Joint Feasibility Study for Mumbai-Ahmedabad High Speed Railway Corridor

Final Report
Volume 2

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Japan International Cooperation Agency(JICA)
Ministry of Railways, Republic of India(MOR)

Japan International Consultants for Transportation Co., Ltd.
Oriental Consultants Global Co., Ltd.
Nippon Koei Co., Ltd

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Abbreviations

Abbreviations	Formal Name
A	Articulated
AC	Alternative Current
ADB	Asian Development Bank
AGV	Automotrice à Grande Vitesse
AP	Affected Person
ASI	Archaeological Survey of India
AT	Auto Transformer Feeding
ATC	Automatic Train Control System
ATP	Auto Transformer Post
AUDA	Ahmedabad Urban Development Authority
AVE	Alta Velocidad Española
BIS	Bureau of Indian Standards
BLT	Build, Lease & Transfer
BOT	Build, Operate & Transfer
BT	Booster Transformer Feeding
BT	Build & Transfer
BTO	Build, Transfer & Operate
CAI	computer-aided instruction
CAM	Cement Asphalt Mortar
CAPEX	Capital Expenditure
CB	Circuit Breaker
CBA	Cost Benefit Analysis
CD	Compact Disc
CDM	Clean Development Mechanism
CDP	City Development Plan
CER	Certified Emission Reductions
CIDCO	City and Industrial Development Corporation of Maharashtra Limited
CMDA	Chennai Metropolitan Development Authority
CMP	Comprehensive Mobility Plans
CMS	Centralized Information Monitoring System
COMTRAC	Computer Aided Traffic Control
CPCB	Central Pollution Control Board, India, India
CRIC	China Rail Investment Corporation
CRT	Cathode-Ray Tube display
CRZ	Coastal Regulation Zone
CTC	Centralized Traffic Control
CVC	Classified Volume Count
CVCF	Constant Voltage Constant Frequency
DB	Deutsche Bahn
DC	Direct Current
DCF	Discounted Cash Flow
DEA	Department of Economic Affairs
DFC	Dedicated Freight Corridor
DMIC	Delhi Mumbai Industrial Corridor development
DMRC	Delhi Metro Rail Corporation Ltd.
DNA-CDM	Designated National Authority-Clean Development Mechanism
DPR	Detailed Project Report
DSCR	Debt Service Coverage Ratio
EAC	Environmental Appraisal Committee, India
EC	Environmental Clearance
ECBs	External Commercial Borrowings
EIA/ESIA	Environmental Impact Assessment/Environmental and Social Impact

Abbreviations	Formal Name
	Assessment
EM&MP	Environmental Management & Monitoring Plan
EMP	Environmental Management Plan
EMU	Electric Multiple Unit
EPA	Environmental Protection Act
EPCS	Electric Power Control System
ERP	Electronic Road Pricing
ES	Executive Summary
EVT	Earthed Voltage Transformer
FEM	Finite Element Method
FMS	Facility Management System
FSI	Forest Survey of India
FSI	Floor Space Index
FTr	Feeding Transformer
GC	General Consultant
GDP	Gross Domestic Product
GHG	Greenhouse Gas
GIDC	Gujarat Industrial Development Corporation
GOI	Government of India
GRDP	Gross Regional Domestic Product
GUDC	Gujarat Urban Development Corporation
HDFC	Housing Development Finance Corporation Limited
HSR	High Speed Rail
HSRA	High Speed Rail Authority
HSRC	High Speed Rail Corporation of India Limited
HUDCO	Housing & Urban Development Corporation
ICC	Integrated Circuit Card
ICE	Inter City Express
ICT	Information & Communication Technology
IDC	Interest During Construction
IDFC	Infrastructure Development Finance Company
IEIA	Initial Environment Impact Assessment
IFCs	Infrastructure Finance Companies
IIFCL	India Infrastructure Finance Company Limited
IL&FS	Infrastructure Leasing & Financial Services Limited
IMF	International Monetary Fund
INR	Indian National Rupees
IOCC	Integrated Operations Control Center
IR	Indian Railway
IR	Involuntary Resettlement
IRFC	Indian Rail Finance Corporation Ltd.
IS	Indian Standard
JETRO	Japan External Trade Organization
JICA	Japan International Cooperation Agency
JNR	Japanese National Railways
JR	Japan Railways
JRTT	Japan Railway Construction, Transport and Technology Agency
LA	Land Acquisition
LA	Lightning Arrester
LAN	Local Area Network
LARAP	Land Acquisition and Resettlement Action Plans
LBS	Load-Break Switch
LCC	Life Cycle Cost
LCX	Leaky Coaxial Cable

Abbreviations	Formal Name
LGV	Ligne à Grande Vitesse
MAP	Million Annual Passengers
METI	Ministry of Economy, Trade and Industry, Japan
MEGA	Metro Link for Gandhinagar and Ahmedabad
MEXT	Ministry of Education, Culture, Sports, Science and Technology
MLIT	Ministry of Land, Infrastructure, Transport and Tourism
MMDA	Madras Metropolitan Development Authority
MMRDA	Mumbai Metropolitan Region Development Authority
MMTS	Multi Modal Transport System
MOEF	Ministry of Environment and Forest, India
MOR	Ministry of Railways, India
MOU	Memorandum of Understanding
MOUD	Ministry of Urban Development
MPSEZ	Mundra Port and Special Economic Zone Ltd
MSK	Minimum Shift Keying
MTC	Metropolitan Transport Corporation
MWCS	Maintenance Work Control System
MoEF	Ministry of Environment and Forest, India
NA	Not Articulated
NATM	New Austrian Tunneling Method
NBFIs	Non-Banking Finance Institutions
NEAA	National Environmental Appellate Authority, India
NH	National Highway
NHAI	National Highways Authority of India
NHSRA	National High Speed Rail Authority
NOC	None Objection Certificate
NRSC	National Remote Sensing Centre
NUDP	National Urban Development Policy
NW-4	National Waterway
O&M	Operation & Maintenance
OCC	Operation Control Center
OCS	Overhead Catenary System
OD	Origin-Destination
ODA	Official Development Assistance
OFC	Optical Fiber Cable
OPEX	Operating Expenses
PAP	Project Affected Person
PAX	Passengers
PC	Power Concentration
PC	Pre-stressed Concrete
PCCP	Power Concentration Concentrated Power
PD	Power Distribution
PDDP	Power Distribution Distributed Power
PDL	Passenger Designated Lines
PE	Private Equity
PH	Public Hearing
PHC	Pre Hardened Copper
PIAs	Project Influenced Areas
PNB	Punjab National Bank
PPDPD	Person Per Day Per Direction
PPM	Post-Project Monitoring
PPP	Public Private Partnership
PPP	Purchasing Power Parity
PRC	Programmed Route Control

Abbreviations	Formal Name
PRIDe	Peninsular Region Industrial Development Corridor
PSU	Public Sector Unit
QC	Quality Control
RBI	Reserve Bank of India (Central Bank)
RC	Reinforced Concrete
RCC	Reinforced Cement Concrete
RDSO	Research Design & Standards Organization, India
RFF	Réseau Ferré de France
RFP	Request for Proposal
RLDA	Rail Land Development Authority
RO	Regional Office
ROB	Road Over Bridge
ROC	Republic of China
ROW	Right of Way
RP	Resettlement Plan
RPC	Railway static unbalanced Power Compensator
RS	Rolling Stock
RSCS	Rolling Stock Control System
RTRI	Railway Technical Research Institute
RVNL	Rail Vikas Nigam Limited
RUB	Road Under Bridge
RYWMS	Railway Yard Work Management System
SBI	State Bank of India
SCADA	Supervisory Control and Data Acquisition
SDH	Synchronous Digital Hierarchy
SEA	Strategic Environmental Assessment
SEAC	State Level Expert Appraisal Committee, India
SEIAA	State Environmental Impact Assessment Agency, India
SFC	Single phase Feeding unbalanced power Conditioner
SHM	Stake Holder Meeting
SNCF	Société Nationale des Chemins de Fer Français
SOD	Schedule of Dimensions
SP	Sectioning Post
SPC	Special Purpose Company
SPCB	State Pollution Control Board, India
SS	Substation
SSB	Single Side Band
SSO	Single Sign-on
SSP	Sub Sectioning Post
SUICA	Super Intelligent Card
TAZ	Traffic Analysis Zone
TBM	Tunnel Boring Machine
TEU	Twenty-foot Equivalent Unit
TGV	Train à Grande Vitesse
THSRC	Taiwan High Speed Rail Corporation
TIFS	Tax Increment Financing Schemes
TOD	Transport Oriented Development
TPS	Transportation Plan System
TSC	Taiwan Shinkansen Consortium
TSI	Technical Specification for Interoperability
TSS	Traction Substation
UN	United Nations
UNFCC	United Nations Framework Convention on Climate Change
UPS	Uninterruptible Power Supply

Abbreviations	Formal Name
USD	United States Dollar
UTI1	Unit Trust of India
UTPCC	Union Territory Pollution Control Committee, India
VA	Volt Ampere
VCT	Voltage and Current Transformer
VFM	Value For Money
VGF	Viability Gap Funding
WACC	Weighted Average Cost of Capital
WPI	Whole Price Index
WTP	Willingness to Pay

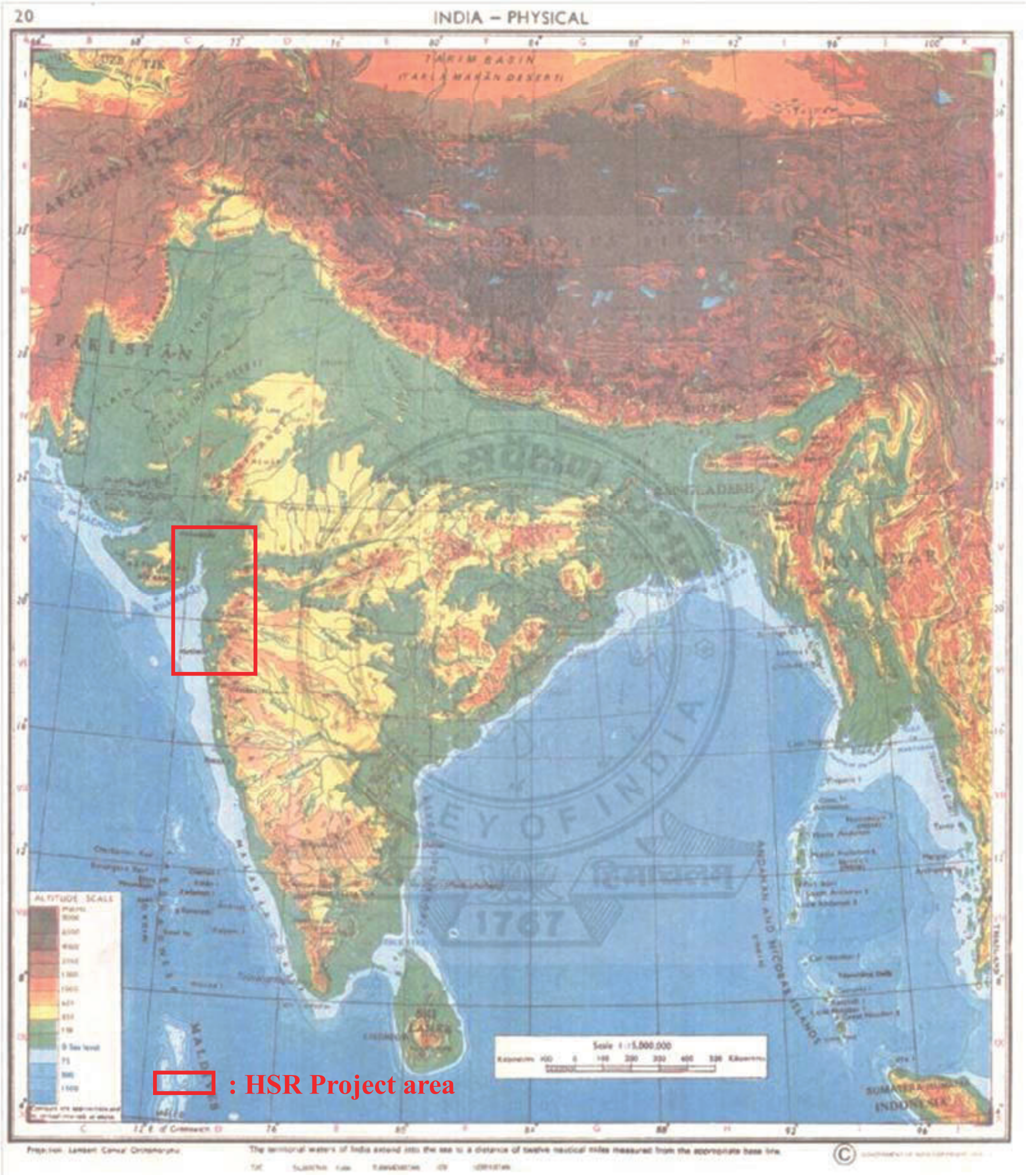
Chapter 6 Natural Condition Survey

6.1 Topographical Condition

6.1.1 General Topography

India lies largely on the Indian Plate, the northern portion of the Indo-Australian Plate, whose continental crust forms the Indian subcontinent. The country is situated north of the equator between 8°4' and 37°6' north latitude and 68°7' and 97°25' east longitude. It is the seventh-largest country in the world, with a total area of 3,166,414 square kilometers. India measures 3,214 km from north to south and 2,933 km from east to west. It has a land frontier of 15,200 km and a coastline of 7,517 km.

The project area is located at West of India facing at Arabian Sea, belonged to Maharashtra State and Gujarat State. Topographical features of Maharashtra State and Gujarat States are summarized below.



Source: Survey of India

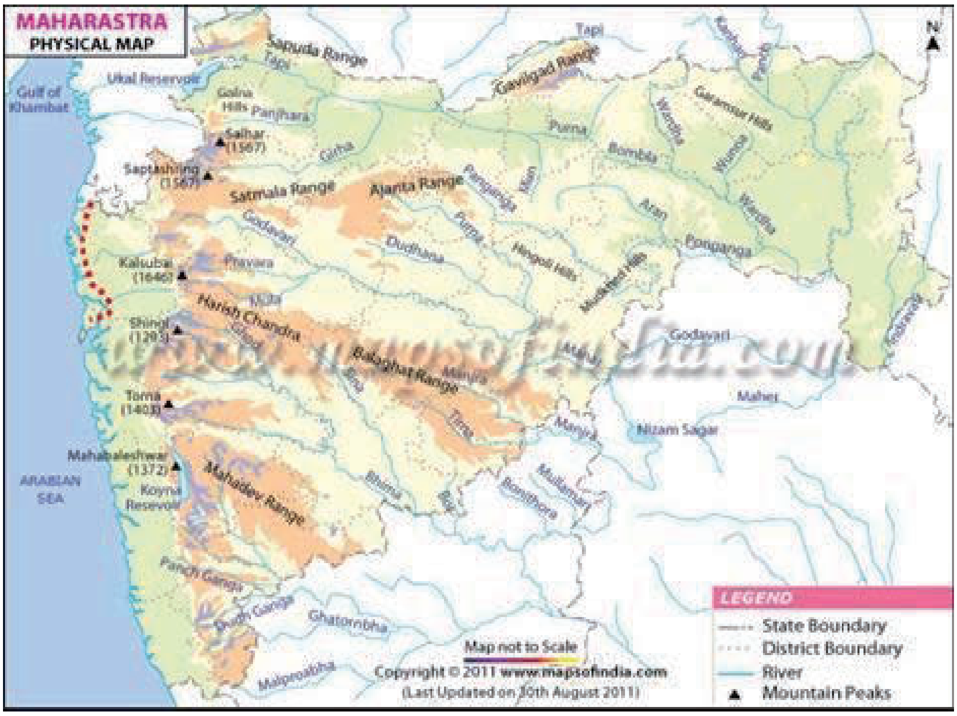
Figure 6.1-1 Physical Map of India

(1) Topography of Maharashtra State

Maharashtra is located between 15.4° & 22.1° latitude and 72.6° & 80.9° longitude and it forms a major part of peninsular India with sea coast length of 720km on Western side. The dominant physical trait of the Maharashtra State is its plateau character. The Sahyadri Range is the physical backbone of Maharashtra, rising on an average to an elevation of 1000m, it falls in steep cliffs to the Konkan on the West. Eastwards, the hill falls in steps through a transitional area known as Mawal to the plateau level. The series of crowing plateau on the crest forms a distinctive feature of the Sahyadri Range
The State is divided physically into two unequal parts as “Coastal strip of Konkan” and “Deccan plateau”.

The coastal area known as Konkan is more rugged in the South than in the north and characterized by hilly topography. Except for the hilly portion near the Sahyadri range, the altitude varies from almost 0 to 100 meter above mean sea level. The Konkan lying between the Arabian Sea and the Sahyadri Range is narrow coastal lowland, barely 50km wide, and it is far from being a plain area. Highly dissected and broken, the Konkan alternates between narrow, steep-sided valleys and low laterite plateau.

Deccan plateau is a land bounded by Satpura and Satmala ranges in the North, Sahyadri ghats in the West and extends in the South-East direction to the state boundary. A number of big rivers like Godavari and Krishna drain at this area. The river basins are hilly and narrow in the West and broad and flat in the East. The valley area is flat with long stretches of deep black alluvial soil on the East of the plateau.



Source: Map of India

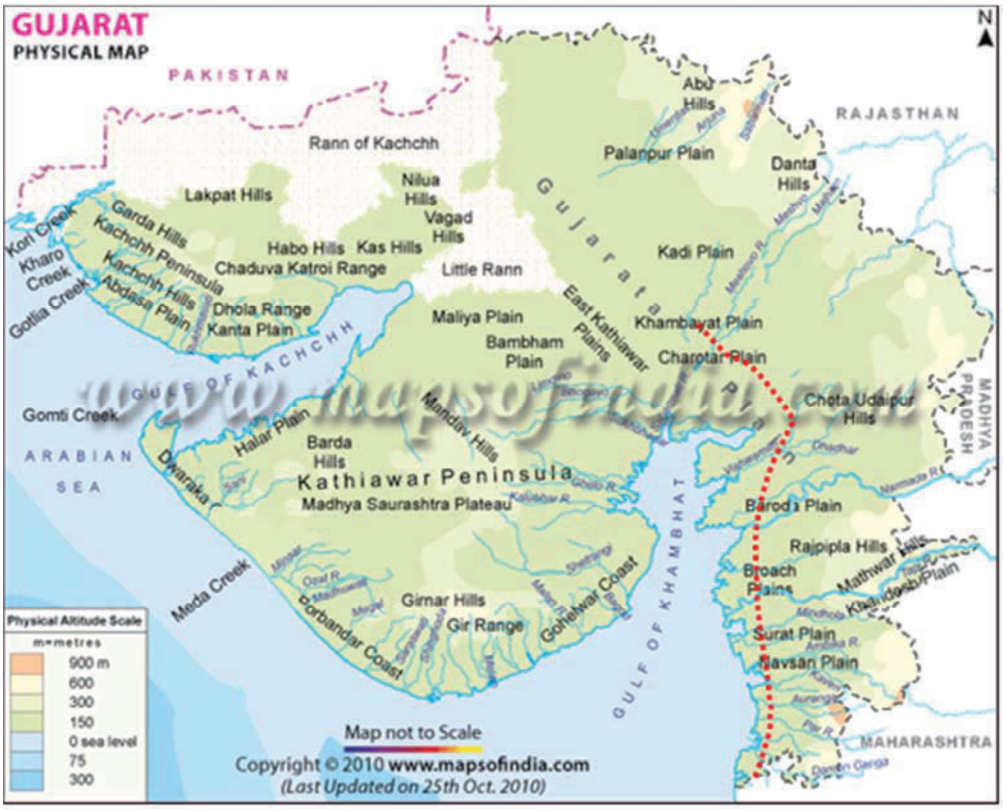
Figure 6.1-2 Physical Map of Maharashtra State

(1) Topography of Gujarat State

Gujarat is located between 20°01' to 24°07' north latitude and 68°04' to 74°04' east longitude, and covers an area of 195,984 square kilometers. Topography of Gujarat shows a wide range of physical features ranging from physiology, drainage, soil to coastal and marine environment, etc. In terms of topography, Gujarat shows a wide variation.

The topography of Gujarat indicates the varied landscape and physical features. The altitude of Gujarat varies almost to 122 meter above mean sea level.

The state of Gujarat is situated on the West coast. Based on the categories of physiographic units as relief, slopes and land forms, the state is divided into three parts as “the Coastal area”, “the plains”, and “the eastern highlands”. Surat, Valsad, Vadodara and Navsari districts come under the “Main land Gujarat” regions. The coastal areas from the Damanganga River upwards north is a narrow coastal belt which is mainly a barren strip of silt and salt marshes which broadens north towards Bharuch district and becomes fertile. The plains area also small strips in these two districts as they merge with the eastern highlands in Bharuch and Surat districts and nearly disappear in the South of Surat. The eastern highlands consist of the Vindhya, Saputara and Sahyadris mountain ranges.



Source: Map of India

Figure 6.1-3 Physical Map of Gujarat State

6.1.2 Topographical Digital Mapping

Based on the initial agreement with JICA and Ministry of Railway (MOR), the Topographical Digital Mapping for 1:50,000 was executed. The work was described in the 6.1.2.
After MOR decided to entrust the work of implementation of HSR projects to RVNL/HSRC on November 2014, then RVNL/HSRC requested the new works and JICA agreed. The newly added works are, Topographical Digital Mapping for 1:10,000, Field Topographic Survey and Control Survey for these Works. The Control Survey was described in the 6.1.3., The Field Topographic Survey was described in the 6.1.4., The Topographical Digital Mapping for 1:10,000 was described in the 6.1.5. respectively. The works are summarized as below;

F/S Study
- ✓ Procurement of ALSO Satellite Image and ASTER GDEM
- ✓ Digital Mapping (The map scale is 1:50,000)
- ✓ The alignment proposed by the map was confirmed at the 2nd JMC.
- ✓ Preliminary Survey of Alignments
- ✓ Procurement of Satellite Image
- ✓ Establishment of DGPS stations & DGPS triangulation survey
- ✓ Rectification of Satellite images & generation of DEM (Digital Elevation Model)
- ✓ Digital Mapping (The map scale is 1:10,000)
- ✓ Topographic survey at important locations (including Ahmedabad St. and Vadodara St.)

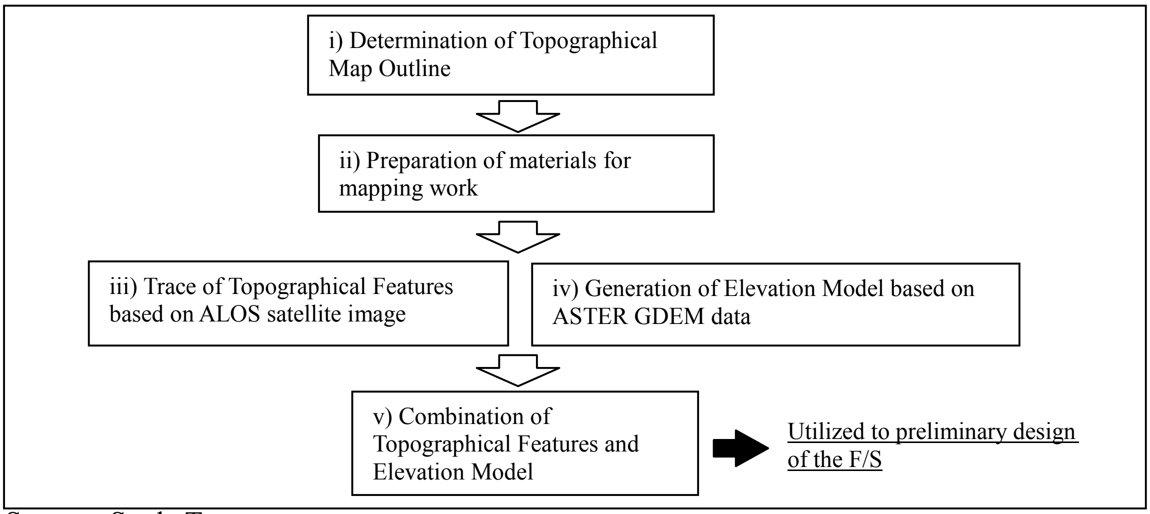
(1) General

In order to conduct the preliminary design in the F/S such as railway alignment plan and structural plans, the topographical map which covers project range of Mumbai – Ahmedabad is required. The topographical map needs to cover the long distance of 500km length and wide range for un-fixed railway alignment plan with some alternative routes.

Because such target area is too large to conduct aerial topographical survey or ground survey for a stage of the F/S, topographical digital mapping by satellite image targeted to 1:50,000-scale is selected.

(2) Procedure and methodology

The work flow of topographical digital mapping work is figured as follows.



Source : Study Team

Figure 6.1-4 Work Flow of Topographical Digital Mapping Work

1) Determination of Topographical Map Outline

a) Mapping area and scale

The topographical map needs to cover the project range of HSR line from Mumbai to Ahmedabad. The HSR route plan would be approximately based on the route proposed on Pre-F/S by MLIT in 2013. However, station location and detailed route location for HSR has not been fixed by Pre-F/S so that it has to be modified during the F/S. Therefore, the topographical map needs to cover such range of possible alternative routes. Hence, mapping area is determined by taking account of this point.

As is mentioned above, the mapping is conducted by topographical digital mapping by satellite image. Due to limited accuracy of the method and materials to be used, the map scale is targeted to 1:50,000.

b) Coordination system

The coordination system for the map is based on UTM (Universal Transverse Mercator) which is widely used in world and can be convenient to match with other information.

The project area which covers Mumbai - Ahmedabad is categorized in UTM Zone N43.

c) Interval of contour line

The interval of contour line on the map is set up as 10m because it can be enough information to be shown in 1:50,000 map in normal. Moreover, it would not mean to generate more sliced contour lines due to characteristic of ASTER GDEM.

d) Map symbols

Map symbols of topographical features on the map are mainly classified as table below:

Table 6.1-1 Map Symbols of Topographical Features

Figure	Name	Remarks
	Building	Traced by ALSO image, etc.
	Canal	Traced by ALSO image, etc.
	Contour Line	Generated by ASTER GDEM
	Forest & Open jungle	Traced by ALSO image, etc.
	Grid in Plan	-
	Road	Traced by ALSO image, etc.
	Pond	Traced by ALSO image, etc.
	Existing Railway Track	Traced by ALSO image, etc.
	River	Traced by ALSO image, etc.

