked	Approved	Scale at A4	Drawing Number	Status	Rev
11-11-11	RSK	KNR	.	1:1	MMD-224604-C-DR-PD-0007	PRE	P0