Note) The table is draft version at time of ITR1 preparation. The modified might be done for the map data if necessary.

Source : Study Team

2) Preparation of materials for mapping work

The topographical digital mapping work conducted by GIS software needs base sources. Here, the work is divided into two major activities. One is to trace “Topographical Features” figured as Step iii) as and the other is to generate “Elevation model” figured as Step iv).

For tracing “Topographical Features”, ALOS satellite image is applied. Also, for generating “Elevation Model”, ASTER GDEM is applied.

The product outline and main specification for ALOS satellite image and ASTER GDEM are explained as follows.

(a) ALOS satellite image

The advanced Land Observing Satellite (ALOS) has been developed to contribute to the fields of mapping, precise regional land coverage observation, disaster monitoring, resource surveying and technology development.
One of ALOS’s objectives is to determine the position of each pixel on the ground precisely. Accordingly, ALOS minimizes the distortion of ground structures and determines position and attitude with high accuracy. For precision spacecraft position determination in particular, a dual frequency GPS receiver and high precision star trackers are mounted on ALOS.
Specially, ALSO has three sensors: the Panchromatic Remothe-sensing Instrument for Stereo Mapping (PRISM), the Advanced Visible and Near Infrared Radiometer type 2 (AVNIR-2), and the Phased Array type L-band Synthetic Aperture Radar (PALSAR).

For the mapping works, ALOS Ortho-Pro is selected which is ortho-rectified production of ALOS satellite image series.
ALSO Ortho-Pro is characterized by its high spatial resolution of 2.5m, high geo-location accuracy and consistent cloudless data. It is highly suited to base geographic dataset for mapping and Geographic Information System (GIS).

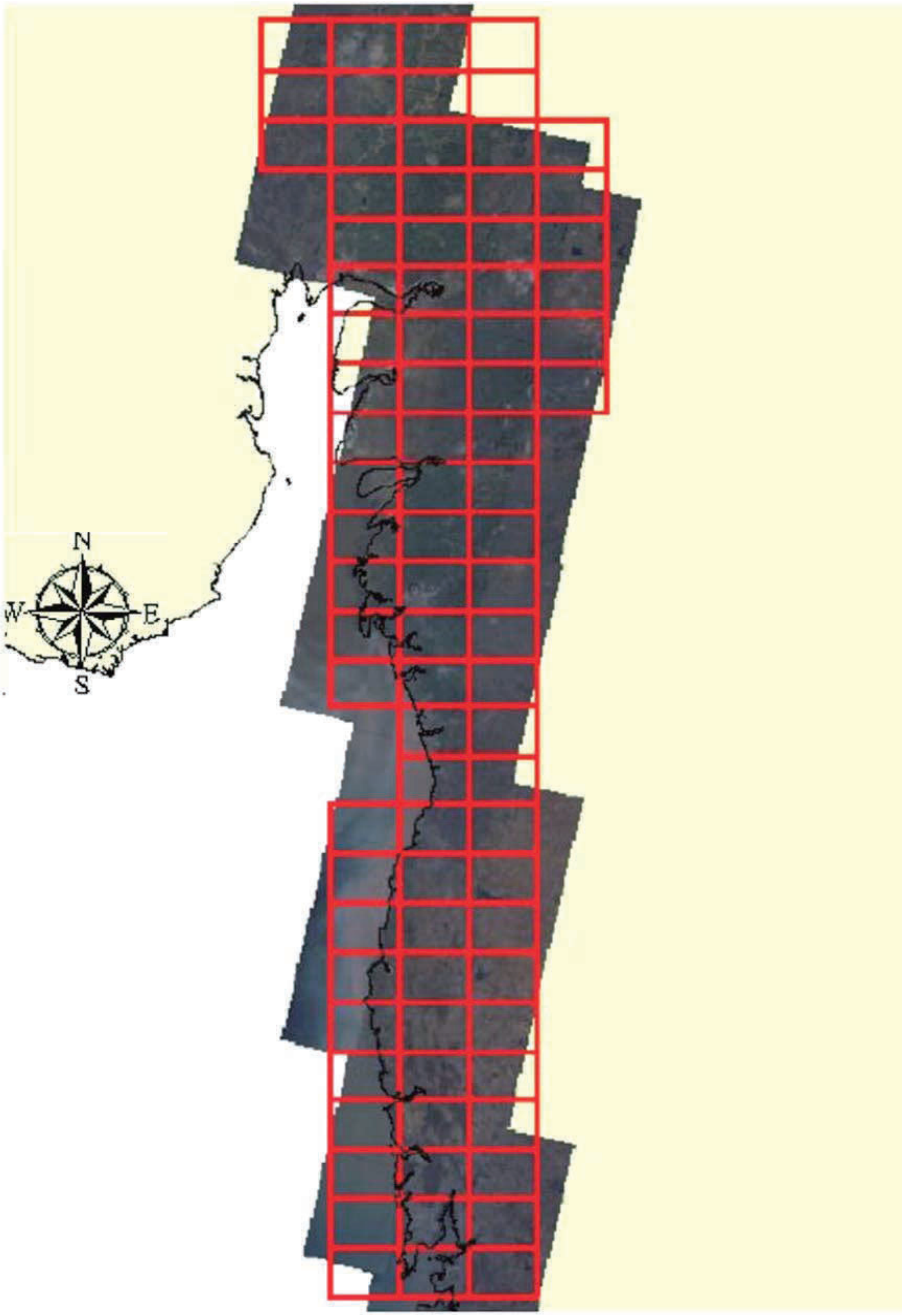
Major specification for ALOS Ortho-Pro is shown as Table 6.1-2 below:

Table 6.1-2 Major Specification for ALOS Ortho-Pro

Items	Description
Resolution	2.5m (Pan-sharpen) or 10m (AVNIR-2)
Sales Unit	1 scene or Square specification area (mosaic)
Band	4 bands (RGB + NIR) / 3 bands (RGB)
Geolocation accuracy	10m @ CE90 (2.5m resolution / 15m @ CE90 (10m resolution)
Format	Geo TIFF
Geographic coordinates	Latitude Longitude (WGS84) / UTM (WGS84)

Source : http://www.alos-restec.jp

The section map of ALOS Ortho-Pro covering to the project area is shown Figure 6.1-5 below.



Source : Supplied by NTT Data

Figure 6.1-5 Section Map of ALOS Ortho-Pro

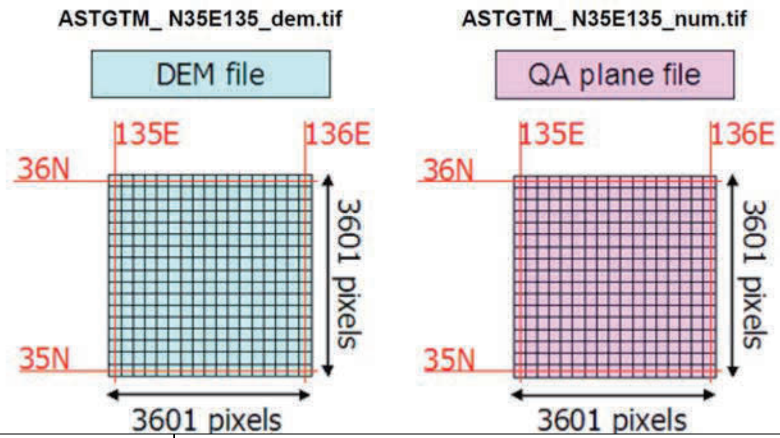
(b) ASTER GDEM

The ASTER Global Digital Elevation Model (ASTER GDEM) is a joint product developed and made available to the public by the Ministry of Economy, Trade, and Industry (METI) of Japan and the United States National Aeronautics and Space Administration (NASA). It is generated from data collected from the Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER), a spaceborne earth observing optical instrument.
The ASTER GDEM is the only DEM that covers the entire land surface of the Earth at high resolution. Since the release of the Version 1 on June 29, 2009, the ASTER GDEM has been widely used by many users and it has greatly contributed to the global earth observing community.

The advantage is that anyone can easily use the ASTER GDEM to display a bird's-eye-view map or run a flight simulation, and this should realize visually sophisticated maps. By utilizing the ASTER GDEM as a platform, institutions specialized in disaster monitoring, hydrology, energy, environmental monitoring etc. can perform more advanced analysis.

Major specification for ASTER GDEM is shown as Figure 6.1-6 below. The section map of ALOS Ortho-Pro covering to the project area is shown Figure 6.1-7.

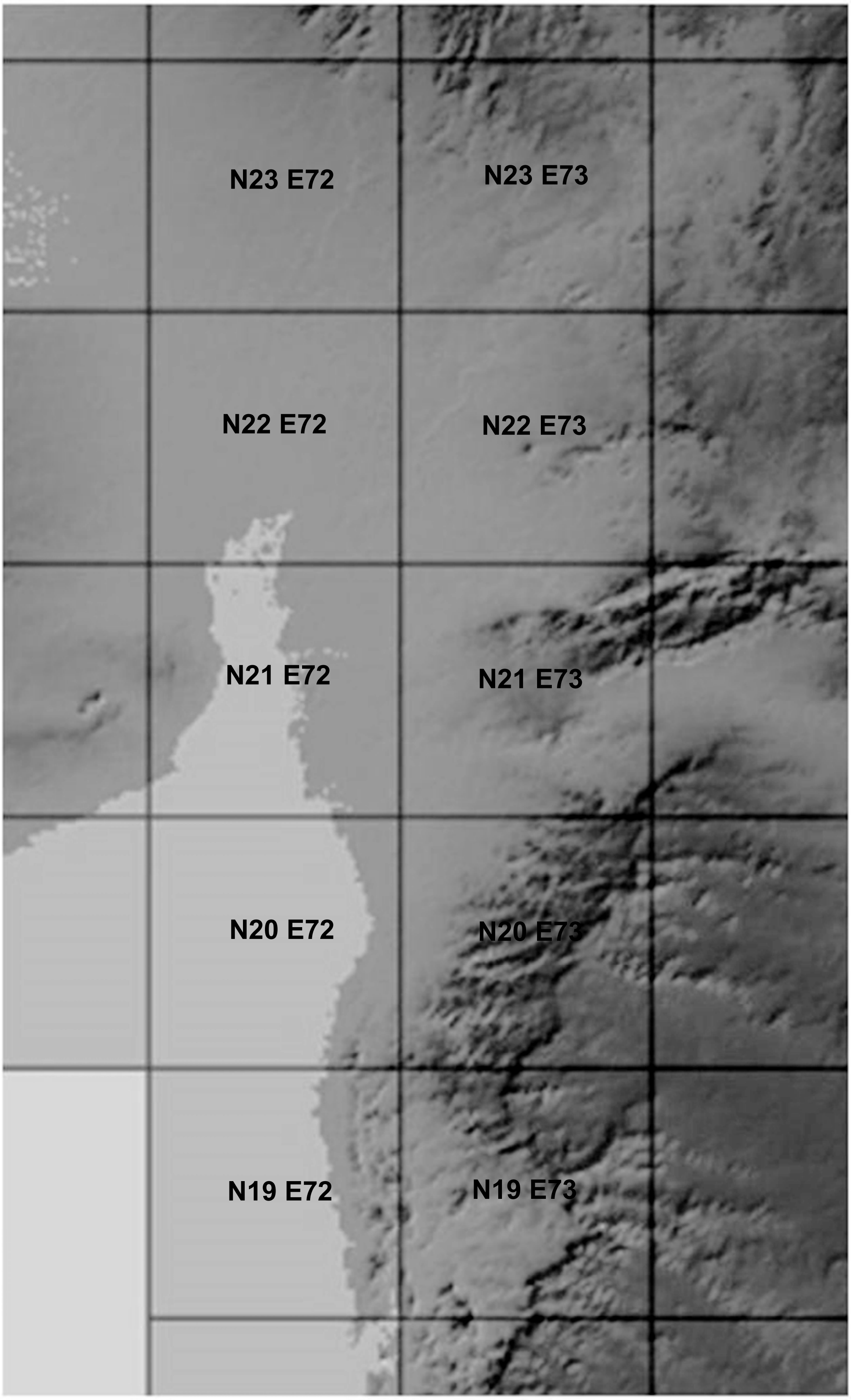
File Name (Example of N35~36, E135~136)



Output format	GeoTIFF, signed 16 bits	
Geographic coordinates	Geographic latitude and longitude	
The Size	3601-by-3601 (1-by-1 degree)	
Posting interval	1 arc-second	
DN values	1m/DN referenced to the WGS 84 / EGM96 geoid-9999 for void pixels, and 0 for sea water body	Stacking number of reference DEM SRTM3:-1,-2 CDED:-6 Alaska DEM:-11 etc.
Coverage	North 83 degrees to south 83 degrees, 22,600 tiles	
Release year	2009 ~	
Data acquisition period	2000 ~ ongoing	
Posting interval	30m	
DEM accuracy (stdev.)	7 ~ 14m	

Source : http://www.jspacesystems.or.jp

Figure 6.1-6 Major Specification of ASTER GDEM



Source : http://gdem.ersdac.jspacesystems.or.jp/search.jsp

Figure 6.1-7 Section Map of ASTER GDEM

3) Trace of topographical features based on ALOS satellite image

Drawing up of topographical features is conducted by tracing ALOS satellite image by using GIS software.

Here, topographical digital map made by MLIT of Pre-F/S can be also useful reference data. However, MLIT map does not cover some area required for possible HSR route alternatives. Also, MLIT map is sometimes not matched with the position of topographical features on ALOS satellite image. The discrepancy would be caused by accuracy and version of referenced information used for MLIT map.

Hence, the work in the F/S is to up-dated the existing MLIT map by ALOS satellite image specially focusing on following points.

- To enlarge total map area for covering HSR planning route. Specially to cover shortage area at Mumbai, Ahmedabad and Vadodara
- To check and modify the position of topographical features along HSR planning route
- To add some information obtained by the F/S study

Traced figures overlayed with ALOS satellite image is shown in Figure 6.1-5 and Figure 6.1-6.

4) Generation of elevation model based on ASTER GDEM

The elevation model is generated from ASTER GDEM data by GIS software. The elevation model is composed of contour lines in 10m intervals which identify elevation values.

The model generated in each section is combined and become a comprehensive data covering the project area of Mumbai - Ahmedabad. (Figure 6.1-10)

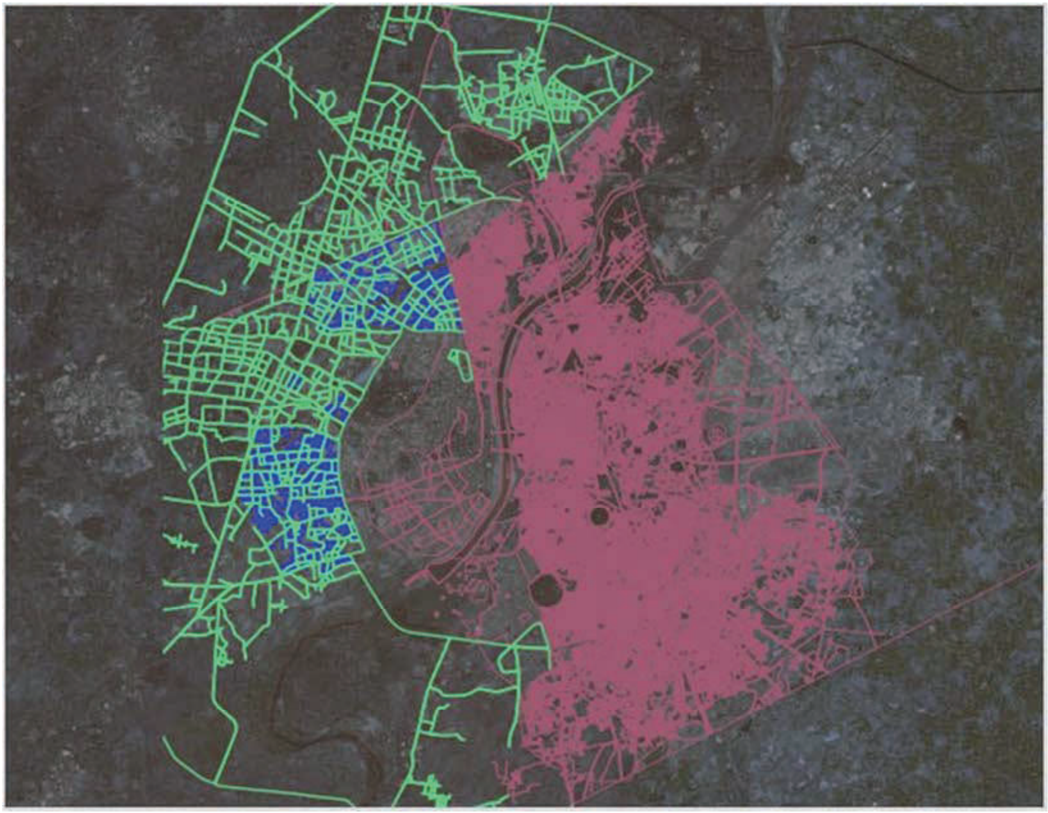
By creation of topographical elevation model, it enables to prepare longitudinal profile and cross-sections of the topography in alignment design work for the selected route at any location. Hence, drawing up of longitudinal profile and cross-sections are conducted by technical software of alignment in railway alignment design.

(3) Combined topographical map

As completion of topographical digital mapping, data of traced topographical features and generated elevation model is combined. (Figure 6.1-11)

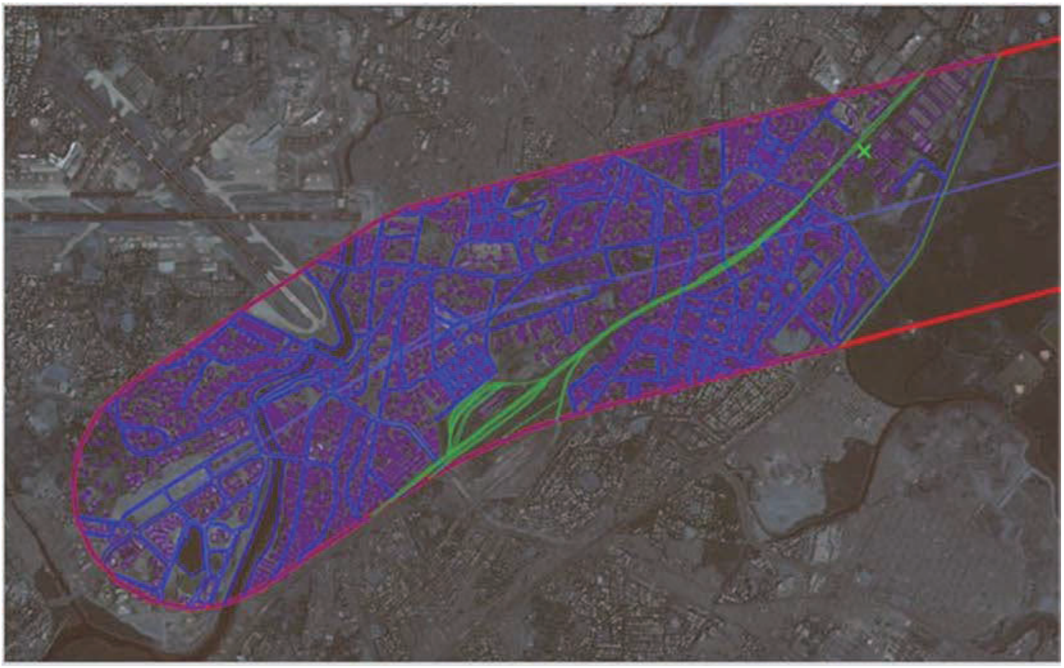
The completed topographical map is used for plan drawings in the F/S study. Please refer to the plan drawings as completed topographical map.

It is noted that topographical digital map made up in the F/S is targeted an accuracy of 1:50,000-scale and only to utilize for preliminary design in the F/S stage. It does not equip same accuracy with the map by actual ground survey or by aerial survey.



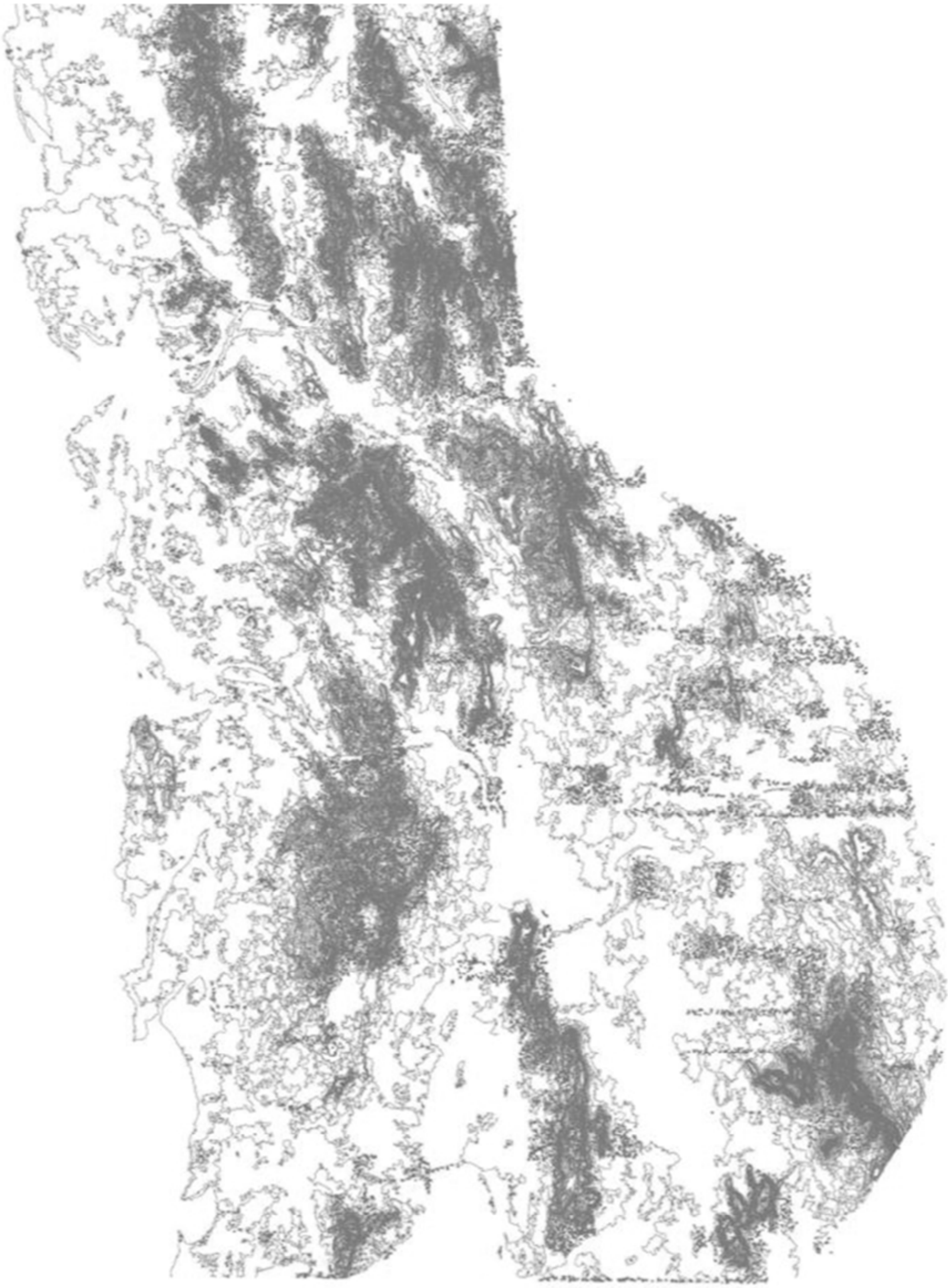
Source : Study Team

Figure 6.1-8 Trace of Topographical Features (Ahmedabad)



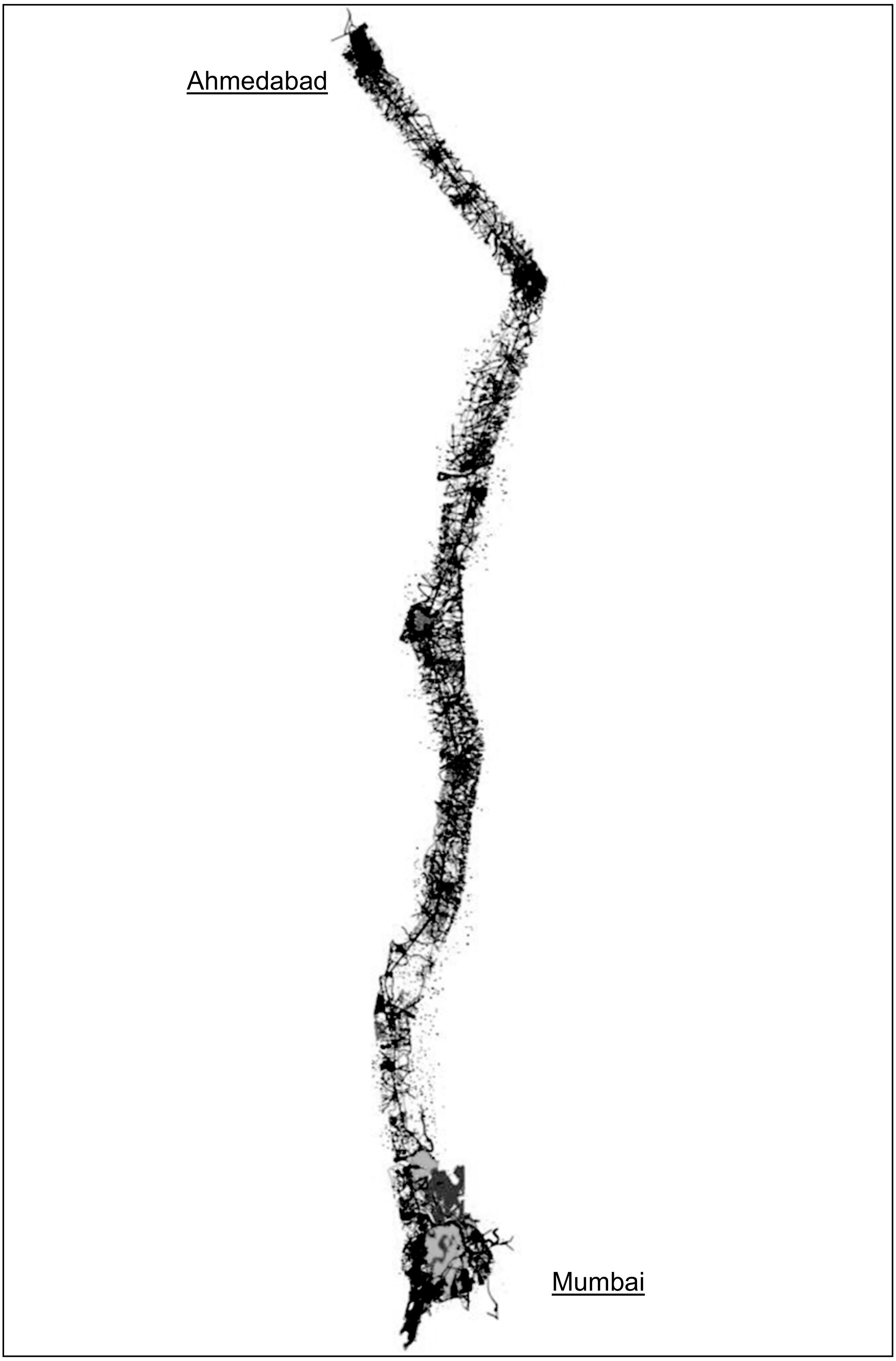
Source : Study Team

Figure 6.1-9 Trace of Topographical Features (Mumbai)



Source : Study Team

Figure 6.1-10 Generated Elevation Model (Mumbai side)



Note) The figure is draft version at time of IRT1 preparation.
Source : Study Team

Figure 6.1-11 Combined Topographical Map

6.1.3 Control Survey

(1) General

The Control Points were established for the Photocontrol Orientation Point for the Aero triangulation for making Digital Elevation Model (DEM) and Digital Topographic Map by the Satellite Imagery (stereo pairs and multispectral data of 0.5 m resolution), and for the Control Points for the Field Topographic Survey for the General Arrangement Drawings, and also for the Control Points which shall be used in succeeding stage, such as Final Location Survey and Construction stage. This is the fundamental work for the succeeding stage, therefore, was carried out with special care in the field observation work and in the data processing.

The Work comprises the collection of survey data of national control points, planning of arrangement of the control points, establishment of the firm control points, control point survey by GPS and direct leveling, data calculations and arrangement, making of accuracy table of control points and reporting etc. The description of the control points was prepared for the future Works also.

Work Flow is as follows;

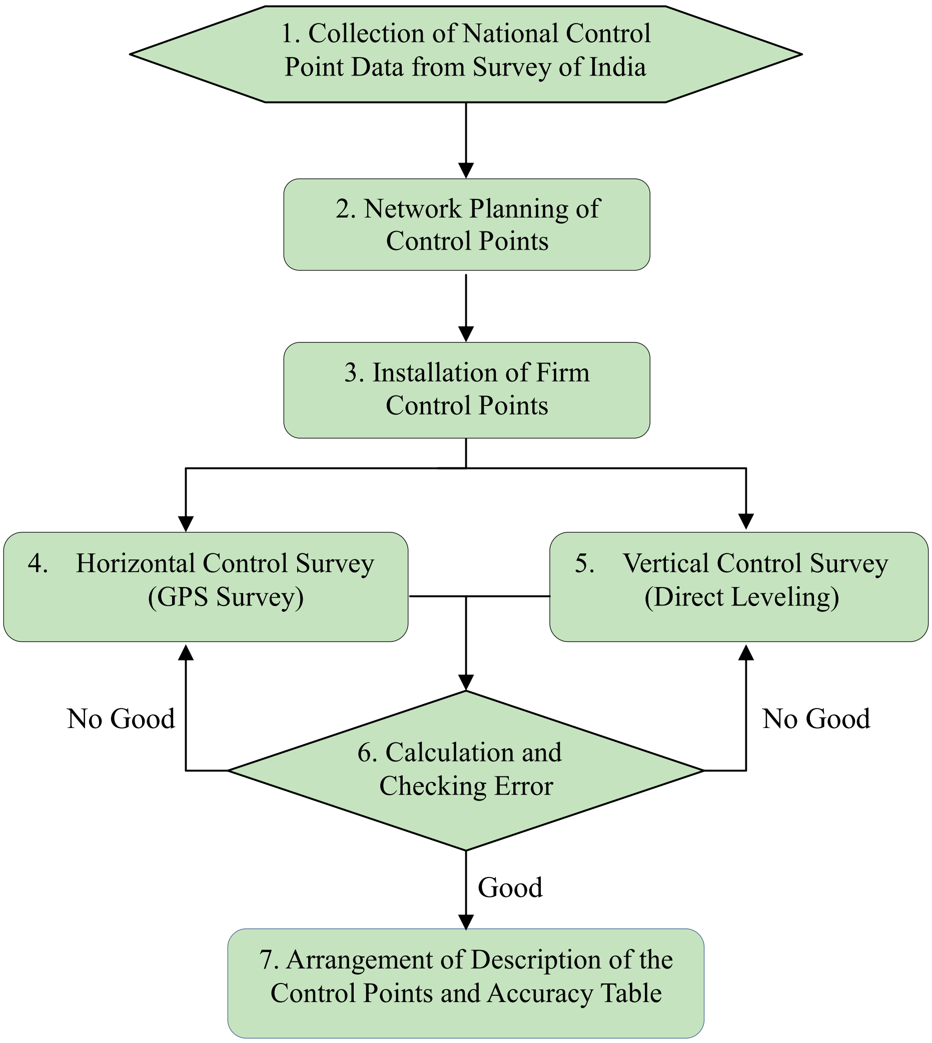


Figure 6.1-12 Work Flow chart of the Control survey

The field survey work was executed by the Local Company under the contract. The Local Company deployed 8 GPS receivers to site for establishment of Control Points to complete within 2 months and 2 GPS receivers, 6 Total Stations for Detailed Field Topographic Survey to complete within 3.5 months. To complete the task one graduate engineer/diploma holder well versed with GPS surveying for establishment of Control Points and another one graduate engineer/diploma holder well versed for Topographic Surveying using Total Station and GPS RTK were deployed for entire duration of the work and all deployed surveyors were well versed with the work to be carried out. All Engineers and surveyors were evaluated, assessed by their CVs and through the actual field work and in case anyone who were not found fit for work anytime during the progress of work were replaced.

Person in charge of Local Company and Equipments used for this work are as follows;

RITES Limited
Mr. Pradeep Tyagi
Joint General Manager / T&S
Address: RITES BHAWAN, 1, Sector-29, Gurgaon-122 001 (India)
Tel. No. +91-(0)124-2818378

Table 6.1-3 Makers, Model and Specification of Main Survey Instruments

No.	Equipment	Maker	Model	Serial No.	Specification
1	GPS	Sokia	GR-X1	640-00801	H: 3mm+0.5ppm, V: 5mm+0.5ppm, Dual frequency
2		Sokia	GR-X1	640-00809	H: 3mm+0.5ppm, V: 5mm+0.5ppm, Dual frequency
3		Sokia	GR-X1	640-00880	H: 3mm+0.5ppm, V: 5mm+0.5ppm, Dual frequency
4		Sokia	GR-X2	1144-10031	H: 3mm+0.5ppm, V: 5mm+0.5ppm, Dual frequency
5		Hemisphere	S320	1861963	H: 3mm+0.5ppm, Dual frequency
6		Hemisphere	S320	1861975	H: 3mm+0.5ppm, Dual frequency
7		Hemisphere	S320	1867691	H: 3mm+0.5ppm, Dual frequency
8		Hemisphere	S320	1867687	H: 3mm+0.5ppm, Dual frequency
9		Spectra	SP80	5425900046	H: 3mm+0.5ppm (RTK 8mm), Dual frequency
10		Spectra	SP80	5425900024	H: 3mm+0. 5ppm (RTK 8mm), Dual frequency
1	Total station	Topcon	GTS-721	330748	30X, 2mm+2ppm, 3”
2		Nikon	DTM-552	010732	33X, 2mm+2ppm, 2”
3		Trimble	TS662	A840684	30X, 2mm+2ppm, 2”
4		Geomax	Zoom20	1803768	30X, 2mm+2ppm, 2”
5		Topcon	ES-102	BS 1806	30X, 2mm+2ppm, 2”
6		Topcon	ES-102	BS 1410	30X, 2mm+2ppm, 2”
1	Level	Sokia	B40	235550	Auto Level, +/-2mm

The Geodetic Datum, Projection (Coordinates System) and Datum Level adopted is as follows; Earth Gravitation Model 2008 was applied for Geoid correction for the GPS calculation.

Table 6.1-4 Geodetic Datum, Projection and Datum Level

Spheroid	WGS84 Semimajor Axis : 6378137m Inverse Flatting : 298.257 223 563
Coordinate System	Universal Transverse Mercator Zone 43N
Origin	Central Meridian : just 75 degree East Latitude : just 0 degree (on the equator) False Northing : 0.000 m False Easting : 500,000.000 m Scale factor of origin : 0.9996
Datum Level	Indian Datum Level (Mean Sea level)

(2) Collection of National Control Point Data and Network Planning

Following GCPs (Ground Control Points) of Survey of India and GTS (Great Trigonometrical Survey) Points were collected from Survey of India and adopted as the Basic Reference Points for the Control GPS and Leveling Works. The Basic Reference Points for the control points were not enough, especially for vertical control. The vertical accuracy for the controls were not enough trustable.

Table 6.1-5 GCPs of Survey of India and GTS points Procured from Survey of India

Name	Northing	Easting	Elevation	Note
HSRMA043	2,175,469.840	262,492.170		Mahim
HSRMA119	2,337,111.670	302,034.290		Bardoli
HSRMA167	2,439,858.980	274,252.940		Jambusar
HSRMA203	2,494,403.240	301,979.950		sarsa
BM11			40.281	Public Offices Near SBI ATM, Near Kuber Bhawan Vadodara
BM19			23.490	Near Haldarwa Village
BM51			25.230	Bridge 264 over river Kurumba Near Bhilad

Based on the principle of Whole-to-Part, at first, Master Control Points (MCPs) were planed at the vertexes of a set of about 10 interconnected Master Triangles of about 50km base length each by connecting with Survey of India's GCPs en route between Mumbai and Ahmedabad. Then a set of smaller interconnected triangles of about 3-5km base length were formed as sub-set of each master triangle along with the alignment for setting of the Survey Control Points (SCPs) at the vertex of the small triangles. Structure of smaller triangles network was such that some of the MCPs were knitted into it. For the Planning of layout of Control Survey Points (MCPs and SCPs), tentative alignment of 500km length between Mumbai and Ahmedabad in kmz file (Google earth compatible) with coordinate system by the UTM Zone 43N was supplied to the contractor for reference.

The coding rule for identification for the Control Survey Points (MCPs and SCPs) was instructed by RVNL as a prefix of HSRMA and a serial number from 001, such as HSRMA001, HSRMA123 etc.

The Planned network was presented on Google images with description of proposed MCPs and SCPs, and the schedule of observation indicating tentative date and time of observation at MCPs and SCPs specifying their locations were also submitted for approval before commencement of the installation.

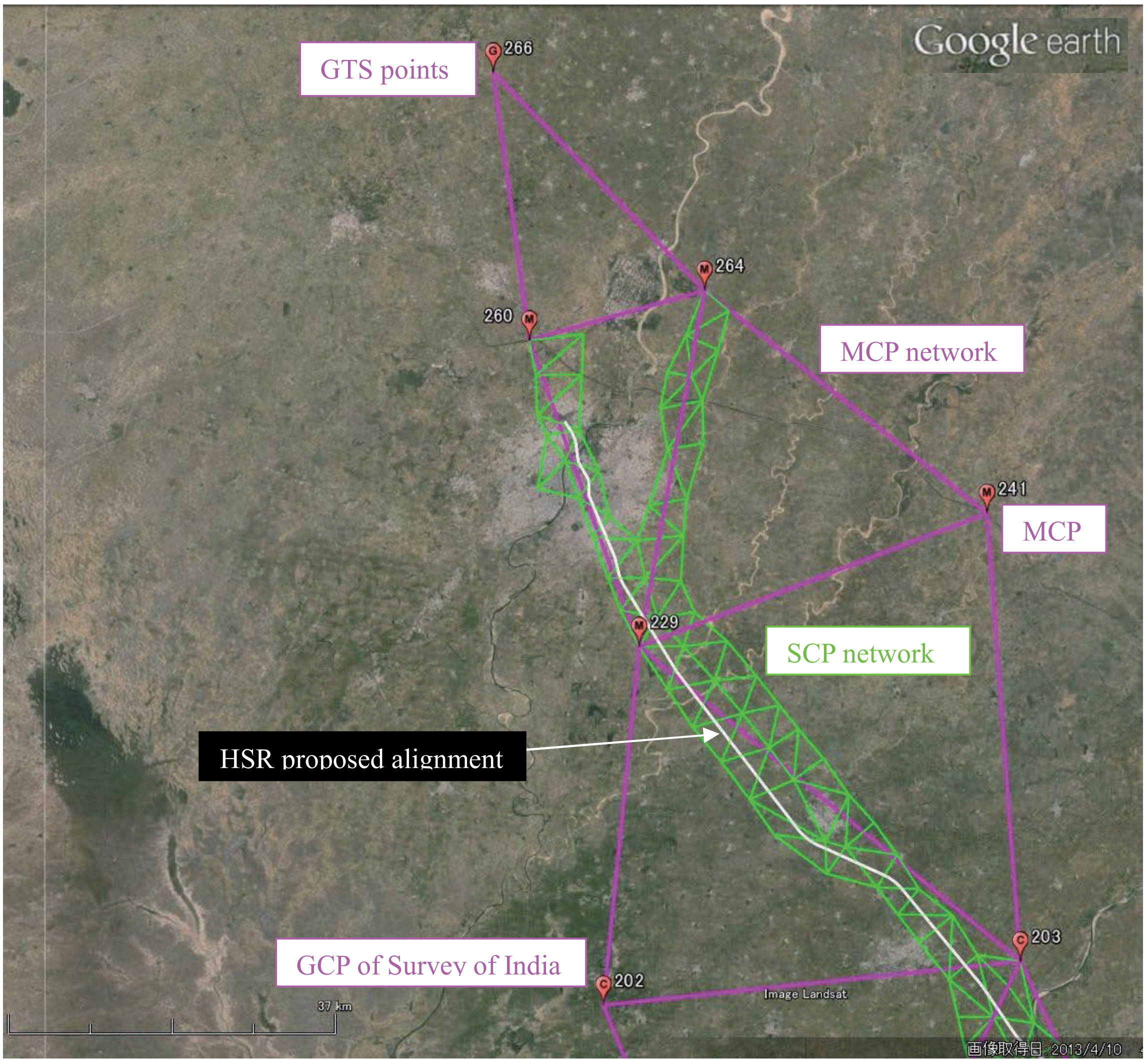


Figure 6.1-13 A Part of Planned Control Points Network Layout

(3) Installation of Control Points

Referring the planned layout, the Control Survey Points (MCPs and SCPs) were selected and installed with following conditions in the field.

- Clear of HT/LT lines, radio / mobile towers, high frequency dish antennas, radar etc.
- Free from multipath problems associated with tall features in thc vicinity.
- Free from foliage.
- Free fiom major obstructions / obstacles.
- Easily available and accessible to the survey team.
- Open to sky with a clear view towards sky at 15 degree angle with horizontal plain.

Fifure 6.1-14 Master Control Point

- Scattered along the periphery of the corridor to ensure fair distribution of MCPs/SCPs points for DEM creation and ortho rectification of the Satellite image.
- MCPs/SCPs must be located on some permanent features which is easily identifiable in the satellite imageries as well as on the ground.

MCPs/SCPs were engraved at least following information;

Not to be engraved	To be engraved
Unique ID :	HSRMA001

Base painting covering engraved text was done followed by filling of engraving with contrast color paint. Engraving, painting and writing work on MCPs/SCPs were carried out neatly and distinctly by engaging a professional. It was not done by unskilled labour/Surveyor/engineer in a scribbled manner.

Some photographs were taken by digita1 camera of at least 10 mega pixels for all MCPs/SCPs/GCPs of Survey of India/GTS points. One photo was taken before painting, after engraving, and three photos were taken after paintng in the short, middle, long range and submitted in digital form with proper indexing and labeling as the Description of Control Points.

(4) Horizontal Control Survey (GPS Survey)

Master Control Points (MCPs) and Survey ControI Points (SCPs) were surveyed using dual frequency GPS (at least 12 channel) and processed using post processing software.

Observations of Master ControI Points (MCPs) were started by establishing a base line (pair of points about 50 km apart) situated at about center of the project area and one was the GCP of Survey of India. All other MCP points were observed with reference to this base line. Other GCPs of Survey of India were connected with the Master Control Network to establish and adjust link with National datum. Subsequently, a smaller network of triangles for Survey Control Points (SCPs) were established with a base length of about 3-5 km.

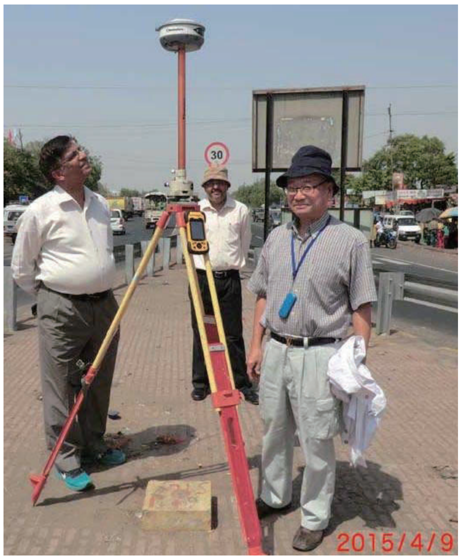


Figure 6.1-15 Horizontal Control Survey (GPS survey)

Prior to the Holizontal Control Survey observation, necessary jungle clearance for approach to site for proper execution of work wherever required was done. Then the Holizontal Control Survey observation and processing was carried out as following procedure;

1) At first, two GPS receivers were deployed simultaneously on the two points on the initial base line. And one was GCP of Survey of India and were observed more than 12 common hours in static mode.

Figure 6.1-16 GCP of Survy of India

2) Thereafer, other MCPs were observed prior to the observation of SCPs. All 8 GPS receivers proceeded observation in one direction from the initial base line by considering of logistic point of view. Simultaneous recordings at the three MCPs forming a triangle was taken more than 12 common hours in the static mode to get accurate results. The triangles included at least one baseline which was fixed previously.

3) The MCPs network were connected to Survey of India's GCPs and GPS data were cross checked with given coordinates of Survey of India.

Figure 6.1-17 GPS Antenna

4) After completing appropreate set of Master triangle network and arriving at adjusted coordinates of the MCPs, GPS teams were deployed to make observations on smaller interconnected triangles i.e. SCPs. Observations on SCPs were started from Ahmedabad side and satellite signals were recorded for more than 3 common hour in the static mode at all the triangle sets including the previously fixed base line.

Figure 6.1-18 GPS Controller

5) In case the additional SCP was necessary to establish to connect Survey of India's elevation datum with the network due to the GTS points which were very far from the network, such SCP were observed for more than 6 common hours in the static mode.

6) The contractor downloaded raw data from GPS receiver to a PC at site.

The conditions of the observation and prosessing of Holizontal Control Survey are summarized as follows ;

- Compatible GPS instrument and accessories of LEICA / Trimble / ASTECH / Spectra-precision / Topcon only Shall be used so as to achieve the required accuracy.
- The GPS receivers should not be older than three years from the date of award of contract. (Latest Calibration Certificate is attached)
- Dual frequency GPS receivers with the required accessories and software are to be used for observations.
- The GPS sets used Shall be with at least 12 channels having differential post processed accuracy of at least ±(5mm+1ppm x BaSeline Length).
- A minimum of 6 healthy satellites should be available during entire duration of observation.
- The following observation times are envisaged :
  Observation hours of Master Control Points for Master triangles > 12 hours
  Observation hours of Survey Control Points for Small triangles > 3 hour
  Observation hours of Survey Control Points for supplemental of GTS points > 6 hours
- During observations, satellite mask angle should be above 15 degree.
- Observations taken with Geometric Dilution of Precision (GDOP) exceeding 4 should not be considered.

- Ambiguity resolution state of post processing must be "FIX".
- The 3D precisions such as RMSs shall be in the appropriate range.
- Ratios (Ambiguity Resolution Validation Value) shall be more then 5.
- The signals from some Satellite which is disabled in an optimum way to get maximum accuracy was deleted and shall not be utilised for the analysis of coordinates.
- Processing shall include triangulation to check for closure error of triangle and apply necessary corrections. Then the accuracy of the comparative analysis of coordinates obtained by observations from subsequent MCP and SCP forming redundant triangles shall be at least 1/100,000 or better.
- For doing the network adjustment, base line Master Control Points were fixed with GCPs of Survey of India for horizontal control.
- The WGS 84 was adopted as reference ellipsoid and UTM 43N was adopted for projection system, EGM 2008 was adopted for correction of ellipsoidal elevation to the elevation on the Geoid.
- Both the Raw Data (in RINEX as well as proprietary formats of GPS manufacturer) as well as the Transfromed Data shall be recorded.
- The observation condition such as antenna height etc. and the parameters used for transformation was duly documented in the Report.
- The data were recorded with details in required format in softcopy and hardcopy forms, duly checked and verified, supported with "not to scale" neat sketches.

(5) Vertical Control Survey (Direct Leveling)

The Vertical Control Survey was carried out by the direct leveling by Auto Level. Network of Master Control Points (MCPs) and Survey ControI Points (SCPs) were connected to nearest available GTS Bench marks of Survey of India en route to get elevation of Survey of India datum. Only 3 nos. of GTS were found and connected. Auto levels which have the calibration certincate of the date which is not earlier than three months from the date of Start of the work, were used for the observation.


Figure 6.1-19 GTS point

The leveling work was started from GTS Bench marks of Survey of India toward to nearest available MCPs/SCPs. Then forward and backward round method or running double method was adopted for surveying. If possible, GTS Bench marks of Survey of India also were taken into the loop of the small triangle/master triangle of MCPs/SCPs. In case of the distance of GTS Bench marks and MCPs/SCPs is very far, a new additional MCP/SCP was established by GPS observation and it simultaneously was connected with GTS Bench marks of Survey of India as above mentioned method.

Leveling work was closed on daily basis and found out closure error. The closure error by the leveling work which was started from a known point and closed at a known point, of daily loop was not exceed $12\sqrt{K}$ mm, where K is the circuit length in kilometer. In case, accuracy of daily loop closure exceeds the limits defined above, entire loop was repeated till desired accuracy is achieved


Figure 6.1-20 Level

The closure error in accuracy limits of above was distributed in the loop and adjusted the reduced level of MCP/SCP. Then adjusted reduced elevation of connected MCP/SCP was fixed. After that, the error between connected one MCP/SCP and subsequent connected MCP/SCP was distributed to arrive at adjusted reduced level of intermediate MCPs/SCPs. The accuracy limits was 12√K mm, K in this case shall be taken distance between MCPs/SCPs as derived from GPS measurements. If it is found beyond accuracy limits, checking resurvey was carried out to remove the excess error.

Figure 6.1-21 Vertical Control Survey (direct leveling)

After RANDOM CHECK with actual vertical control survey in the field by same manner as mentioned above, adjusted reduced levels of all the MCPs and SCPs with raw observation data, calculation sheets and descriptions of each control mark were recorded in equivalent format of MS office excel.

(6) Results and Accuracy

Total number of MCPs were 28 and SCPs were 255.
Because of limited reference control points (basic national control points), the accuracys were not confirmed well, therefore the control survey shall be carried out to reconfirm the accuracy in the succeeding stage.

Following results and data were arranged and taken custody.

- Raw data in soft copy (in RINEx as well as proprietary format of GPS manufacturer)
- Field survey sheet and Calculation sheet and Accuracy table such as GPS base line report and adjusted report etc.
- Statement of coordinates of MCPs/SCPs, containing MCP/SCP number, Latitude, Longitude and Elipsoidal Height, Northing, Easting and Elevation (MSL) on grid coordinates description as an excel sheet.
- A bound book "Location Identifier" of MCPs/SCPs, containing photograph, not to scale neat sketch duly indexed which is arranged in sequence following numbering scheme and its Soft copy of this book in PDF environment.
- A elaborating report on methodology adopted and projection parameters and transformation set by Local Company.

6.1.4 Field Topographic Survey

(1) General

The Detailed Field Topographic Survey was executed by GPS and/or Total Station for making basic map for the General Arrangement Drawings and for the reference data for design of the Alignment. The Work comprises of establishment of supplementary control points, field topographic survey, data arrangement, calculation and mapping. The 3 Dimensional Digital Topographic Map showing all existing natural and artificial features was produced based on string concept and compiled in AutoCAD or AutoCAD readable format (e.g. DXF format).

The Work Flow is as follows;

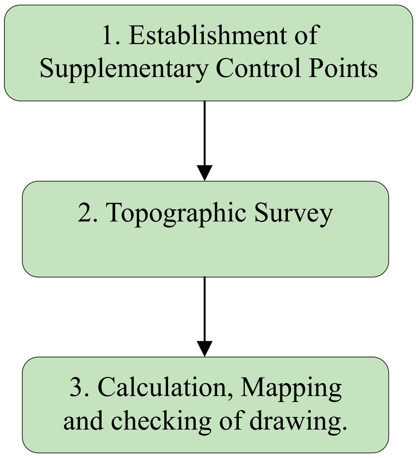


Figure 6.1-22 Work Flow chart of the Field Topographic Survey

The field survey work was executed by the Local Company under the contract same as the Control Survey by GPS. The Local Company deployed 2 GPS receivers and 6 Total Stations to site for the Work to complete within 3.5 months. There was one graduate engineer/diploma holder well versed for Topographic Surveying using Total Station and GPS RTK were deployed for entire duration of the work and all deployed surveyors were well versed with the work. All Engineers and surveyors were evaluated, assessed by their CVs and through the actual field work, in case anyone who was not found fit for work anytime during the progress of work were replaced.

Person in charge of Local Company and Equipment used for this work are as same as paragraph 19.3.2 (1) General.

The Geodetic Datum, Projection (Coordinates System) and Datum Level are also as same as paragraph 19.3.2 (1) General.

Topographic Survey locations are in the area of interest along the corridor of proposed High Speed Railway between Mumbai and Ahmedabad. There are about 164 locations covering an area of about 1,200ha. Summary of locations are as follows:

- 4 station locations (about 50m x 1200m at each location)
- 2 depot-cum-workshop/yard (about 50 ha at each location)
- 158 nos. of NH/SH/Railway/River etc. crossings and residential area

The actual topographic survey locations are shown from the next pages with the UTM WGS-84 Zone 43N coordinates;

Table 6.1-5 (1) Topographic Survey Location and Area

No.	Name	UTM 43N (WGS84) (Northing)	(Easting)	Length (m)	Width (m)	area (ha)	Note
1	Sabarmati Station and area	2553835	252880			384.4	
2	Ahmedabad Station	2548559	254295			57.3	
3	SH144	2532887	260802	140	200	2.8	
4	Meshwa river A2	2527561	264288	100	400	4	(riverside 20m, land 80m)river cross
5	Meshwa river A1	2527478	264342	100	400	4	(riverside 20m, land 80m)river cross
6	Vatrak river A2	2524988	265973	100	400	4	(riverside 20m, land 80m)river cross
7	Vatrak river A1	2524820	266081	100	400	4	(riverside 20m, land 80m)river cross
8	SH60-2	2522929	267317	140	200	2.8	
9	Mohar river A2	2516952	271224	100	400	4	(riverside 20m, land 80m)river cross
10	Mohar river A1	2516877	271274	100	400	4	(riverside 20m, land 80m)river cross
11	Habitant-28	2515853	271946	50	100	0.5	
12	NH8-8	2513156	273714	140	200	2.8	
13	Existing Railway-12	2509734	276245	140	200	2.8	
14	SH89	2507831	279756	140	200	2.8	
15	NH8-7	2507139	281200	140	200	2.8	
16	Habitant-27-1	2506316	282921	120	100	1.2	shown in kmz
17	SH150	2506081	283417			4	
18	Existing Railway-11	2505885	283825	140	200	2.8	
19	SH75	2502547	288977	140	200	2.8	
20	SH60-1	2499202	291650	140	200	2.8	
21	Existing Railway-10	2498099	292531	140	200	2.8	
22	SH83	2496262	293997	140	200	2.8	
23	SH188-2	2486920	300771	140	200	2.8	
24	Mahi river A2	2484423	303075	100	400	4	(riverside 20m, land 80m)river cross
25	Mahi river A1	2484013	303578	100	400	4	(riverside 20m, land 80m)river cross
26	Expressway-3	2483635	304037	200	200	4	
27	Habitant-27	2481459	306680	540	100	5.4	
28	Vadodara topo survey area					138.0	
29	Vadodara Station	2468363	312531			72.4	
30	DFC-7	2456949	309637	140	200	2.8	
31	Dhadhar river A2	2447063	303070	100	400	4	(riverside 20m, land 80m)river cross
32	Dhadhar river A1	2447021	303043	100	400	4	(riverside 20m, land 80m)river cross
33	SH160	2446061	302405	140	200	2.8	
34	SH161	2435099	295990	140	200	2.8	
35	Habitant-25	2432183	294972	100	100	1	
36	Habitant-24-2	2425032	292485	400	100	4	
37	Habitant-24-1	2422977	291769	200	100	2	
38	DFC-6	2410783	287645	140	200	2.8	
39	Existing Railway-8	2404320	287895	140	200	2.8	
40	SH64	2404289	287896	140	200	2.8	
41	SH6	2400225	288117	140	200	2.8	
42	Narmanda river A2	2398917	288188	100	400	4	(riverside 20m, land 80m)river cross
43	Narmanda river A1	2397715	288253	100	400	4	(riverside 20m, land 80m)river cross
44	DFC-5	2394762	288413	140	200	2.8	
45	NH228-1	2393405	288485	140	200	2.8	
46	SH166	2375939	286541	140	200	2.8	
47	Expressway-2	2374781	286085	200	200	4	
48	Habitant-23-2	2374382	285896	200	100	2	
49	Habitant-23-1	2373154	285312	300	100	3	
50	Kim river A2	2371309	284433	100	400	4	(riverside 20m, land 80m)river cross
51	Kim river A1	2371261	284410	100	400	4	(riverside 20m, land 80m)river cross

Table 6.1-5 (2) Topographic Survey Location and Area

No.	Name	UTM 43N (WGS84) (Northing)	(Easting)	Length (m)	Width (m)	area (ha)	Note
52	Habitant-22-2	2370500	284048	300	100	3	
53	SH65	2368682	283268	140	200	2.8	
54	Existing Railway-7	2364280	283533	140	200	2.8	
55	DFC-4	2364248	283542	140	200	2.8	
56	SH605	2358378	285078	140	200	2.8	
57	Habitant-22-1	2355634	285798	400	200	8	
58	Tapi river A2	2355201	285909	150	400	6	(riverside 20m, land 130m)river cross
59	Tapi river A1	2354669	286048	100	400	4	(riverside 20m, land 80m)river cross
60	Habitant-21	2352327	286354	500	100	5	
61	SH167	2352022	286327	140	200	2.8	
62	Habitant-20-1	2343797	285361	160	100	1.6	
63	NH6	2343600	285347	140	200	2.8	
64	Existing Railway-6	2341456	285172	140	200	2.8	
65	Habitant-20	2338826	284959	340	100	3.4	
66	Habitant-19	2334618	284618	70	100	0.7	
67	SH170-2	2334523	284611	140	200	2.8	
68	Habitant-18	2333808	284554	70	100	0.7	
69	SH168	2333407	284521	140	200	2.8	
70	Mindhola river A2	2329250	284993	100	400	4	(riverside 20m, land 80m)river cross
71	Mindhola river A1	2329179	285025	100	400	4	(riverside 20m, land 80m)river cross
72	SH196	2327609	285719	140	200	2.8	
73	NH8-5	2321262	288517	140	200	2.8	
74	Purna river A2	2319864	289134	100	400	4	(riverside 20m, land 80m)river cross
75	Purna river A1	2319589	289255	100	400	4	(riverside 20m, land 80m)river cross
76	SH88	2318023	289945	140	200	2.8	
77	Habitant-17-4	2317824	290034	100	100	1	
78	SH170-1	2316642	290554	140	200	2.8	
79	NH8-4	2315487	290927	140	200	2.8	
80	Ambica river A2	2308926	292379	100	400	4	(riverside 20m, land 80m)river cross
81	Ambica river A1	2308788	292408	100	400	4	(riverside 20m, land 80m)river cross
82	Habitant-17-3	2304432	293373	80	100	0.8	
83	SH703	2304326	293397	140	200	2.8	
84	Habitant-17-2	2303044	293575	100	100	1	
85	Existing Railway-5	2301540	293442	140	200	2.8	
86	Habitant-17-1	2297472	292634	160	100	1.6	
87	NH360	2297327	292606	140	200	2.8	
88	Habitant-16-6	2296602	292462			0.5	
89	Habitant-16-5	2296223	292387	80	100	0.8	
90	Kaveri river(N) A2	2294995	292142	100	400	4	(riverside 20m, land 80m)river cross
91	Kaveri river(N) A1	2294897	292123	100	400	4	(riverside 20m, land 80m)river cross
92	Kaveri river(S) A2	2293159	291777	100	400	4	(riverside 20m, land 80m)river cross
93	Kaveri river(S) A1	2293062	291759	100	400	4	(riverside 20m, land 80m)river cross
94	NH8-3	2290986	291348	140	200	2.8	
95	SH67	2281915	289713	140	200	2.8	
96	Aurange river A2	2279098	289420	100	400	4	(riverside 20m, land 80m)river cross
97	Aurange river A1	2278751	289384	100	400	4	(riverside 20m, land 80m)river cross
98	Habitant-16-4	2277644	289270	260	100	2.6	
99	Habitant-16-3	2274079	288899	300	100	3	
100	Par river A2	2271148	288596	100	400	4	(riverside 20m, land 80m)river cross
101	Par river A1	2270847	288564	100	400	4	(riverside 20m, land 80m)river cross
102	SH186	2269285	288404	140	200	2.8	

Table 6.1-5 (3) Topographic Survey Location and Area

No.	Name	UTM 43N (WGS84) (Northing)	(Easting)	Length (m)	Width (m)	area (ha)	Note
103	Habitant-16-2	2262099	287660	360	100	3.6	
104	Kolak river A2	2256497	287091	100	400	4	(riverside 20m, land 80m)river cross
105	Kolak river A1	2256346	287086	100	400	4	(riverside 20m, land 80m)river cross
106	SH5	2251748	286940	140	200	2.8	
107	Habitant-16-1	2249590	286105	480	100	4.8	
108	SH185-2	2249295	285986	180	200	3.6	
109	Habitant-15-4	2249050	285884	120	100	1.2	
110	Habitant-15-3	2248627	285711	200	100	2	
111	Daman Ganga river A2	2248045	285472	100	400	4	(riverside 20m, land 80m)river cross
112	Daman Ganga river A1	2247720	285339	100	400	4	(riverside 20m, land 80m)river cross
113	Habitant-15-2	2244201	283900	220	100	2.2	
114	SH185-1	2243898	283776	140	200	2.8	
115	Habitant-15-1	2242996	283408	260	100	2.6	
116	NH8-2	2233729	279614	140	200	2.8	
117	SH73	2227356	277450	140	200	2.8	
118	SH74	2201039	269481	140	200	2.8	
119	Habitant-14-1	2188971	268753	200	100	2	
120	Boisar Road	2188802	268742	140	200	2.8	
121	Habitant-14	2182402	268359	200	100	2	
122	Habitant-13	2181674	268315	640	100	6.4	
123	DFC-3	2170433	268604	140	200	2.8	
124	Existing Railway-4	2170321	268611	140	200	2.8	
125	Habitant-12-2	2159705	270924	420	100	4.2	
126	Vaitarna river A2	2158839	271243	100	400	4	(riverside 20m, land 80m)river cross
127	Vaitarna river A1	2156847	271978	100	400	4	(riverside 20m, land 80m)river cross
128	Existing Railway-3-2	2156710	272028	140	200	2.8	
129	Habitant-12-1	2154480	272586	400	100	4	
130	Habitant-11	2149276	273215	1660	100	16.6	
131	DFC-2	2148379	273433	140	200	2.8	
132	Habitant-10	2148174	273503	100	100	1	
133	Habitant-9	2147266	273887	460	100	4.6	
134	Gokhivare Rd	2146979	274012	140	200	2.8	
135	Habitant-8-3	2145861	274502	160	100	1.6	
136	Habitant-8-2	2144067	275289	270	100	2.7	
137	Habitant-8-1	2143485	275566	540	100	5.4	
138	Habitant-special	2142839	276218			5	
139	Expressway-1	2142201	276682	200	200	4	
140	Habitant-7	2141788	277368	300	100	3	
141	NH8-1	2141217	278768	140	200	2.8	
142	Habitant-6-2	2140124	281225	260	100	2.6	
143	Chinchoti Anjur Phata Rd-2	2139947	281494	140	200	2.8	
144	Habitant-6-1	2139760	281749	260	100	2.6	
145	Habitant-5	2139416	282155	220	100	2.2	
146	Chinchoti Anjur Phata Rd-1	2138340	283070	140	200	2.8	
147	DFC-1	2137122	284043	140	200	2.8	
148	Existing Railway-3-1	2137068	284098	140	200	2.8	
149	Branch of Ulhas river A2	2132602	290734	100	400	4	(riverside 20m, land 80m)river cross
150	Branch of Ulhas river A1	2132498	290795	100	400	4	(riverside 20m, land 80m)river cross
151	Habitant-4	2130012	291805	120	100	1.2	
152	SH35	2129892	291855	140	200	2.8	
153	Habitant-3	2129155	292228	460	100	4.6	

Table 6.1-5 (4) Topographic Survey Location and Area

No.	Name	UTM 43N (WGS84) (Northing)	(Easting)	Length (m)	Width (m)	area (ha)	Note
154	NH3	2127828	293222	140	200	2.8	
155	Habitant-2	2126376	294402	210	100	2.1	
156	Thane Depot	2126350	294971			7	
157	Ulhas river A2	2124605	295477	100	400	4	(riverside 20m, land 80m)river cross
158	Ulhas river A1	2124156	295728	100	400	4	(riverside 20m, land 80m)river cross
159	Existing Railway-2	2123775	295937	140	200	2.8	
160	Habitant-1	2122868	296439	500	100	5	
161	Existing Railway-1	2121875	296743	140	200	2.8	
162	Habitant-0	2118107	294645	220	100	2.2	
163	NH4	2117856	294473	140	200	2.8	
164	Mumbai Station	2109672	275335			42.6	

(2) Supplementary Control Points Survey

In case of the plural MCP/SCP is not existing near the location of Topographic Survey area, supplementary control points were established prior to the Topographic Survey by GPS and/or by the Total Station. The Topographic Survey was carried out based on the above mentioned supplementary control points.

The supplementary control points were established by same manner and accuracy with SCPs by GPS or traverse survey by Total Station which start from MCP/SCP and close to MCP/SCP. Depending upon the situation, additional supplementary points were established by additional secondary, tertiary closed traverse survey to cover the topographic survey area. These closed traverse strated and closed to known points such as MCP/SCP and/or traverse stations established during traversing. Numbering for the control points were systematically arranged, concise and lucid. Limits of accuracy of these traverses were as follows ;

Figure 6.1-23 Traverese survey

Figure 6.1-24 Total station & Prism

Angular closure error	;	$15\sqrt{N}$	N=Number of angle observation
Total linear closure error	;	1 / 10,000	(after angular adjustment)

All Total Stations used for this observation were minimum 3" (three second) accuracy as per DIN standard with data downloading facility of reputed brands with Calibration Certificate and data were recorded directly on to it. The GPS receivers were same quality with GPS receivers for Control Points Surveying.

(3) Detail Topographic Survey and Mapping

Detailed Topographic Survey of congested areas like station locations, depot cum workshops/yard, road highway crossing, DFC crossing, Expressway crossing, river crossing and Railway crossing were executed by GPS & Total Station survey. All existing natural and artificial features were surveyed by the Total Stations or by GPS in RTK mode or by combination of both, based on the above mentioned supplementary control points.

Figure 6.1-25 Topographic survey observation & Pole prism as target

The supplemaentary control points were used as the instrument station, back reference station of Total stations and Reference Base station of GPS RTK survey. For the Total Station survey, back reference target was observed not only at beginning but also at end and appropriate intervals during observation to confirm the stability of Total Station. GPS survey data in RTK mode were also evaluated as same as GPS survey data in static mode and recorded with same information with static mode such as, observation hours, GDOP, masking angle, tracking satellites numbers, ambiguity resolution state, RMS of three 3 dimensional elements, Ratio (Ambiguity Resolution Validation Value), antenna height etc. for each observation.

Prior to the Topographic Survey observation, necessary jungle clearance for approach to site and to make visible from control points to observation targets for proper execution of work wherever required was done. Then basically, all existing topographical details to prepare the 1 : 1,000 scale topographic map such as followings were observed and recorded for Detail Topographic Survey;

- Buildings, Building line, Property line, houses, bridges, culverts, ROW stakes, landmarks, Spot levels at an average interval of the order of 10 m to depict actual ground.etc.
- Features such as rivers, nala, canals, drainages, river banks, ponds, roads, slope shoulder, slope toe, ridges, cliffs, railway lines, electric lines, village boundary,etc. were defined as one string each.
- Details regarding bunds, guided streams and irrigation works in the vicinity of the proposed area were collected since these might affect the future safety of the area.
- Land slide area, unstable hill slopes caused dislocations, were enquired into from local authorities. Then informations regarding this were compiled and furnished.
- The data on nature of terrain viz: Sandy, stony, vegetation, etc. and type of ground were recorded and mentioned on the topographic map.
- The description of features and annotation to suffice the purpose of design of alignment and structures were shown in the 3D Topographic Map.
- A brief and easily understandable sketches for surveyed points and area with respect to traverse stations, topographical details register with observation information, date of survey, numbering of each page and signature of surveyor were recorded in a field.

- Also Traverse Register, containing the traverse calculation and coordinates of supplementary control points with their description and downloaded data etc. were recorded.
- The 3D Topographic Maps were finally verified with actual topographic features in the field physically using hard copies and were cross verified by Ortho photos generated from satellite imagery and Google Earth, 3D Topographic Maps were corrected and compiled in AutoCAD or AutoCAD readable format (e.g. DXF format) and preserved by hard copy and soft copy.
- The observed data were downloaded and calculated, plotted and mapped every day. The raw data from TotaI Station/GPS were processed in ASCII/GENIO/XML format compatible with MX software duly checked and verified.

(4) Code, Symbol and Layer structure for the 3D Topographic Map

The Plan of 3 Dimensional Topographic Map was prepared so as to suit the Scale of 1:1000. The feature code, layer structure, line thickness, color and symbols were systematically arranged, concise, lucid and standardized to be acceptable to MX software for designing and processing as table of below.

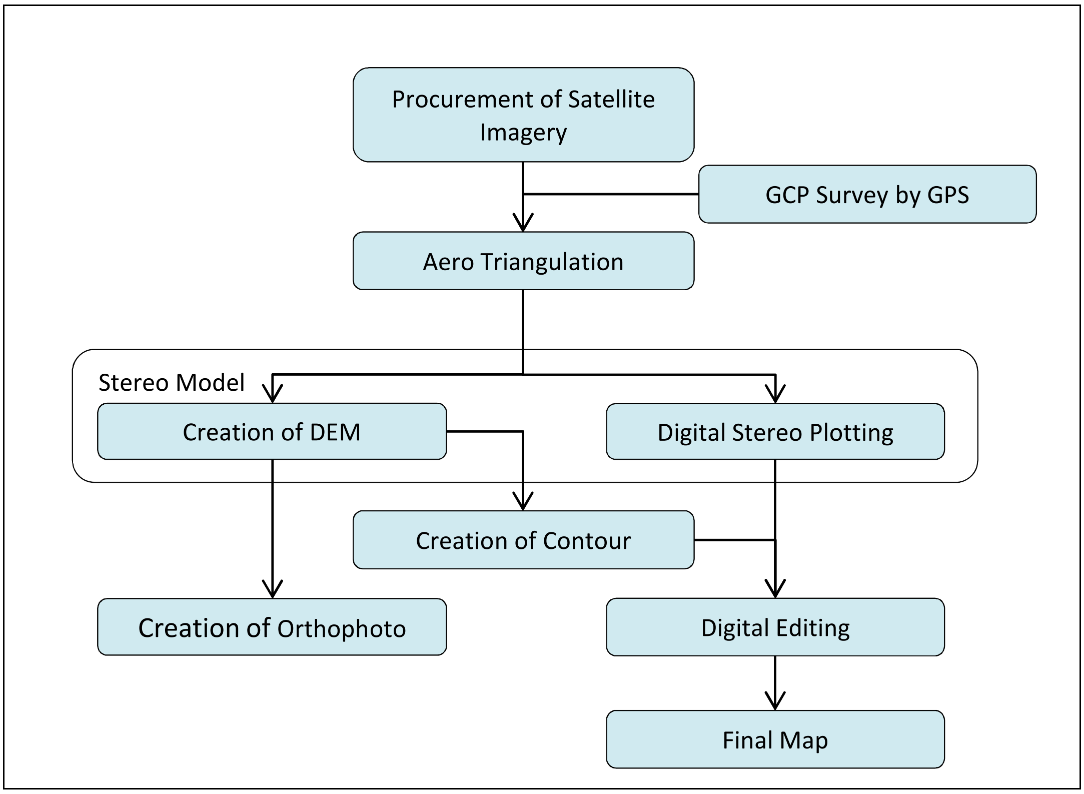
Table 6.1-6 Code, Layer, Color and Symbol for Topographic Features

OBJECT/CODE	LAYER NAME	COLOUR	LEGEND
STRUCTURES	STRUCTURES	212	HOUSE SHOP HUT BLDG SHED OFFICE HOTEL TEMPLE PLEASE MENTION THE NAME OF IMP. STRUCTURES e.g. OFFICE, HOTEL, HOSPITAL
RE	ROAD	22	
CF	BOUNDARY WALL/COMPOUND WALL	MAGENTA	
CF	FENCED LINE	8	
WPL	WATER PIPE LINE	162	
NGL	NEUTRAL GROUND LEVELS	WHITE	NGL
PF	PLATE FORM	163	
TC	EXT. TRACK CENTRE (BG)	WHITE	
CT	CART TRACK	WHITE	
PLP	LAMP POST	8	
WT	WATER TANK	BLUE	
OHE	OVER HEAD ELECTRIC MASK	8	
FM	FOULING MARK	WHITE	FM
TD	TOP OF DRAIN	202	
FOB	FOOT OVER BRIDGE	WHITE	
TAP	TAP/ HAND PUMP	BLUE	
TR	TREE	GREEN	
ECB/EJB	EXCEL COUNTER/JUNCTION BOX	8	EB EB
SIG	SIGNAL POLE	WHITE	
EP	ELECTRIC POLE	8	
EJB	JUNCTION BOX	8	EB EB
IL	INVERT LEVEL	WHITE	WHITE
GT	GATE	8	
MH	MANHOLE	150	MH MH
SRJ	STOCK RAIL JOINT	WHITE	
PTPL	TELEPHONE POLE	45	
DPL	DIESEL PIPE LINE	83	
BC	BUILDING CORNER	212	
BC-OFF	BUILDING OFFSET	212	
BRDG	BRIDGE	211	
CU	CULVERT	WHITE	
FLT	FLOOD LIGHT TOWER	WHITE	

6.1.5 Satellite Image Processing and Digital Elevation Model Creation.

(1) General

Digital topographic map with scale of 1:10,000 and digital elevation model (DEM) are needed in order to adjust an alignment which has designed based on 1:50,000 map and DEM made by JICA study team. JICA study team decided to procure high resolution satellite image (0.5m resolution) for making the map and DEM. The work comprises procurement of satellite image, ground control survey, aero triangulation, creation of DEM, digital stereo plotting and mapping. All works were carried out by the local consultant. The work flow of satellite image processing for making the map and DEM is as follows;



Source: JICA Study Team

Figure 6.1-12 Work Flow Chart of Satellite Image Processing

(2) Specifications of Map and DEM

The specifications of the map and DEM are summarized in Table 6.1-. The items of specifications are explained hereinafter.

Table 6.1-7 Specifications of the Map and DEM

Digital topographic map	
Coverage are	3,077km2 (Ahmadabad – Mumbai)
Map Scale	1:10,000
Coordination System and Datum Level	Coordination System: WGS84, UTM Zone 43N Datum Level: Mean Sea Level
Interval of Contour	Intermediate contour: 2m Index contour: 10m

Digital Elevation Model	
Coverage are	3,077km2(Ahmadabad – Mumbai)

Grid Spacing	10m
Type of Elevation Data	Digital Terrain Model
Coordination System and Datum Level	Coordination System: WGS84, UTM Zone 43N Datum Level: Mean Sea Level

Source: JICA Study Team

1) Mapping Area

The mapping area is along the planned alignment by JICA study team has length of 500km. The width is 5km and partly is 3km. Furthermore, the mapping area has been modified to cover the proposed route by RVNL. Total mapping area came to approximately 3,200km.

2) Map Scale

Map scale was determined as 1:10,000 due to following two points;

- The map and DEM requires higher accuracy than the map with scale of 1:50,000 and ASTER DEM prepared by JICA study team.
- The Engineering Code (Ministry of Railways) specifies that map scale of 1:10,000 is required for Preliminary Survey.

3) Contour Interval

Two meter interval of contour line is described for the map with scale of 1:10,000 in many cases. Therefore, intermediate contour of two meter interval and index contour of ten meter interval was applied to the map for this study.

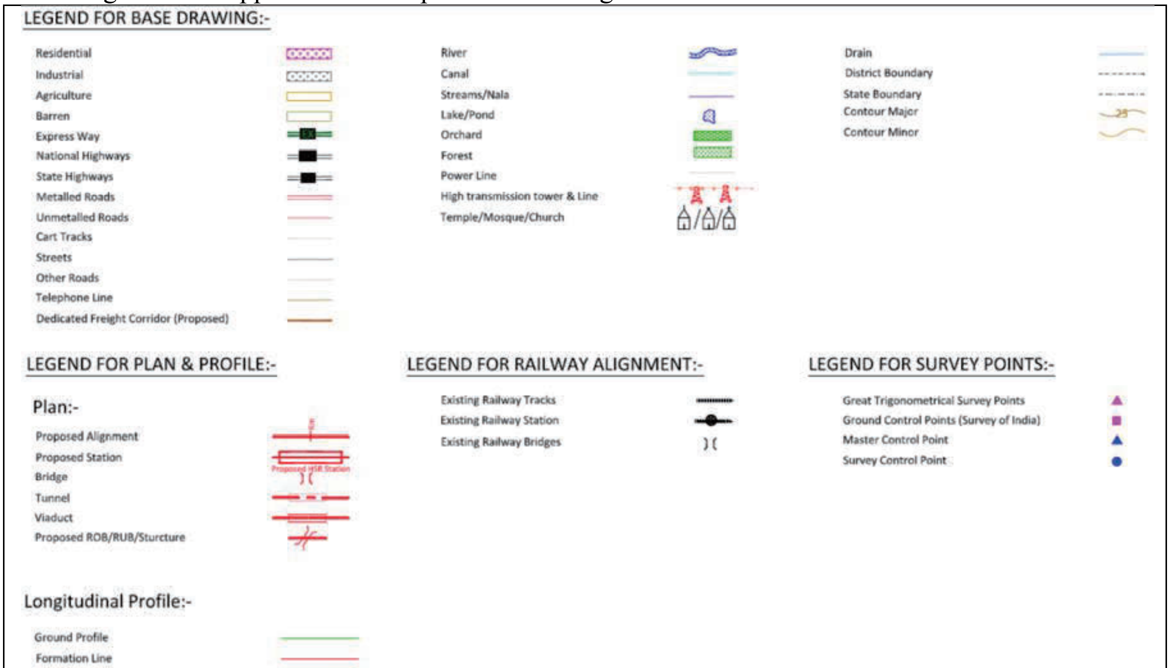
4) Coordination System and Datum Level

Following coordination system and datum level is applied for the mapping area.

- Coordination System: WGS84, UTM Zone 43N
- Datum Level: Indian Datum Level (Mean Sea Level)

5) Map Legend

Legend to be applied to the map is shown in Figure 6.1-13.



Note: This map legend is draft version at time of Draft Final Report.

Source: JICA Study Team

Figure 6.1-13 Map Legend

6) Accuracy

According to Digital Globe's product guide, the stereo pair image of World View 2 can horizontal and vertical accuracy of five (5) m without GCP. When the image processing is done with GCP, the accuracy can be improved. However, it can't achieve same accuracy by actual survey.
The accuracy of DEM becomes lower than above mentioned accuracy because grid spacing and density of break lines and of mass points affects to the accuracy.

(3) Methodology of Image Processing

1) Procurement of Satellite Image
A Satellite image of World View 2 from Digital Globe was procured by local consultant through National Remote Sensing Centre (NRSC).
Characteristics of satellite image are following three points.
   - High resolution (Resolution of 0.5m)
   - Stereo pair image
   - New collection data

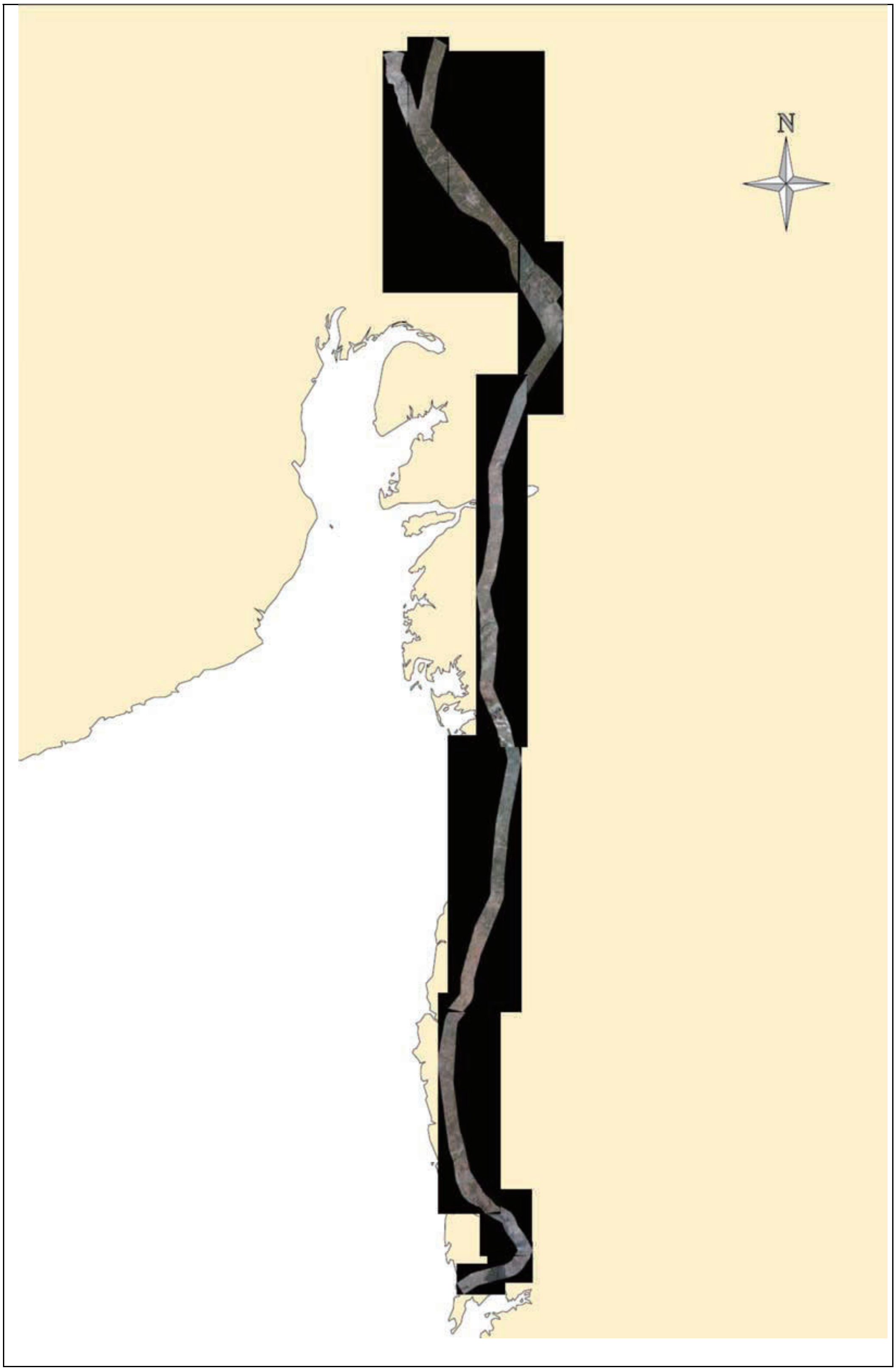
The map with scale of 1:50,000 prepared by JICA study team was made from orthophoto from satellite image with resolution of 2.5m. In order to improve an accuracy of the map and DEM, stereo pair image with resolution of 0.5m was selected. Stereo pair image is not available in archive therefore, new fresh data collection was procured. Data collection was conducted from February 20th, 2015 to March 22nd, 2015. Therefore, recent situation of building and land use along the planned route can be known by satellite image. Due to cloud cover, data recollection was carried out for 5% of area of interest.
Specifications of satellite image are as follows

Table 6.1-8 Specifications of Satellite Image

Satellite	World View2
Duration of Data Collection	February 20th, 2015 – March 22nd, 2015
Resolution	0.5m: Panchromatic 2.0m: Multispectral
Cloud Cover	Up to 15%
Bands	4-Band Bundle
Bit Depth	16-bit
File Format	NITF2.0

Source: JICA Study Team

The area captured is shown in Figure 6.1-14



Source: JICA Study Team

Figure 6.1-14 Captured Area

2) Ground Control Survey
Ground control survey was carried out to obtain necessary horizontal and vertical data of ground control point for aero triangulation of the satellite image. Ground control points were located on permanent features which is easily identifiable in the satellite imageries as well as on the ground. For the details, refer to the chapter 6.1.3

3) Aero Triangulation
The aero triangulation was carried out in accordance with following manner;
- The bundle adjustment by SocetSet software was used.
- Tie points were adjusted to plan metric details which are identifiable on the satellite image.
- Photo coordinates of ground control points and tie points were measured by using digital stereo plotter.
- Transformation from photo coordinates to Geodetic Coordinates was performed base on ground control points of the model
- Allowable error was less than two meter for both horizontal and vertical.

4) Digital Stereo Plotting
By using the result of aero triangulation, digital stereo plotting carried out.
The features visible on the satellite image and important for planning of alignment were plotted by digital stereo plotter. The following features were extracted from the satellite image.

Table 6.1-9 Extracted Feature

1 Settlements
Buildings (within a distance of 250m on each side of the center line of HSR Route)
Residential Area Boundaries
Industrial Area Boundaries
2 Highways
National Highways
State Highways
3 Roads
Metalled roads
Unmetalled roads
Other roads
Streets
4 Existing Railway Infrastructure
Railway tracks
Stations
Bridges
Road Under Bridge
Road Over Bridge
5 Water Bodies
Rivers
Streams/Nala
Canal
Lake
Pond
6 Transmission Lines and High Tension Tower if visible on image
7 Land
Agriculture

Barren
Forest
8. Any other feature visible on image and important for planning

Source: JICA Study Team

Considering time frame, there are two area of digital stereo plotting as mentioned below;

- Area1 covers an alignment width of 500m (250m on either side of the centerline of the planned route). In this area, all feature as seen in the satellite image were digitized and shown separately. The buildings and other structures in the settlements were shown separately and individually.
- Area2 covers remaining area. In this area, the settlements were shown in cluster enclosed in a boundary. Other features e.g. roads, railways, water bodies and transmission towers as seen in the satellite image were shown separately.

5) Digital Editing
The name of river, road, cities, public facilities and religious facility were annotated on the map. Annotation of the map was collected from the Toposheets (Scale of 1:50,000) issued by Survey of India and Google Map.

6) Final Map
Output of above mentioned process was used to create a final map. Extracted features, contour lines and map annotation were edited and compiled

7) Creation of Digital Elevation Model
Digital elevation model (DEM) was generated from stereo pair of the satellite image. In order to have DEM which truly represents actual terrain, it is necessary to plot break lines where there is change terrain and mass points which represent spot elevations. Road edges, railway lines, embankments, canals, rivers and streams were compiled as break lines.
DEM created meets the following specifications;

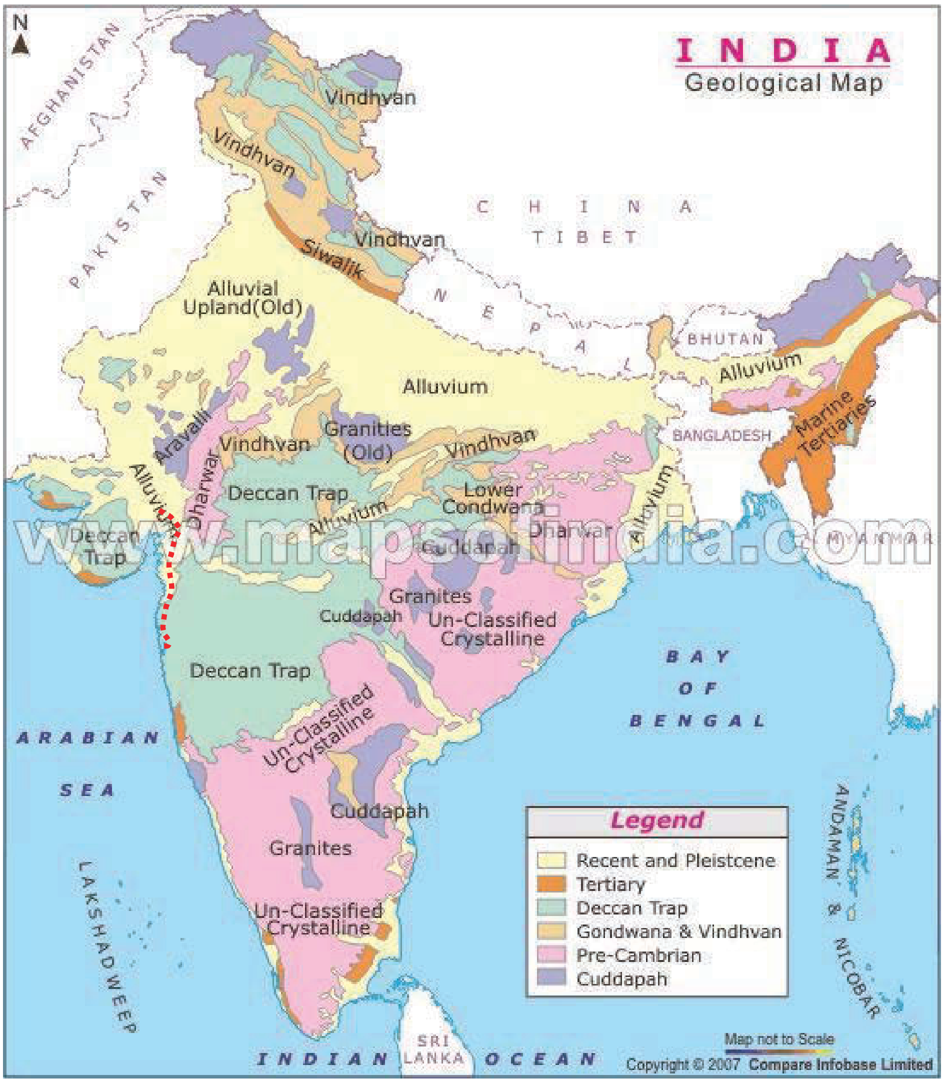
- DEM are corrected for vegetation, built-up areas, etc. so as to find the bare earth.
- Water bodies like lake, pond and other retention water bodies have same elevation on their surface and at the edge of water body.
- Natural and manmade infrastructural items e.g. rivers, canals, roads, railway formation, etc. are identifiable in DEM.
- No gap or hole is present inside DEM
- DEM data are seamless across edges.

6.2 Geological Information

6.2.1 Outline of Geology and Soil in India

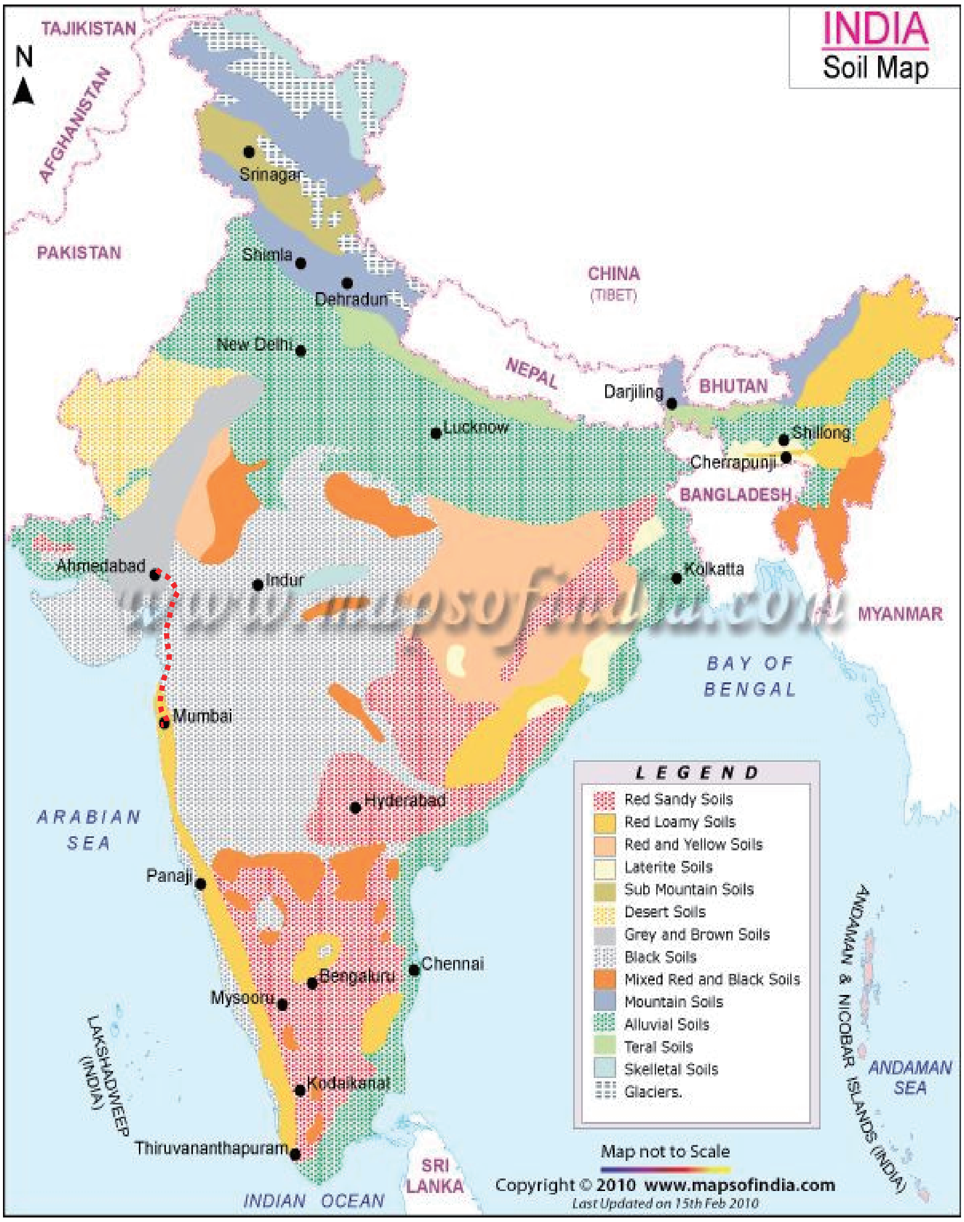
(1) Geological and soil conditions

Figure 6.2-1 and Figure 6.2-2 show the geological and soil conditions of Maharashtra State and Gujarat State.
In terms of the geology around the proposed route, the Maharashtra State and the southern part of Gujarat State are classified as Deccan Traps. On the other hand, the areas near Vapi and to the north of it have deposits of alluvial and diluvial layers.
In terms of the soil around the proposed route, the coast facing the Arabian Sea has red loam and black soil while Ahmedabad, which is inland, has brown soil.
In addition, India is known for wide distribution of black cotton soil (known as Regular soil in India), as shown in Figure 6.2-3. The proposed route will pass through some of those areas.
A characteristic of the soil is that its physical properties change substantially according to its moisture content. In the dry season, the soil will dry up and contract significantly, causing large cracks on the earth's surface. In the rainy season, however, the soil becomes wet and expands, making it sticky and thus sealing the cracks.



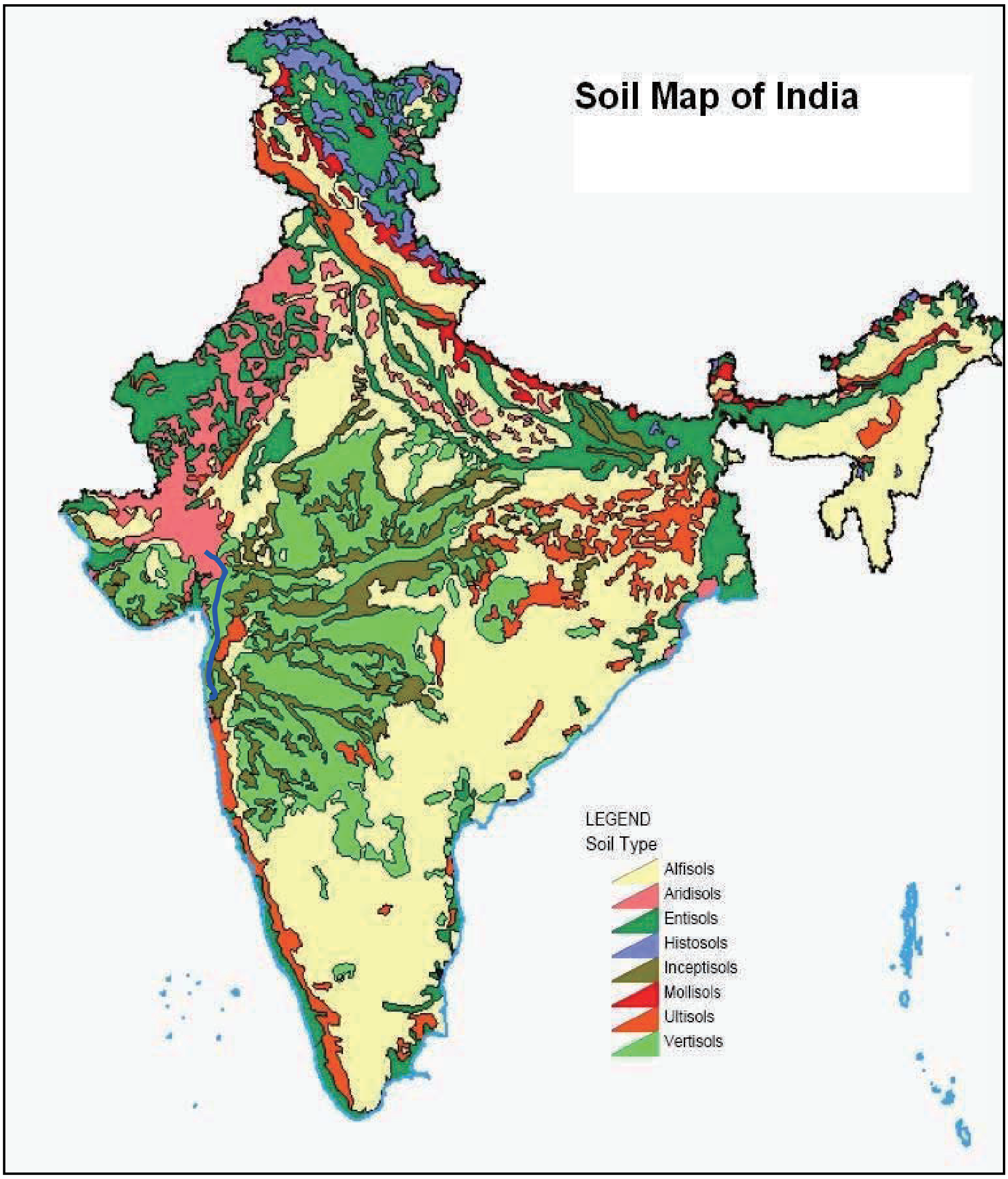
Source: Map of India

Figure 6.2-1 Geological Map



Source: Map of India

Figure 6.2-2 Soil Map



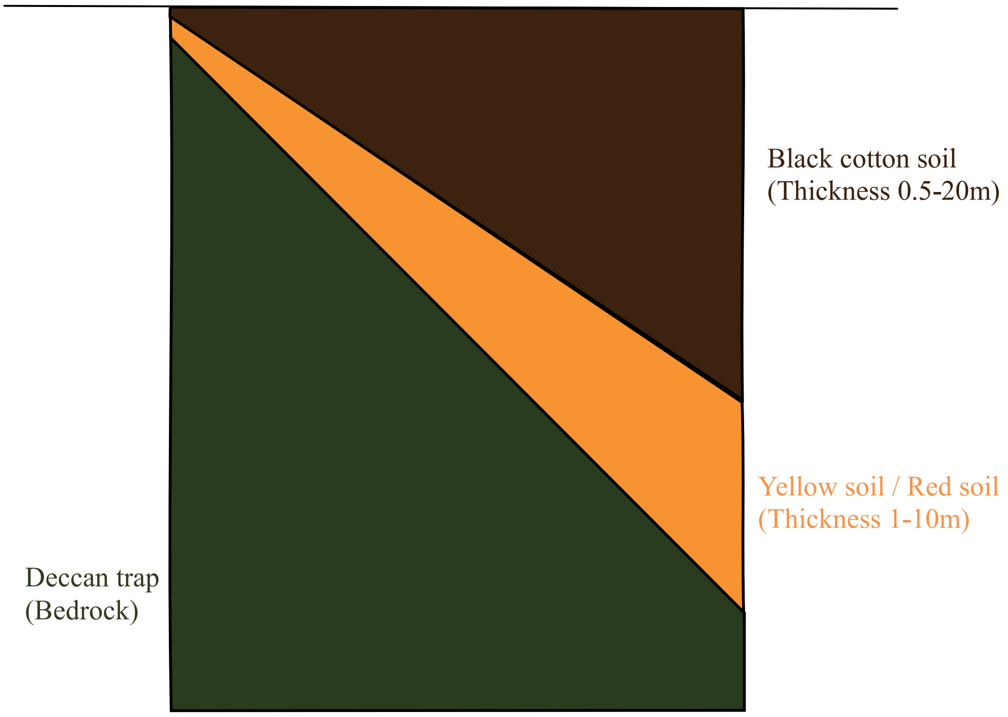
Source: NATIONAL INSTITUTE OF HYDROLOGY Roorkee, India Homepage

Figure 6.2-3 Distribution of Vertisols

(2) Information about the black cotton soil

Black cotton soil is formed by the weathering of basalt. Generally, Black cotton soil is distributed in a flat terrain, poor drainage, and where plants do not grow much. However, it is suitable for the cultivation of cotton.

The depth distribution of black cotton soil in India, there is also up to about 20m from the surface at the deepest. There is a red soil or yellow soil on the bottom, there is bedrock (basalt, Deccan trap) thereunder. Schematic cross-sectional view is shown in Figure 6.2-4.



Source: D.Mohan, R.K.Bhandari(1978) , BLACK COTTON SOILS OF INDIA, TSUCHI-TO-KISO JSSMFE. Vol.26, No.11, pp47-52. (in Japanese)

Figure 6.2-4 Columnar section of the area where distribution of the black cotton soil

Soil characteristics of the black cotton soil are as previously indicated in the Table 6.2-1. Black cotton soil belongs to the A-7 groups according to soil taxonomy of AASHTO.

Table 6.2-1 Soil property of black cotton soil

		Dhar	Barwaha	Phadegaon
Liquid limit (WL)	46~97 %	63	57	79
Plastic limit (Ip)	21~63 %	32	33	38
Shrinkage limit	7~30%	12	12	12
Grain size analysis	Clay: 32~70% Silt: 17~43% Sand: 1~26% Gravel: 0~8%	Clay: 49%	Clay: 49%	Clay: 62%
Specific gravity	2.66~2.75	2.70	2.66	2.74
Organic matter content	0.4%~2.4%	0.73	1.3	1.16
Particle size classification	Clay-like or Loamy soil	Clay-like or Loamy soil	Clay-like or Loamy soil	Clay-like or Loamy soil

Source: D.Mohan, R.K.Bhandari(1978) , BLACK COTTON SOILS OF INDIA, TSUCHI-TO-KISO JSSMFE. Vol.26, No.11, pp47-52. (in Japanese)

Black cotton soil is considered that was derived from erosion of basalt in the surface and penetration of cohesive soil with organic matter. Black cotton soil is rich in calcium carbonate and colloid content. In a wet condition, expansion is large and in a dry condition, shrinkage is large. If black cotton soil is dry, cracks of the polygon are generated in the surface layer. From Figure 6.2-5, it is apparent that cracking conditions are different between wet and dry areas.

Figure 6.2-5 Black cotton soil of the surface layer

Black cotton soil is prone to slake. Figure 6.2-6 shows black cotton soil in water. The left picture is right after the soil has soaked in water. The right picture is the soil in water has left for 4 hours (See Figure).

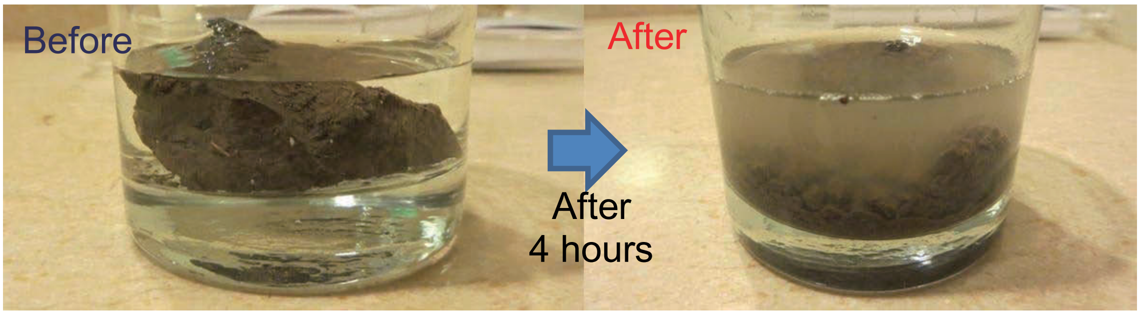


Figure 6.2-6 Slaking of Black cotton soil

Table 6.2-2 describes relation to the expansion degree, liquid limit and plasticity index.

Table 6.2-2 Relation to the expansion degree, liquid limit and plasticity index

	%	Degree of Expansion	Risk of Soil Structure	
Liquid Limit (WL)	20~35	Low	No Problem	
	35~50	Middle	Intermediate	
	50~70	High	Risky	Dhar、Barwaha
	70~90	Very High	Very Risky	Phadegaon
Plasticity index (Ip)	0~12	Low	No Problem	
	12~23	Middle	Intermediate	
	23~32	High	Risky	
	32~	Very High	Very Risky	Dhar、Barwaha Phadegaon

Source: D.Mohan, R.K.Bhandari(1978) , BLACK COTTON SOILS OF INDIA, TSUCHI-TO-KISO JSSMFE. Vol.26, No.11, pp47-52. (in Japanese)

From the facts of relation to the degree of expansion, liquid limit and plasticity index, degree of expansion is high in the vicinity of Mumbai - Ahmedabad. Therefore, some measures are necessary. The degree of expansion is up from 10% to 30%. In addition, it may be considered that the pressure does not exceed the 2.5kg/cm2 in the value of the above plasticity index and liquid limit.

6.2.2 Plan of Geological Survey

(1) Outline of survey

In order to understand the geological properties of the main part of the planned route, we conduct geological survey in the vicinity of the route. For example, distribution of the black cotton soil, crossing portion of the large rivers, undersea tunnel and major mountain tunnel, etc. The main survey methods are described as Table 6.2-3. Detailed results of the survey will be reported in interim report 2.

Table 6.2-3 Geotechnical Investigation Method

Method	Planned Structures	Notes
Drilling	All	
SPT	All	Soil
RQD	All	Rock
PS Logging	All	
Density of Soil Particles	All	Soil
Particle Size Distribution of Soils	All	Soil
Liquid Limit and Plastic Limit of Soils	All	Soil
Bulk Density of Soils	All	Soil
Bulk Density of Rock	All	Rock
Unconfined Compression Test of Soils	All	Soil
Confined Compression Test for Rocks	All	Rock
One-Dimentional Consolidation Properties of Soils Using Incremental Loading	Open Section & TBM Tunnel	Soil
Triaxial Compression Test on Soils (CUbar)	Open Section & TBM Tunnel	Soil
Triaxial Compression Test on Soils (CU)	Open Section & TBM Tunnel	Soil
Water Content of Soils	Open Section & TBM Tunnel	Soil
Water Content of Rock	Open Section & TBM Tunnel	Rock
Fine Fraction Content of Soils	Open Section & TBM Tunnel	
Pressuremeter Test in Borehole	All	
Determination of Hydraulic Properties of Aquifer in Single Borehole	All	Soil
Determination of Hydraulic Conductivity of Rock Mass Using Injection Technique in Single Borehole	NATM Tunnel	Rock
Measuring Pore Water Pressure Using Electric Transducer in Borehole	All	
Measuring Groundater Level in Borehole	All	Soil

(2) Investigation of the Mumbai urban area

Drilling depth is expected to about 10m below from the bottom of the tunnel because the plan passing through underground in Mumbai city. According to the knowledge of the past, unconsolidated marine clay layer is distributed to approximately 10m from the surface, and tuff breccia and basalt are distributed to the depth greater than it.

(3) Investigation of the Thane Creek section

Thane Creek section has an undersea tunnel in proposed route plan. We implement a drilling to a depth which enables to grasp the geology of the sea floor under the cross-strait.

(4) Investigation of the area where distribution of the black cotton soil

We implement a drilling survey in black cotton soil distribution areas in the northern route. The depth of boring will be the available check point for the layer thickness of black cotton soil. According to the knowledge of the past, free swelling index of almost all samples show more than 50 in southern Gujarat, and some of them show more than 80. It means that the degree of expansion is highly.

(5) Investigation of the location across the large rivers

The drilling is carried out in both sides of the long bridge, for example Tapi River, Narmada River and Mahi River, etc. The depth of boring will be the available check point for the basement. According to the findings of other institutions in the Mahi River, it seems that gravel layer which is in about 30m deeper from the surface is a ground support.

(6) Investigation of the mountain tunnel section

Mountain tunnel is planned to construct at south areas of Vapi Station only. It is assumed that the tunnel section locates in the geology of basalt as Deccan traps are spreading. Drilling depth is expected to about 10m below from the bottom of the tunnel.

6.2.3 Implementation of Geological Survey

To grasp the geological properties at major parts on the planned route, Study team is promoting geological surveys at BCS-distributed areas, large-river crossing points and areas close to important mountain and submarine tunnels (See Figure 6.2-7～6.2-9 and Table 6.2-4).

Figure 6.2-7 Map of Borehole Locations (No.1,3,9, 12-22)

Figure 6.2-8 Map of Borehole Locations (No.23-33)

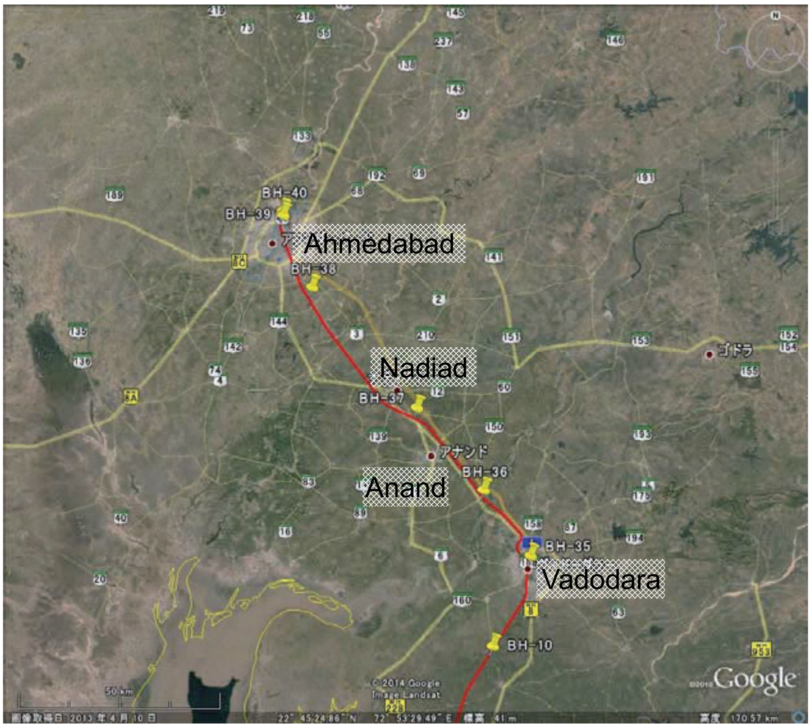


Figure 6.2-9 Map of Borehole Locations (No.10, 35-40)

Table 6.2-4 Geotechnical Survey Method

Method	Planned Structures	Notes
Drilling	All	
SPT (N-Value)	All	Soil
RQD	All	Rock
Density of Soil Particles	All	Soil
Particle Size Distribution of Soils	All	Soil
Atterberg Limits (Liquid Limit, Plastic Limit and Shrinkage Limit of Soils)	All	Soil
Bulk Density of Soils	All	Soil
Bulk Density of Rock	All	Rock
Unconfined Compression Test of Soils	All	Soil
Confined Compression Test for Rocks	All	Rock
One-Dimentional Consolidation Properties of Soils Using Incremental Loading	Open Section & TBM Tunnel	Soil
Triaxial Compression Test on Soils (CUbar)	Open Section & TBM Tunnel	Soil(Clay)
Triaxial Compression Test on Soils (CD)	Open Section & TBM Tunnel	Soil(Sand)
Water Content of Soils	Open Section & TBM Tunnel	Soil
Water Content of Rock	Open Section & TBM Tunnel	Rock
Fine Fraction Content of Soils	Open Section & TBM Tunnel	
Free Swell Index	Open Section	Soil(Clay)
Swelling Pressure	Open Section	Soil(Clay)
Determination of Hydraulic Properties of Aquifer in Single Borehole	All	Soil
Determination of Hydraulic Conductivity of Rock Mass Using Injection Technique in Single Borehole	Tunnel	Rock
Measuring Pore Water Pressure Using Electric Transducer in Borehole	All	
Measuring Groundwater Level in Borehole	All	Soil

(1) Borehole Drilling

Study team has implemented boring surveys at seven points in tunnel sections and 28 points in open sections, in the presence of experts to witness the surveying work. See Figure 6.2-10 for the scenes of boring surveys and witness by experts.

Figure 6.2-10 Borehole Drilling and On-site Witnessing by Experts

(2) Laboratory test

Table 6.2-5 lists the items addressed in the laboratory tests. In the same way as in the boring tests, experts were present to witness the tests in a test room of the contracted company (Figure 6.2-11).

Table 6.2-5 Laboratory Tests

Method	Notes
Density of Soil Particles	For Soil
Particle Size Distribution of Soils	For Soil
Atterberg Limits (Liquid Limit, Plastic Limit and Shrinkage Limit of Soils)	For Soil (Shrinkage limit is for Clayey Soil.)
Bulk Density of Soils	For Soil
Bulk Density of Rock	For Rock
Unconfined Compression Test of Soils	For Soil
Confined Compression Test for Rocks	For Rock
One-Dimentional Consolidation Properties of Soils Using Incremental Loading	For Soil
Triaxial Compression Test on Soils (CUbar)	For Clayey Soil
Triaxial Compression Test on Soils (CD)	For Sandy Soil
Water Content of Soils	For Soil
Water Content of Rock	For Rock
Fine Fraction Content of Soils	For Soil
Free Swell Index	For Clayey Soil
Swelling Pressure	For Clayey Soil

Figure 6.2-11 Preparation of Atterberg Limits Test

6.2.4 Summary of Geotechnical Survey

Below summarized are the results obtained from the boring and laboratory tests. See the annex for the details of the results obtained from the boring and laboratory tests this time.

(1) Investigation of the Mumbai Urban Area

As the high-speed railway is planned to run underground in the Mumbai urban areas, Study team drilled boreholes down to a level an ID below the tunnel bottom. According to the knowledge obtained from the geological surveys in the Mumbai Metro line 3 project and other sources, it is said that an unsolid marine clay layer distributes to a level 10 m below the surface layer, with basalt and tuff breccia following suit beyond. Basalt and tuff breccia have weathered to a great extent. The ROD of such weathered rocks is mostly less than 50%.

(2) Investigation of the Thane Creek Section

As there is a submarine tunnel along the conceivable route in the Thane creek section, Study team will perform boring surveys on both banks down to a level where Study team can grasp the submarine geology (i.e., to a level an ID below the tunnel bottom). According to the knowledge obtained from the Vashi Bridge surveys and other sources, it is said that an unsolid marine clay layer distributes to a level 14 to 17 m below the surface layer, with weathered basalt extending beyond.

(3) Investigation of the Location across the Large Rivers

Study team implemented boring surveys on one or both of the banks of the Tapi, Narmada and Mahi Rivers, where long bridges would be built, by drilling boreholes down to a level 40 m below the surface layer a level where Study team was able to confirm that it is 5m below the bed rock. According to the boring surveys at off-bank points close to the Narmada and Sabarmati Rivers, a layer having an N-value of less than 30 distributes to a level approx. 12 to 14 m below the surface layer, with a layer having an N-value of 50 or over spreading beyond.

(4) Investigation of the Earthwork Section

Study team implemented boring surveys down to a level 40 m below the surface layer or a level where Study team was able to confirm that it is 5 m below the bed rock in earth structure sections principally to grasp the distributions of black cotton soil and soft ground layer, which would pose a problem in constructing embankments. See section 6.2.5 for the black cotton soil and soft ground layers, which provide conditions to be observed in construction earth structures.

(5) Investigation of the Mountain Tunnel Section

Mountain tunnels are planned only in the south of the Vapi station. As tunnel sections are located in the area where Deccan Trap distributes, the natural ground is thought to consist of basalt in large part. Study team drilled boreholes down to a level an ID below the tunnel bottom. The Deccan Trap basalt is hard and solid judging from the observed conditions of exposure (Figure 6.2-12). However, it seems that weathering has progressed on small earth covering parts. As the geological map issued by the Indian Geological Survey Institute (GSI) and other available materials indicate that faults and joints have developed at some parts in Deccan Trap areas, attention shall be paid to fragility of the ground due to the existence of fractured zones and spontaneous outbreak of spring water from underground water veins.

Figure 6.2-12 Outcrop of Basalt

6.2.5 Summary of Special Condition Ground

(1) Black Cotton Soil

According to the analysis of the specimens Nos. 10, 32, 33, 34 and 38, the values of free swelling index (FSI) exceed 35, a yardstick value to indicate high "expansibility," with the values of specimens Nos. 33 and 34, in particular, exceeding 50 to suggest extremely high expansibility. Measurement by boring surveys indicate that the underground water level is lower than a depth of 8 m or over, with only small water content existing in and around the surface layer. To suppress the effect of the black cotton soil in the surface layer on the embankments, therefore, it is important to prevent invasion of water including rainwater from outside.
As current surveys don't provide the definite scope of distribution of black cotton soil, Study team estimated the ratios of its distribution between stations based on literature (soil maps). See Figure 6.2-13～6.2-15 and Table 6.2-6 for the scope of distribution and ratios of distribution between stations, respectively.

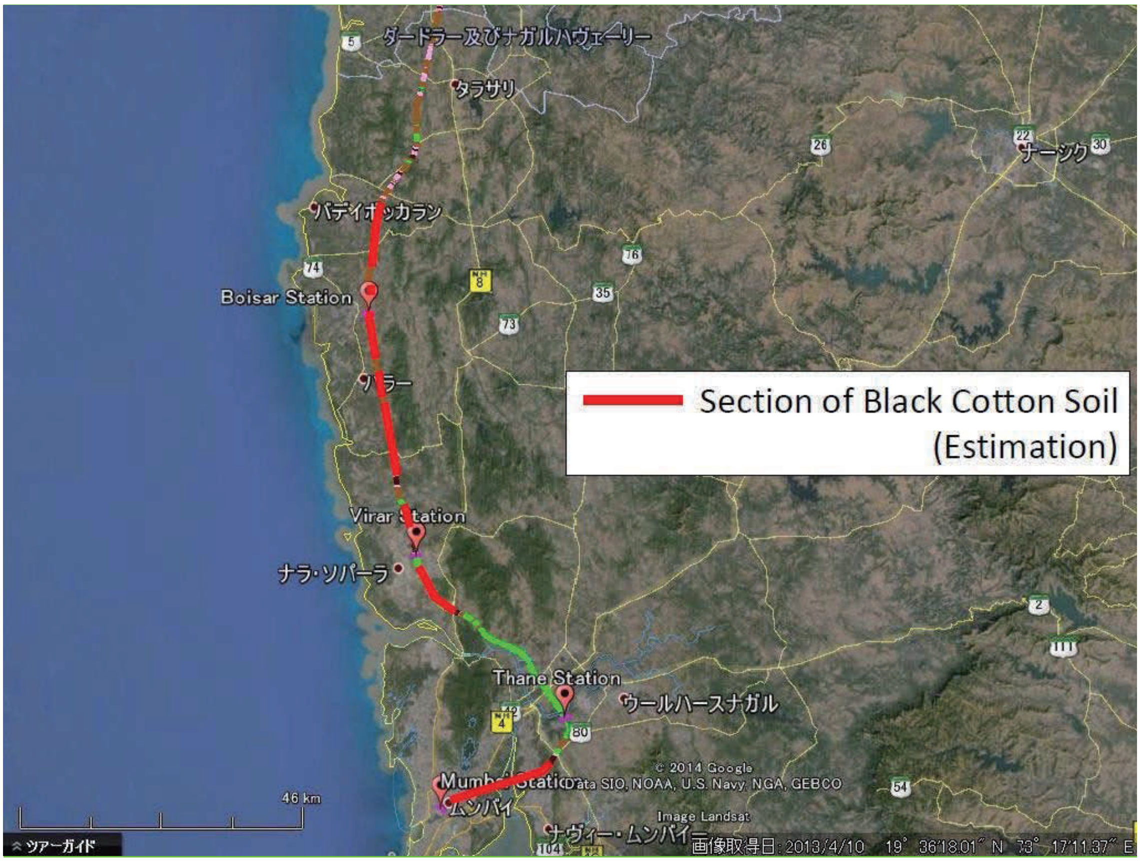


Figure 6.2-13　Section of Black Cotton Soil (1)
Source: Maharashtra SOILS and Gujarat SOILS (National Bureau of Soil Survey & Land Use Planning)

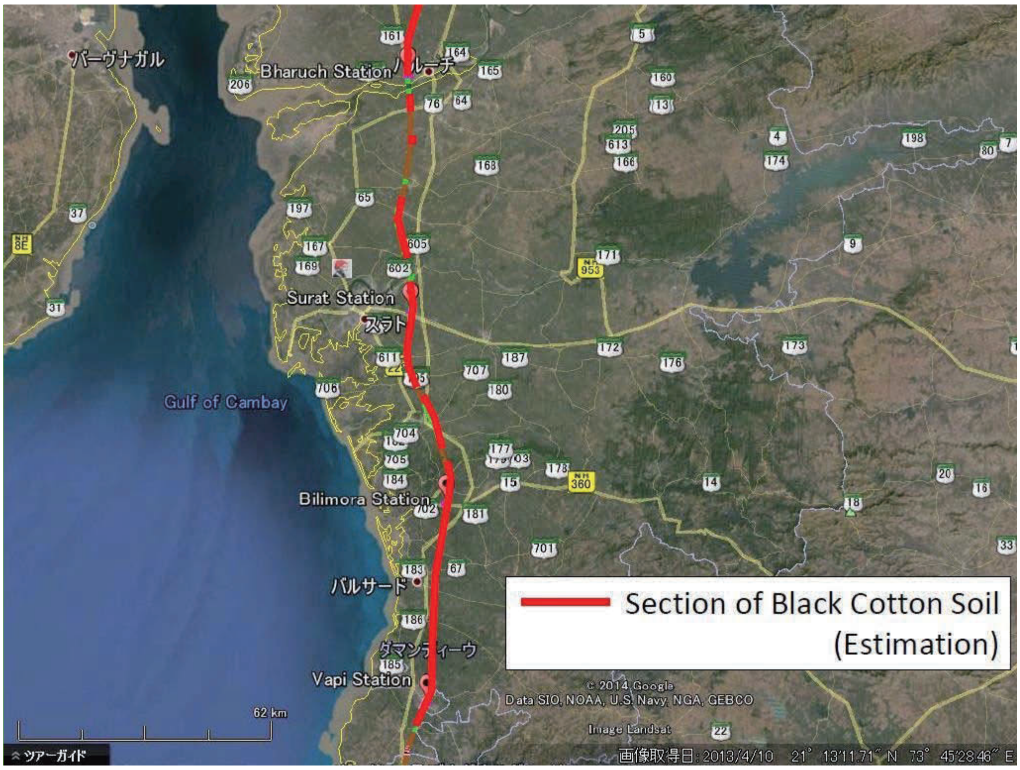


Figure 6.2-14 Section of Black Cotton Soil (2)

Source: Maharashtra SOILS and Gujarat SOILS (National Bureau of Soil Survey & Land Use Planning)

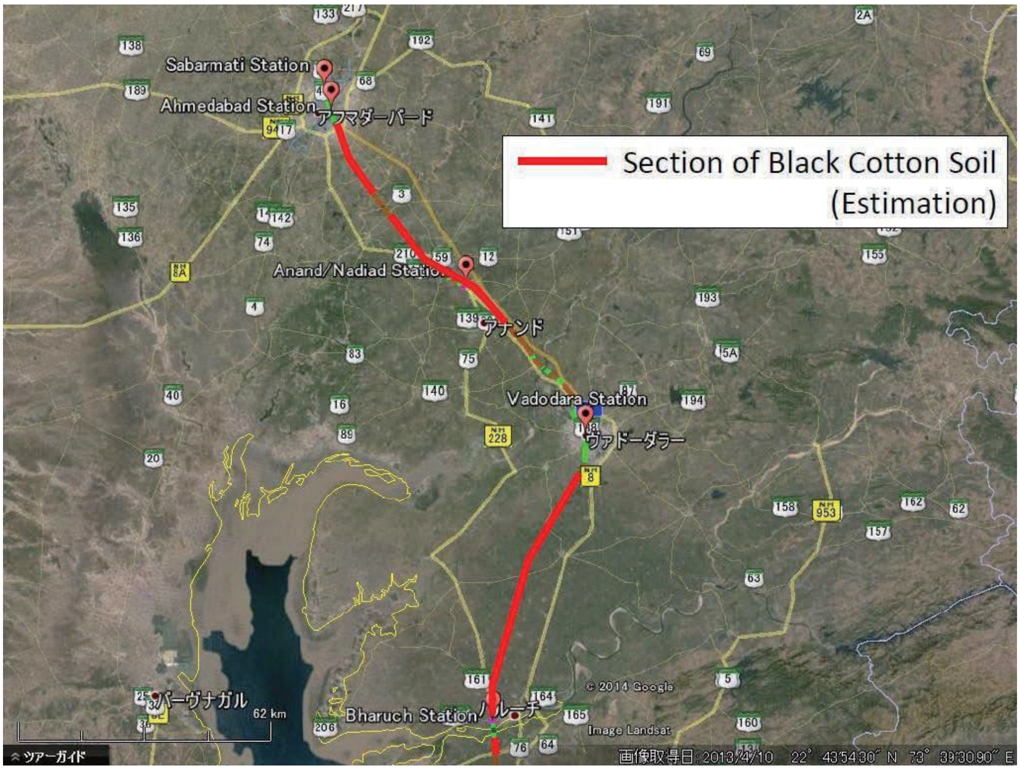


Figure 6.2-15 Section of Black Cotton Soil (3)

Source: Maharashtra SOILS and Gujarat SOILS (National Bureau of Soil Survey & Land Use Planning)

Table 6.2-6 Percentage of Black Cotton Soil

Section	Percentage (%)
Mumbai - Thane	75%
Thane - Virar	30%
Virar - Boisar	65%
Boisar - Vapi	30%
Vapi - Bilimora	100%
Bilimora - Surat	90%
Surat - Bharuch	55%
Bharuch - Vadodara	90%
Vadodara - Anand / Nadiad	30%
Anand / Nadiad - Ahmedabad	85%
Ahmedabad - Sabarmati	0%

Source: Maharashtra SOILS and Gujarat SOILS (National Bureau of Soil Survey & Land Use Planning)

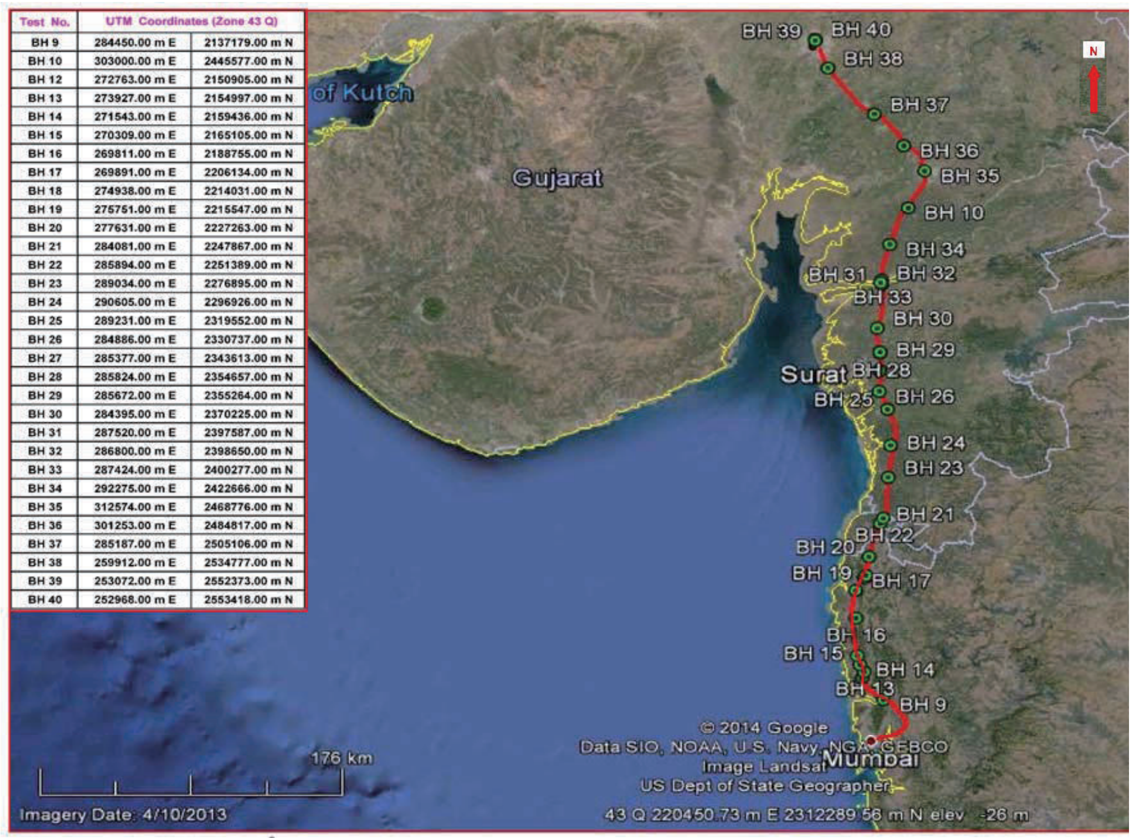
(2) Soft Ground

The strength required for railway subgrades is N-value 4 or over. Subgrades of which the N-value is lower than 4 require soil improvement work. However, there are no layers having an N-value smaller than 8 found in the surveys implemented this time or in the surveys in the past, either. Accordingly, Study team assumes in this report that there are no sections where countermeasures against soft grounds are required.

6.2.6 Geological Data collection for Preliminary Survey of Alignment

(1)The location of Boreholes point

This Figure 6.2-16 shows the boreholes point in this study.



Test No.	UTM Coordinates (Zone 43 Q)	
BH 9	284450.00 m E	2137179.00 m N
BH 10	303000.00 m E	2445577.00 m N
BH 12	272763.00 m E	2150905.00 m N
BH 13	273927.00 m E	2154997.00 m N
BH 14	271543.00 m E	2159436.00 m N
BH 15	270309.00 m E	2165105.00 m N
BH 16	269811.00 m E	2188755.00 m N
BH 17	269891.00 m E	2206134.00 m N
BH 18	274938.00 m E	2214031.00 m N
BH 19	275751.00 m E	2215547.00 m N
BH 20	277631.00 m E	2227263.00 m N
BH 21	284081.00 m E	2247867.00 m N
BH 22	285894.00 m E	2251389.00 m N
BH 23	289034.00 m E	2276895.00 m N
BH 24	290605.00 m E	2296926.00 m N
BH 25	289231.00 m E	2319552.00 m N
BH 26	284886.00 m E	2330737.00 m N
BH 27	285377.00 m E	2343613.00 m N
BH 28	285824.00 m E	2354657.00 m N
BH 29	285672.00 m E	2355264.00 m N
BH 30	284395.00 m E	2370225.00 m N
BH 31	287520.00 m E	2397587.00 m N
BH 32	286800.00 m E	2398650.00 m N
BH 33	287424.00 m E	2400277.00 m N
BH 34	292275.00 m E	2422666.00 m N
BH 35	312574.00 m E	2468776.00 m N
BH 36	301253.00 m E	2484817.00 m N
BH 37	285187.00 m E	2505106.00 m N
BH 38	259912.00 m E	2534777.00 m N
BH 39	253072.00 m E	2552373.00 m N
BH 40	252968.00 m E	2553418.00 m N

Source: Geological Survey for Mumbai-Ahmedabad High Speed Railway Study

Figure 6.2-16 Boring Survey Point

(2)Scope of Geological Investigation

Initially, forty (40) boreholes were planned to be drilled along the alignment. However, due to non-availability of necessary permissions and other local issue at some locations, thirty one (31) boreholes were successfully drilled along the alignment.

Table 6.2-7 Scope of Geological Investigation

S. No.	BH No.	State	Location	Type	UTM Coordinates, m		Borehole Termination Depth, m	Permeability Test Depth
					Easting, m	Northing, m		
1	BH 9	Maharastra		Open Section	284450	2137179	15.0 m	FPT at 5.0 m
2	BH 10	Gujarat		Open Section	303078	2446689	40.3 m	FPT at 25.0 m
3	BH 12	Maharastra	Virar St.	Open Section	272763	2150905	6.0 m	
4	BH 13	Maharastra	Wadhiv Cr.	Open Section	271198	2155870	5.0 m	
5	BH 14	Maharastra	Wadhiv Cr.	Open Section	271543	2159436	6.5 m	
6	BH-15	Maharastra	NATM Tn.	Tunnel Section	269783	2163959	*Borehole in Progress on site*	
7	BH 16	Maharastra	Boisar St.	Open Section	266932	2189446	5.0 m	
8	BH 17	Maharastra	Bs-Vp1	Open Section	269891	2206134	10.0 m	
9	BH 18	Maharastra	NATM Tn.	Tunnel Section	274938	2214031	39.0 m	
10	BH 19	Maharastra	NATM Tn.	Tunnel Section	275751	2215547	45.0 m	
11	BH 20	Maharastra	Bs-Vp2	Open Section	277625	2227247	11.0 m	
12	BH 21	Gujarat	Daman Ganga Rv.	Open Section	284731	2247580	14.5 m	
13	BH 22	Gujarat	Vapi St.	Open Section	285894	2251389	7.0 m	
14	BH 23	Gujarat	Vp-Bm	Open Section	289050	2276898	8.0 m	
15	BH 24	Gujarat	Bilimora St.	Open Section	292149	2297350	21.0 m	FPT at 6.0 m
16	BH 25	Gujarat	Purna Rv.	Open Section	289231	2319552	40.4 m	FPT at 13.0 m
17	BH 26	Gujarat	Bm-Sr	Open Section	284593	2330625	40.3 m	FPT at 23.0 m
18	BH 27	Gujarat	Surat St.& Dp.	Open Section	285758	2344626	40.2 m	FPT at 18.0 m
19	BH 28	Gujarat	Tapi Rv.	Open Section	285825	2354664	40.4 m	FPT at 15.0 m
20	BH 29	Gujarat	Tapi Rv.	Open Section	285672	2355264	40.4 m	FPT at 14.5 m
21	BH 30	Gujarat	Sr-Br	Open Section	284389	2370233	40.45 m	FPT at 6.0 m
22	BH 31	Gujarat	Narmada Rv.	Open Section	287520	2397587	40.15 m	FPT at 15.5 m
23	BH 32	Gujarat	Narmada Rv.	Open Section	286800	2398650	40.3 m	FPT at 15.5 m
24	BH 33	Gujarat	Bharuch St.	Open Section	287424	287424	40.3 m	FPT at 11.5 m
25	BH 34	Gujarat	Br-Vd	Open Section	292276	2422666	40.36 m	FPT at 11.5 m
26	BH 35	Gujarat	Vadodara St.	Open Section	312589	2468689	40.3 m	FPT at 33.5 m
27	BH 36	Gujarat	Mahi Rv.	Open Section	301268	2484853	40.3 m	FPT at 26.5 m
28	BH 37	Gujarat	Anand/Nadiad St.	Open Section	285189	2505101	40.3 m	FPT at 13.0 m
29	BH 38	Gujarat	Ahmedabad Dp.	Open Section	259912	2534777	40.36 m	FPT at 29.5 m
30	BH 39	Gujarat	Sabarmati Rv.	Open Section	253053	2552383	40.3 m	FPT at 10.0 m
31	BH 40	Gujarat	Sabarumati St.	Open Section	252968	2553418	40.22 m	FPT at 12.5 m

(3)Ground water level

The measure depth of groundwater encountered at the boreholes locations is mentioned in the individual boreholes and summarized as here in below:

Table 6.2-8 Ground Water Level

BH No.	UTM Coordinates		Measured Groundwater Table below EGL, m	Period of Measurement
	Easting, m	Northing, m		
BH 9	284450	2137179	2.9 m	August, 2014
BH 10	303078	2446689	23.5 m	July, 2014
BH 12	272763	2150905	Not Met	September, 2014
BH 13	271198	2155870	1.0 m	September, 2014
BH 14	271543	2159436	0.4 m	September, 2014
BH-15	269783	2163959	10.8 m	October, 2014
BH 16	266932	2189446	Not Met	September, 2014
BH 17	269891	2206134	Not Met	August, 2014
BH 18	274938	2214031	1.0 m	August, 2014
BH 19	275751	2215547	0.6 m	August, 2014
BH 20	277625	2227247	Not Met	August, 2014
BH 21	284731	2247580	3.1 m	July, 2014
BH 22	285894	2251389	Not Met	August, 2014
BH 23	289050	2276898	4.0 m	August, 2014
BH 24	292149	2297350	4.0 m	September, 2014
BH 25	289231	2319552	10.7 m	August, 2014
BH 26	284593	2330625	11.3 m	August, 2014
BH 27	285758	2344626	17.0 m	July, 2014
BH 28	285825	2354664	13.6 m	August, 2014
BH 29	285672	2355264	12.4 m	July, 2014
BH 30	284389	2370233	4.1 m	July, 2014
BH 31	287520	2397587	2.8 m	June, 2014
BH 32	286800	2398650	13.6 m	June, 2014
BH 33	287424	287424	9.2 m	July, 2014
BH 34	292276	2422666	8.7 m	July, 2014
BH 35	312589	2468689	9.0 m	August , 2014
BH 36	301268	2484853	21.1 m	July, 2014
BH 37	285189	2505101	10.1 m	July, 2014
BH 38	259912	2534777	15.2 m	July, 2014
BH 39	253053	2552383	7.1 m	July, 2014
BH 40	252968	2553418	8.0 m	July, 2014

(4) Field permeability test results

1) In soil (Falling Head method)

Nineteen (19) field permeability tests have been conducted by falling head method. The test results are summarized as here in below:

Table 6.2-9 Field Permeability Test Results (in Soil)

S.No.	Test Location	Test Designation	Test Depth below EGL , m	Soil Classification	Coefficient of Permeability (k), cm/s	Presentation of Results
1	BH-9	FPT-1	5.0 m	Clayey silt	4.4×10^{-6}	Plates 112 & 113
2	BH-10	FPT-2	25.0 m	Silty Fine sand	1.20×10^{-4}	Plates 114 & 115
3	BH-24	FPT-3	6.0 m	Silty Fine sand	1.9×10^{-4}	Plates 116 & 117
4	BH-25	FPT-4	13.0 m	Clayey silt	4.29×10^{-6}	Plates 118 & 119
5	BH-26	FPT-5	23.0 m	Clayey silt	2.79×10^{-6}	Plates 120 & 121
6	BH-27	FPT-6	18.0 m	Silty Fine sand	1.2×10^{-4}	Plates 122 & 123
7	BH-28	FPT-7	15.0 m	Fine sand	1.1×10^{-4}	Plates 124 & 125
8	BH-29	FPT-8	14.5 m	Clayey silt	4.1×10^{-6}	Plates 126 & 127
9	BH-30	FPT-9	6.0 m	Silty clay	3.84×10^{-6}	Plates 128 & 129
10	BH-31	FPT-10	15.5 m	Silty clay	4.68×10^{-6}	Plates 130 & 131
11	BH-32	FPT-11	15.5 m	Silty clay	2.9×10^{-6}	Plates 132 & 133
12	BH-33	FPT-12	11.5 m	Silty clay	2.14×10^{-6}	Plates 134 & 135
13	BH-34	FPT-13	11.5 m	Silty clay	2.75×10^{-6}	Plates 136 & 137
14	BH-35	FPT-14	33.5 m	Clayey silt	2.49×10^{-6}	Plates 138 & 139
15	BH-36	FPT-15	26.5 m	Clayey silt	5.48×10^{-6}	Plates 140 & 141
16	BH-37	FPT-16	13.0 m	Silty clay	8.68×10^{-6}	Plates 142 & 143
17	BH-38	FPT-17	29.5 m	Clayey silt	1.26×10^{-6}	Plates 144 & 145
18	BH-39	FPT-18	10.0 m	Clayey silt	1.67×10^{-6}	Plates 146 & 147
19	BH-40	FPT-19	15.5 m	Clayey silt	5.36×10^{-6}	Plates 148 & 149

2) In Rock (Single Packer Method)

One (1) in-situ permeability tests was conducted in rock by Single Packer Method at BH-15 location. The mean coefficient of permeability and Lugeon value are tabulated below:

Table 6.2-10 Field Permeability Test Results (in Rock)

Test Location	Test Designation	Test Depth below EGL (RL), m	Core Recovery, %	RQD, %	Mean Coefficient of Permeability, cm/sec	Mean Lugeon Value	Presentation of Results
BH-15	PT-1	40.0 m	90 %	73 %	6.3×10^{-6}	6.4	Plate 153 & 154

(5)Soil feature of HSR route between Stations

(1)The result of boreholes survey

The below shows the result of survey as detailed feature of both HSR route and DFC in each borehole spots.
Show them next page.

1)Virar~Boisar

○HSR

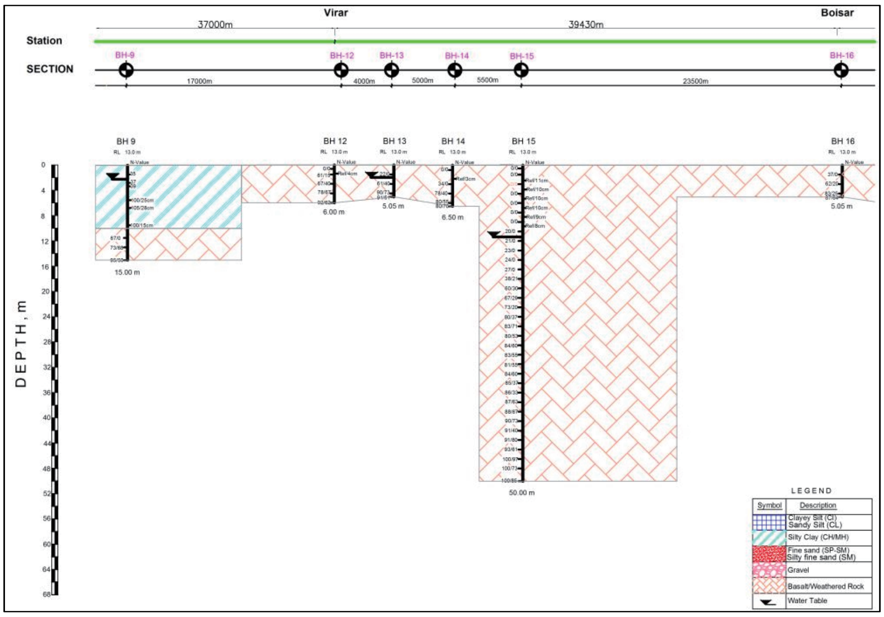


Figure 6.2-17 Boring Survey Point (between Virar Station and Boisar Station)

Table 6.2-11 Stratigraphy Profile Encountered at the Boreholes (between Virar Station and Boisar Station)

Borehole	Depth, m		Description	SPT Values	Core Recovery, %	RQD, %
	From	To				
BH-9	0.0	6.0	Hard brown clayey silt	35-39	-	-
	6.0	10.0		100+	-	-
	10.0	11.5	Weak to moderately strong, dark green BASALT, intensely fractured, moderately weathered	-	67	0
	11.5	15.0		-	73 & 95	50 & 68
BH-12	0.0	1.0	Very weak BASALT, completely weathered		0	0
	1.0	2.5	Weak to moderately strong green, BASALT, intensely to moderately fractured, slightly weathered	-	61	15
	2.5	6.0		-	61-92	40-73
BH-13	0.0	1.5	Moderately strong to strong green BASALT intensely to moderately fractured, moderate to slightly weathered	-	22	0
	1.5	5.1		-	61-91	40-73
BH-14	0.0	1.5	Very weak BASALT, completely weathered	-	0	0
	1.5	3.0	Moderately strong to strong green BASALT, intensely to moderately fractured, moderately weathered	-	34	0
	3.0	6.5		-	78-80	40-70
BH-15	0.0	9.0	Very weak BASALT, completely weathered	-	0	0
	9.0	16.5	Weak BASALT, very intensely fractured, highly weathered	-	20-27	0
	16.5	24.0	Moderately strong to strong grey BASALT, intensely fractured, moderately weathered	-	38-80	20-37
	24.0	50.0		-	80-100	37-85
BH-16	0.0	1.5	Moderately weak to moderately strong green BASALT, very intensely to moderately fractured, moderately to slightly weathered	-	37	0
	1.5	5.1		-	62-87	20-64

○DFC

Figure 6.2-18 Boring Survey Point from DFC

2)Boisar～Vapi

○HSR

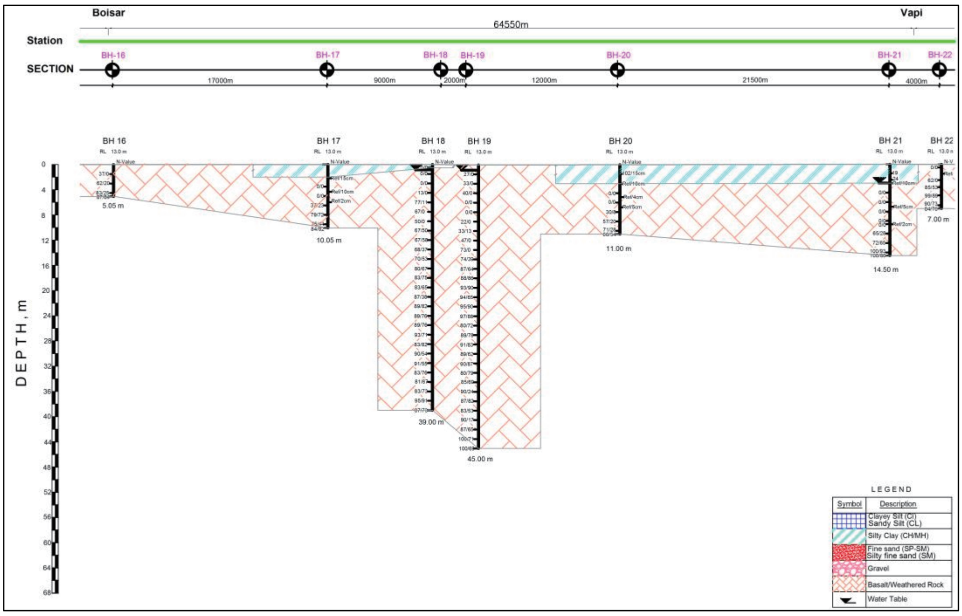


Figure 6.2-19 Boring Survey Point (between Boisar Station and Vapi Station)

Table 6.2-12 Stratigraphy Profile Encountered at the Boreholes
(between Boisar Station and Vapi Station)

Borehole	Depth, m		Description	SPT Values	Core Recovery, %	RQD, %
	From	To				
BH-16	0.0	1.5	Moderately weak to moderately strong green BASALT, very intensely to moderately fractured, moderately to slightly weathered	-	37	0
	1.5	5.1		-	62-87	20-64
BH-17	0.0	2.0	Silty clay with rock fragments	-		
	2.0	5.0	Very weak BASALT, completely weathered	-	0	0
	5.0	6.5	Moderately strong reddish brown BASALT, moderately fractured, moderately weathered	-	37	23
	6.5	10.5		-	79-84	72-82
BH-18	0.0	0.5	Hard brown silty clay with rock fragments	-	0	0
	0.5	3.0	Very weak BASALT, completely weathered	-	0	0
	3.0	9.0	Very weak to moderately strong, dark green BASALT, very intensely fractured, completely to highly weathered	-	13-67	0
	9.0	39.0	Moderately strong to strong dark green amygdaloidal BASALT, intensely to moderately fractured, slightly weathered	-	67-95	50-91
BH-19	0.0	4.5	Weak BASALT, very intensely fractured, highly weathered	-	27-40	0
	4.5	7.5	Very weak Basalt, completely weathered	-	0	0
	7.5	13.5	Weak Basalt very intensely fractured highly weathered	-	22-47	0-13
	13.5	42.0	Moderately strong to strong dark green to brown amygdaloidal BASALT slightly to moderately fractured, slightly weathered	-	74-97	17-90
	42.0	45.0	Moderately strong dark green amygdaloidal BASALT, moderately fractured, moderately weathered	-	100	69-71
BH-20	0.0	3.0	Silty Clay with rock fragments	100+		
	3.0	6.0	Very weak BASALT, completely weathered	100+	0	0
	6.0	11.0	Moderately weak to moderately strong, reddish brown BASALT, very intensely to moderately fractured, moderately weathered	-	30-71	8-54
BH-21	0.0	3.0	Very stiff grey silty clay	19-24		
	3.0	9.5	Very weak BASALT, completely to completely weathered	100+	0	0
	9.5	11.0	Moderately strong dark green BASALT, slightly fractured, moderately weathered	-	65	28
	11.0	14.5		-	72-100	65-93

○DFC

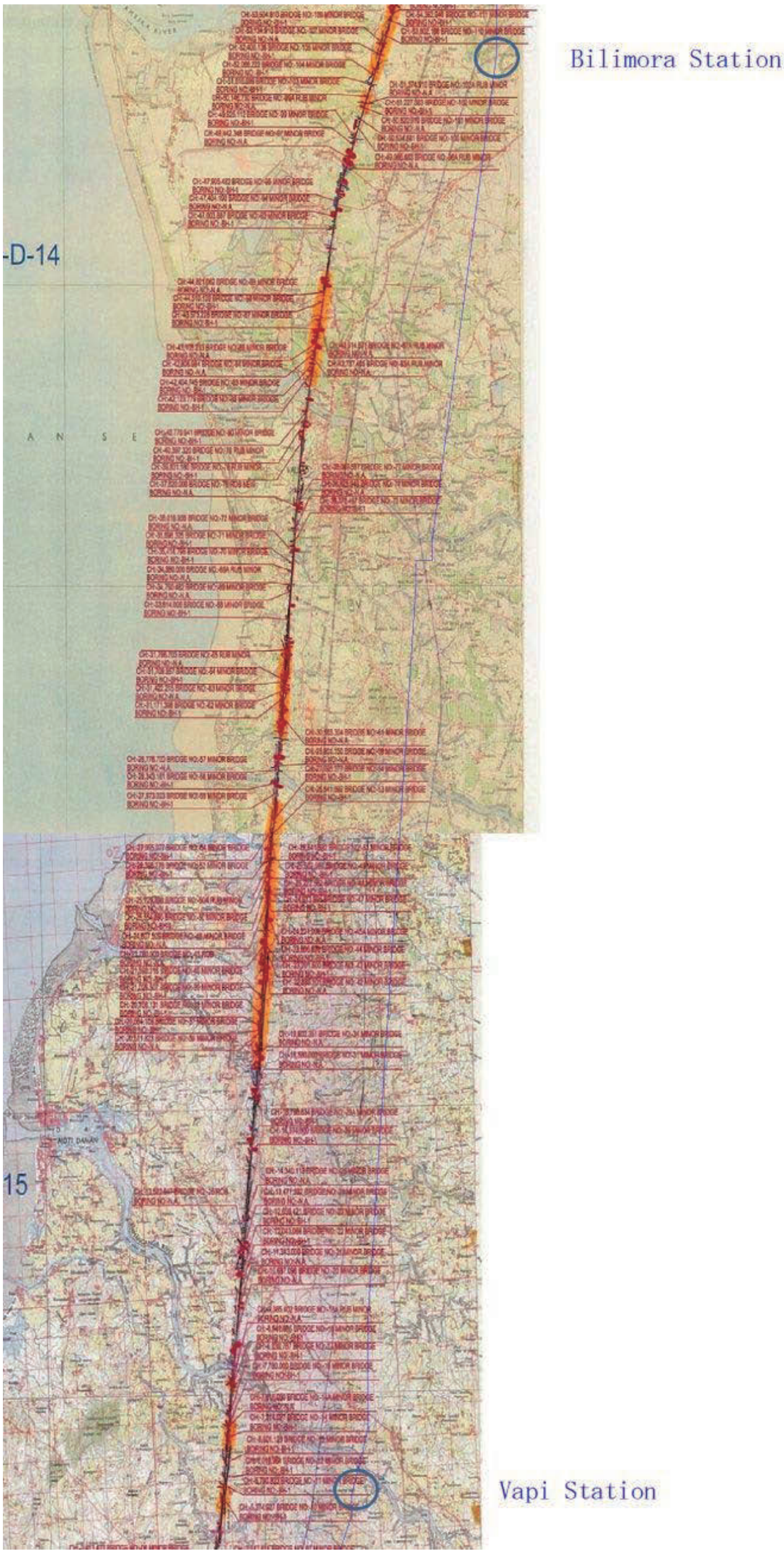


Figure 6.2-20 Boring Survey Point from DFC

3)Vapi～Bilimora

○HSR

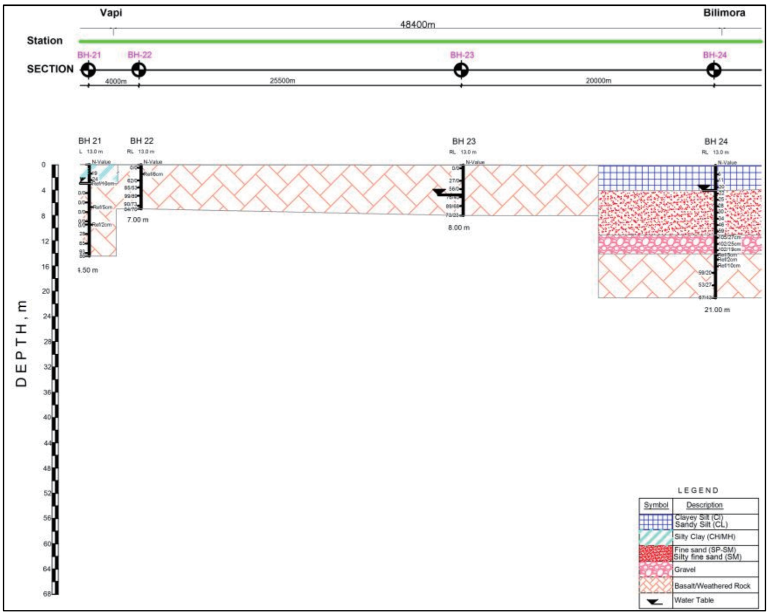


Figure 6.2-21 Boring survey point (between Vapi Station and Bilimora Station.)

Table 6.2-13 Stratigraphy Profile Encountered at the Boreholes (between Vapi Station and Bilimora Station)

Borehole	Depth, m		Description	SPT Values	Core Recovery, %	RQD, %
	From	To				
BH-22	0.0	1.5	Very weak to strong, dark green BASALT, very intensely to slightly fractured, moderately weathered	100+	0	0
	1.5	3.5	Moderately strong to strong, slightly fractured,	-	62-85	0-53
	3.5	7.0		-	84-99	53-76
BH-23	0.0	3.0	Very weak to moderately strong, dark green BASALT, very intensely to slightly fractured moderately weathered, very weak, completely weathered	-	0-56	0
	3.0	8.0	Moderately strong BASALT, very intensely to slightly fractured	-	73-89	23-68
BH-24	0.0	4.0	Firm to very stiff grey clayey silt	6-20	-	-
	4.0	11.0	Medium dense to very dense silty medium to coarse sand	20-59	-	-
	11.0	13.8		100+	-	-
	13.8	16.0	Gravel & rock fragments	100+	-	-
	16.0	21.0	Very weak to moderately strong dark green BASALT, completely to moderately weathered	100+	59-67	20-43

○DFC

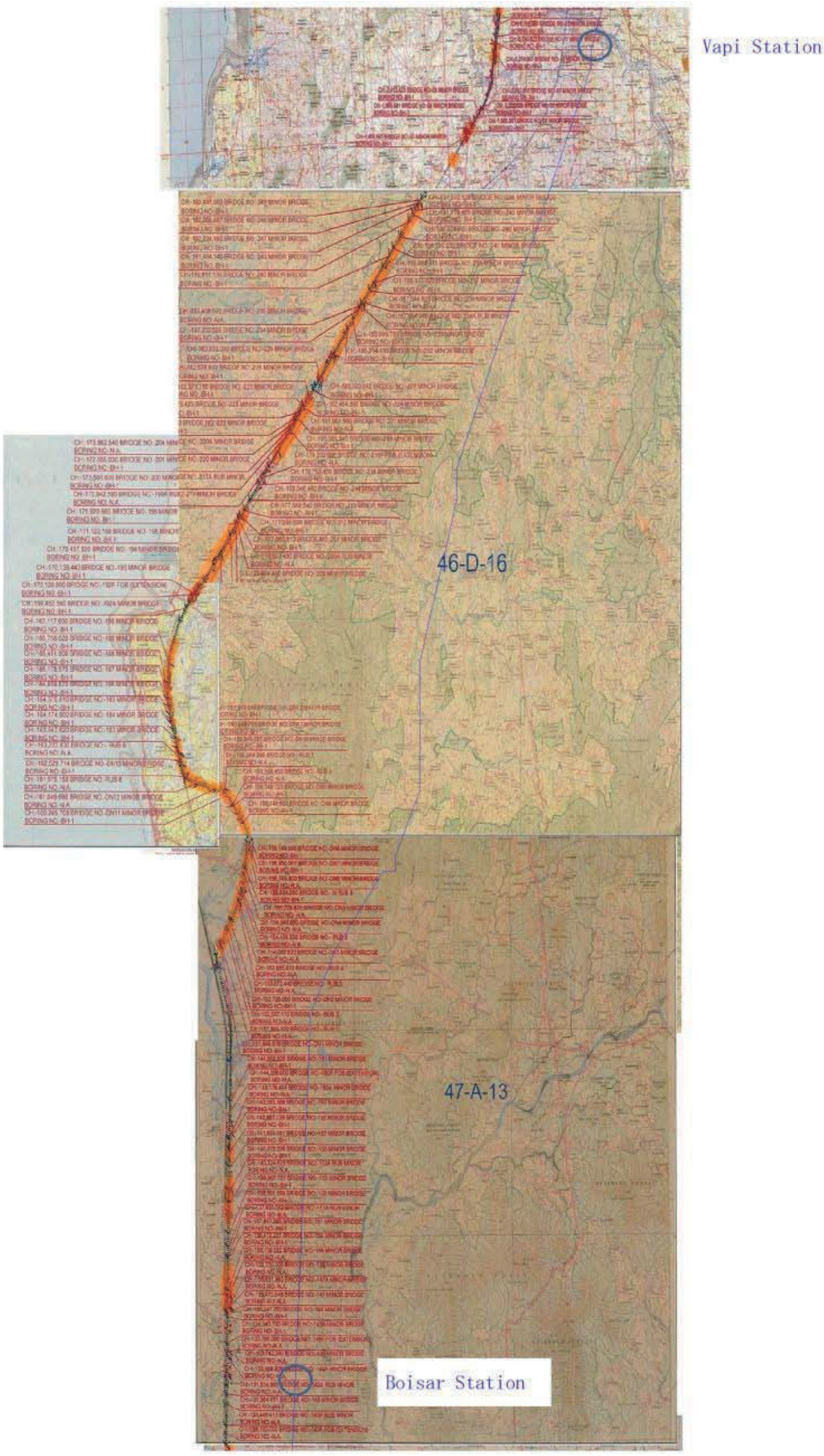


Figure 6.2-22 Boring Survey Point from DFC

4)Bilimora～Surat

○HSR

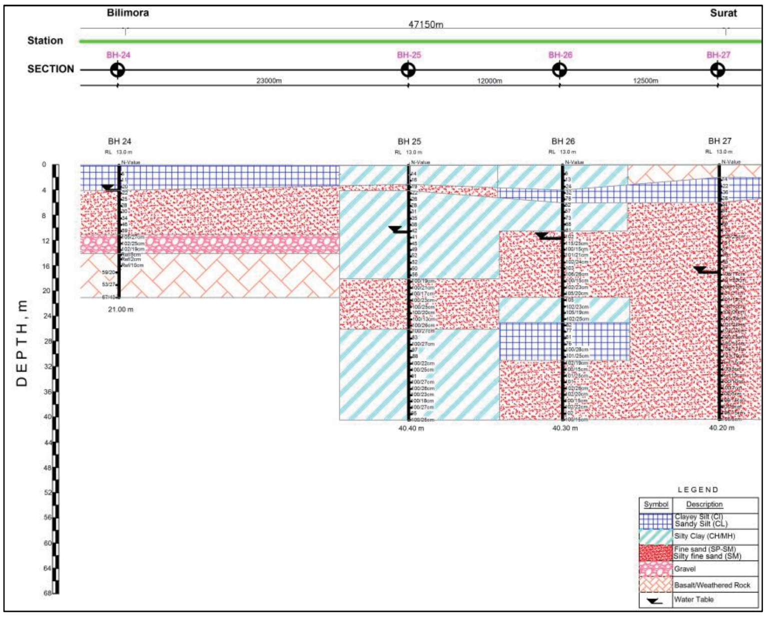


Figure 6.2-23 Boring Survey Point (between Bilimora Station and Surat Station)

Table 6.2-14 Stratigraphy Profile Encountered at the Boreholes
(between Bilimora Station and Surat Station)

Borehole	Depth, m		Description	SPT Values
	From	To		
BH-25	0.0	3.0	Stiff to very stiff grey silty clay	14-16
	3.0	4.0	Medium dense brown silty fine sand with gravel	19
	4.0	9.0	Very stiff to hard brown silty clay	22-35
	9.0	18.0	Hard brown silty clay	38-56
	18.0	19.0	Very dense grey silty medium to coarse sand intermixed with gravel	100+
	19.0	26.0	Very dense grey silty medium to coarse sand with gravel	100+
	26.0	36.0	Hard brown silty clay	83-100+
	36.0	40.4	Hard brown silty clay	95-100+
BH-26	0.0	4.0	Firm to very stiff grey silty clay	6-24
	4.0	6.0	Dense to very dense brown sandy silt	32-78
	6.0	10.5	Hard grey silty clay	52-81
	10.5	15.0	Very dense grey silty fine sand	100+
	15.0	18.0	Very dense grey fine sand	100+
	18.0	21.0	Very dense grey silty fine sand with traces of gravel	100+
	21.0	25.0	Hard grey silty clay	100+
	25.0	31.0	Hard brown clayey silt	61-100+
	31.0	40.3	Very dense brown silty fine sand	100+
BH-27	0.0	2.0	Fill- Silty clay	
	2.0	2.5	Stiff brown clayey silt	
	2.5	6.0	Medium dense to dense brown sandy silt	14-36
	6.0	9.0	Dense to very dense grey silty medium to coarse sand with gravel	44-84
	9.0	10.0	Very dense brown sandy silt	86
	10.0	40.2	Very dense grey silty medium to coarse sand	37-100+

○DFC

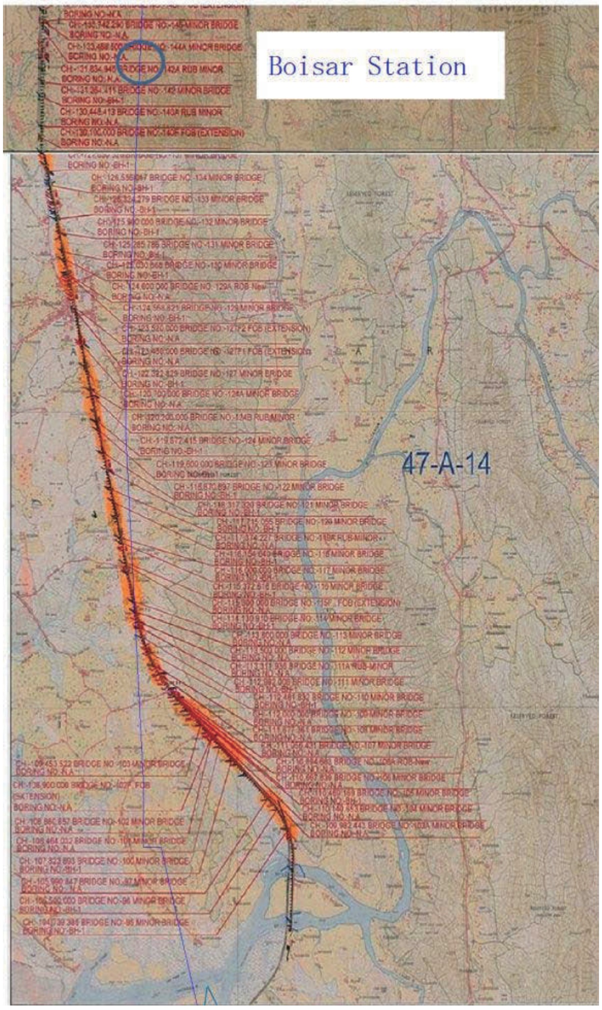


Figure 6.2-24 Boring Survey Point from DFC

5)Surat～Bharuch

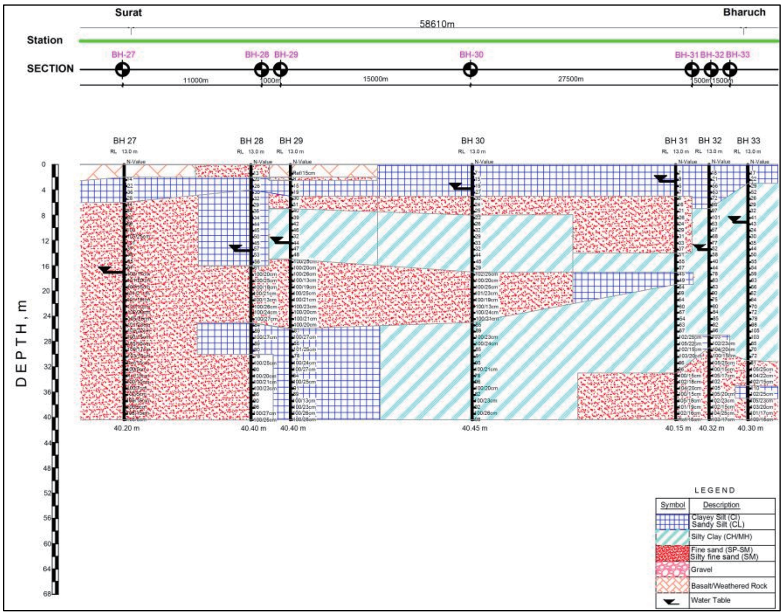


Figure 6.2-25 Boring Survey Point (between Surat Station and Bharuch Station)

Table 6.2-15 Stratigraphy Profile Encountered at the Boreholes
(between Surat Station and Bharuch Station)

Borehole	Depth, m		Description	SPT Values
	From	To		
BH-28	0.0	2.0	Medium dense grey silty fine to coarse sand with gravel	13
	2.0	4.0	Very stiff brown clayey silt	20-26
	4.0	16.0	Dense brown sandy silt	29-56
	16.0	25.0	Very dense grey silty medium to coarse sand	61-100+
	25.0	30.0	Very dense brown sandy silt	84-100+
	30.0	40.4	Very dense grey silty fine sand	78-100+
BH-29	0.0	2.0	Rock fragments with sandy silt matrix	100+
	2.0	2.5	Loose brown sandy silt with gravel	8
	2.5	5.0	Very stiff brown clayey silt	15-19
	5.0	5.5	Medium dense brown sandy silt with traces of gravel	30
	5.5	7.0	Dense grey silty fine sand	31
	7.0	15.0	Hard brown silty clay with traces of gravel	32-48
	15.0	26.0	Very dense grey silty medium to coarse sand intermixed with gravel	100+
	26.0	28.0	Hard brown clayey silt	81-100+
	28.0	40.4	Very dense brown sandy silt with traces of gravel	66-100+
BH-30	0.0	5.0	Firm to very stiff grey silty clay	7-27
	5.0	8.0	Medium dense brown sandy silt	24-30
	8.0	17.0	Very stiff to hard brown silty clay	22-45
	17.0	25.0	Very dense grey silty medium to coarse sand with gravel	100+
	25.0	40.5	Hard brown silty clay	78-100+
BH-31	0.0	5.0	Firm to stiff grey clayey silt	7-9
	5.0	11.5	Loose to dense grey fine sand	6-29
	11.5	14.0	Dense grey silty medium to coarse sand intermixed with gravel	31-37
	14.0	17.0	Hard brown silty clay	51-57
	17.0	19.0	Hard brown clayey silt	45-49
	19.0	33.0	Hard brown silty clay	54-100+
	33.0	40.2	Very dense grey silty fine to coarse sand	100+
BH-32	0.0	7.0	Medium dense to very dense brown sandy silt	18-98
	7.0	27.0	Hard brown silty clay	44-100+
	27.0	29.0	Very dense sandy silt with traces of gravel	100+
	29.0	40.3	Very dense grey silty fine sand	100+
BH-33	0.0	3.0	Medium dense brown sandy silt	17-22
	3.0	31.0	Very stiff to hard brown silty clay	24-100+
	31.0	35.0	Very dense grey silty fine sand	81-100+
	35.0	37.0	Very dense sandy silt with traces of gravel	100+
	37.0	40.3	Very dense grey silty fine sand	100+

6)Bharuch～Vadodara

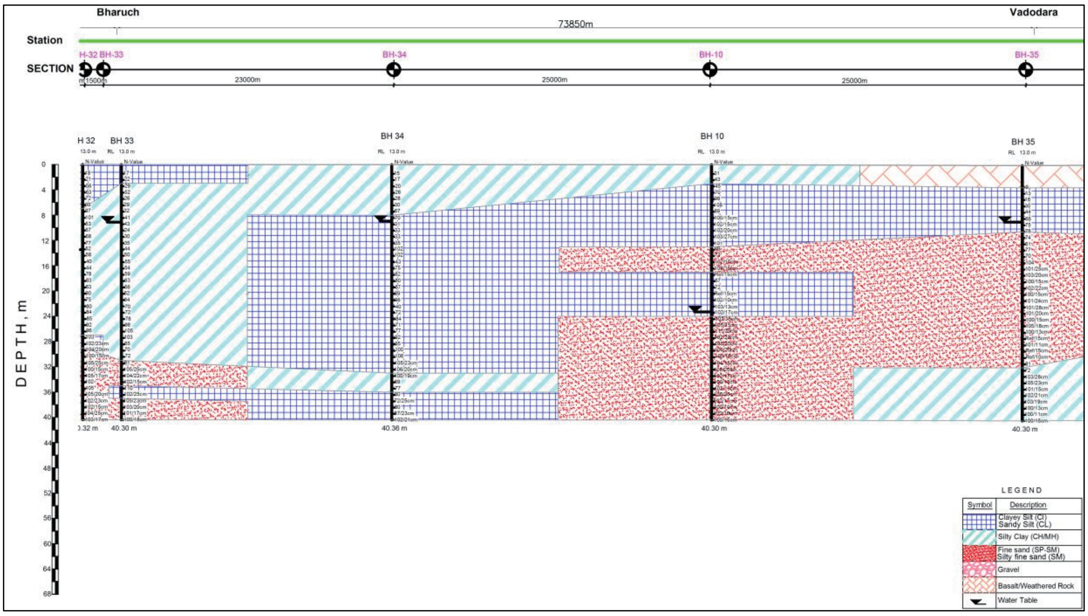


Figure 6.2-26 Boring survey point (between Bharuch Station. and Vadodara Station.)

Table 6.2-16 Stratigraphy Profile Encountered at the Boreholes
(between Bharuch Station and Vadodara Station)

Borehole	Depth, m		Description	SPT Values
	From	To		
BH-34	0.0	8.0	Very stiff to hard grey silty clay	15-67
	8.0	33.0	Hard brown clayey silt	31-100+
	33.0	36.0	Hard brown silty clay	77-100+
	36.0	40.4	Hard brown clayey silt	80-100+
BH-10	0.0	3.0	Hard grey silty clay	31 & 43
	3.0	13.0	Dense to very dense brown sandy silt	45-100+
	13.0	17.0	Very dense brown silty fine sand with traces of gravel	68-100+
	17.0	24.0	Very dense brown sandy silt with traces of gravel	67-100+
	24.0	40.3	Very dense brown silty fine to coarse sand with gravel	100+
BH-35	0.0	2.5	Fill: Silty sand with brick bats and boulders	-
	2.5	5.0	Loose to medium dense brown sandy silt	13-Sep
	5.0	9.0	Very stiff to hard brown clayey silt	16-66
	9.0	10.5	Very dense brown sandy silt	75-78
	10.5	32.0	Very dense brown silty fine sand	61-100+
	32.0	40.3	Hard grey silty clay	81-100+

7) Vadodara～Anand/Nadiad

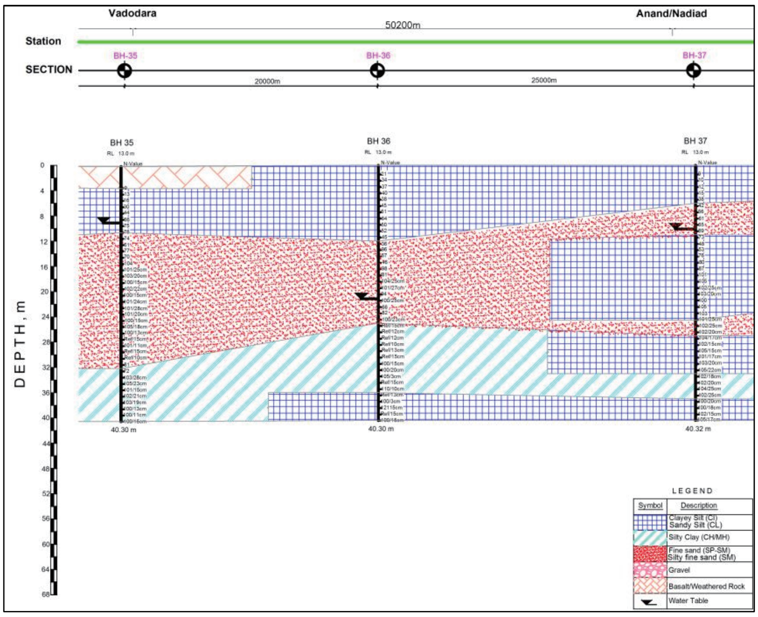


Figure 6.2-27 Boring Survey Point
(between Vadodara Station and Anand/Nadiad Station)

Table 6.2-17 Stratigraphy Profile Encountered at the Boreholes
(between Vadodara Station and Anand/Nadiad Station)

Borehole	Depth, m		Description	SPT Values
	From	To		
BH-36	0.0	6.0	Medium dense to dense grey sandy silt	21-40
	6.0	8.0	Hard brown clayey silt	45-61
	8.0	12.0	Very dense brown sandy silt	45-64
	12.0	24.5	Dense to very dense brown silty fine sand with traces of gravel	36-100+
	24.5	25.0	Very dense grey silty medium to coarse sand intermixed with gravel	100+
	25.0	29.0	Hard brown silty clay	100+
	29.0	36.0	Hard brown silty clay	100+
	36.0	40.3	Very dense brown sandy silt with gravel	100+

8) Anand/Nadiad～Ahmedabad

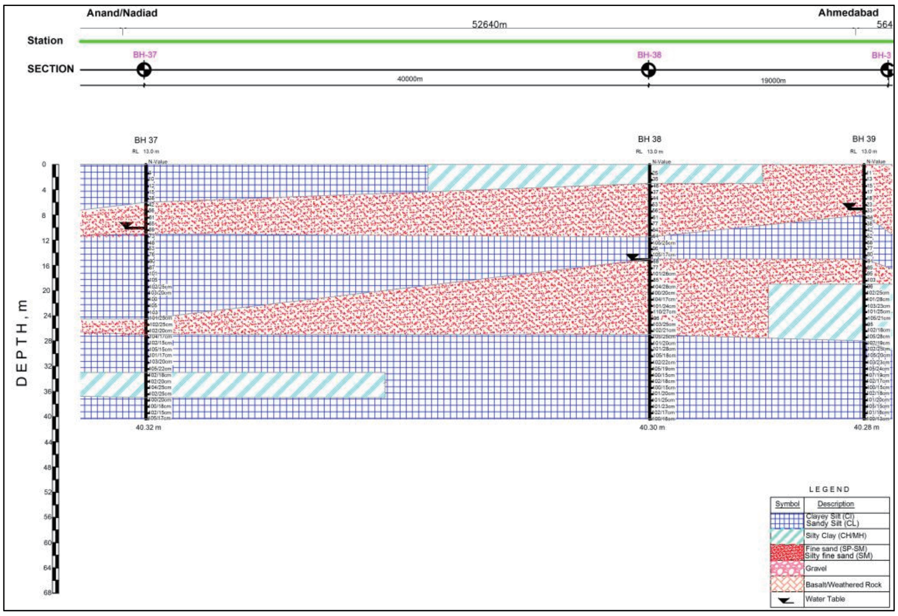


Figure 6.2-28 Boring Survey Point
(between Anand/Nadiad Station and Ahmedabad Station)

Table 6.2-18 Stratigraphy Profile Encountered at the Boreholes
(between Anand/Nadiad Station and Ahmedabad Station)

Borehole	Depth, m		Description	SPT Values
	From	To		
BH-37	0.0	6.0	Loose to dense brown sandy silt	9-38
	6.0	11.0	Dense to very dense brown silty fine sand with gravel	42-69
	11.0	12.0	Hard brown clayey silt with gravel	48-73
	12.0	21.0	Very dense brown sandy silt with gravel	53-100+
	21.0	24.5	Hard brown clayey silt	100+
	24.5	25.0	Very dense grey silty medium to coarse sand intermixed with gravel	100+
	25.0	27.0	Very dense brown silty fine sand	100+
	27.0	33.0	Hard brown clayey silt with gravel	100+
	33.0	37.0	Hard brown silty clay	100+
	37.0	40.3	Very dense brown sandy silt with traces of gravel	100+
BH-38	0.0	3.0	Very stiff to hard silty clay	25-35
	3.0	5.0	Dense brown silty fine sand with traces of gravel	37-46
	5.0	10.0	Dense to very dense brown fine sand with gravel	44-77
	10.0	11.5	Very dense brown silty fine sand with gravel	84
	11.5	15.0	Hard brown clayey silt	64-100+
	15.0	20.0	Very dense brown fine sand	68-100+
	20.0	27.0	Very dense grey silty fine to coarse sand with gravel	96-100+
	27.0	40.3	Hard brown clayey silt	100+

9)Ahmedabad～Sabarmati

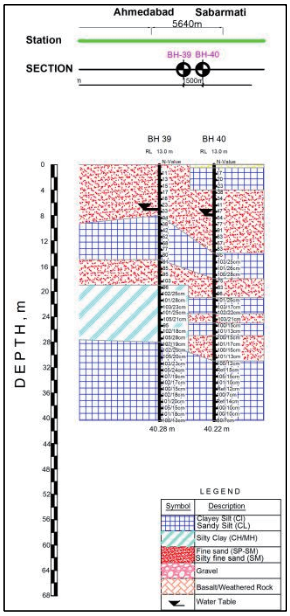


Figure 6.2-29 Boring Survey Point
(between Ahmedabad Station and Sabarmati Station)

Table 6.2-19 Stratigraphy Profile Encountered at the Boreholes
(between Ahmedabad Station and Sabarmati Station)

Borehole	Depth, m		Description	SPT Values
	From	To		
BH-39	0.0	8.0	Medium dense to dense brown silty fine to coarse sand	11-33
	8.0	13.0	Dense to very dense brown sandy silt	34-68
	13.0	15.0	Hard brown clayey silt	77-80
	15.0	18.0	Very dense brown silty fine to coarse sand with traces of gravel	85-95
	18.0	19.0	Very dense grey silty medium to coarse sand intermixed with gravel	100+
	19.0	28.0	Hard brown silty clay	95-100+
	28.0	33.0	Very dense brown sandy silt with gravel	100+
	33.0	37.0	Hard brown clayey silt with gravel	100+
	37.0	40.3	Very dense brown sandy silt with traces of gravel	100+
BH-40	0.5	4.0	Medium dense brown sandy silt	17-23
	4.0	14.0	Dense to very dense brown silty fine to coarse sand with gravel	38-91
	14.0	18.0	Hard brown clayey silt	95-100+
	18.0	21.0	Very dense brown silty fine sand with gravel	75-96
	21.0	23.5	Hard brown clayey silt	100+
	23.5	25.0	Very dense brown silty fine to coarse sand with gravel	100+
	25.0	27.0	Hard brown clayey silt	100+
	27.0	31.0	Very dense brown silty fine sand with gravel	100+
	31.0	33.0	Hard brown clayey silt	100+
	33.0	40.2	Very dense brown silty fine to coarse sand with traces of gravel	100+

(6)Photograph of Rock Core Samples

Figure 6.2-30 Photograph of Rock Core Sample (BH-No.24)

(7) Summary of Geological Date Collection

These helped to collect the Geological data of DFC.
It is comprised of wide ballast layer between Mumbai and Bilimora.
After Bilimora, it is mixed lot of layer.
According to 6.2-1, Black Cotton Soil is estimated to have the depth from 4m to 20m.
And these data should be considered for deigning the basement and pia type structures, avoiding the settlement and the influence of the other around structures.
Black Cotton soil is existing on the entire HSR route except from Ahmedabad to Sabarmati. Therefore needs arises to gather more information about the Black Cotton Soil along with HSR route.

6.3 Hydrological Condition

6.3.1 River System

(1) Basins related to HSR route

In India, river basin is divided into 25 basins as the basic hydrological units for water resource planning and management under Water Resource Information System project in India (India-WRIS) developed by Central Water Commission (CWC) and Indian Space Research Organization (ISRO).
Based on the classification defined by India-WRIS project, the river basin related to planning HSR route between Mumbai -Ahmedabad falls in West flowing rivers from Tapi to Tadri, Tapi Basin, Narmada Basin, Mahi Basin and Sabarmati Basin.

1) West flowing rivers from Tapi to Tadri

The basin covers parts of Maharashtra, Gujarat, Karnataka, Goa and Union Territory of Dadra & Nagar Haveli and Daman & Diu having an area of 55,940 Sq.km with maximum length and width of 796 km and 137 km. It spreads between 72°33' to 75°14' east longitudes and 14°17' to 21°13' north latitudes. The basin is bounded by Gujarat plains on the north, by Western Ghats on north-east and east, and by Arabian Sea in the west and south.

Various rivers in the basin does not meet into one forming a major stream, rather they flow independently and drains directly into the Arabian Sea. The independent rivers at further North of Mumbai in the basin are Ulhas River, Vaitarna River, Dama Ganga, Kolak River, Par River, Aurange River, Kaveri River, Ambica River, Rurna River, Mindhola River, mainly.

2) Tapi Basin

Tapi basin extends over states of Madhya Pradesh, Maharashtra and Gujarat having an area of 65,145 Sq.km with a maximum length and width of 534 & 196 km. It lies between 72°33' to 78°17' east longitudes and 20°9' to 21°50' north latitudes. Situated in the Deccan plateau, the basin is bounded by the Satpura range on the north, by the Mahadev hills on the east, by the Ajanta Range and the Satmala hills on the south and by the Arabian Sea on the west. The hilly region of the basin is well forested while the plains are broad and fertile areas suitable for cultivation.

3) Narmada Basin

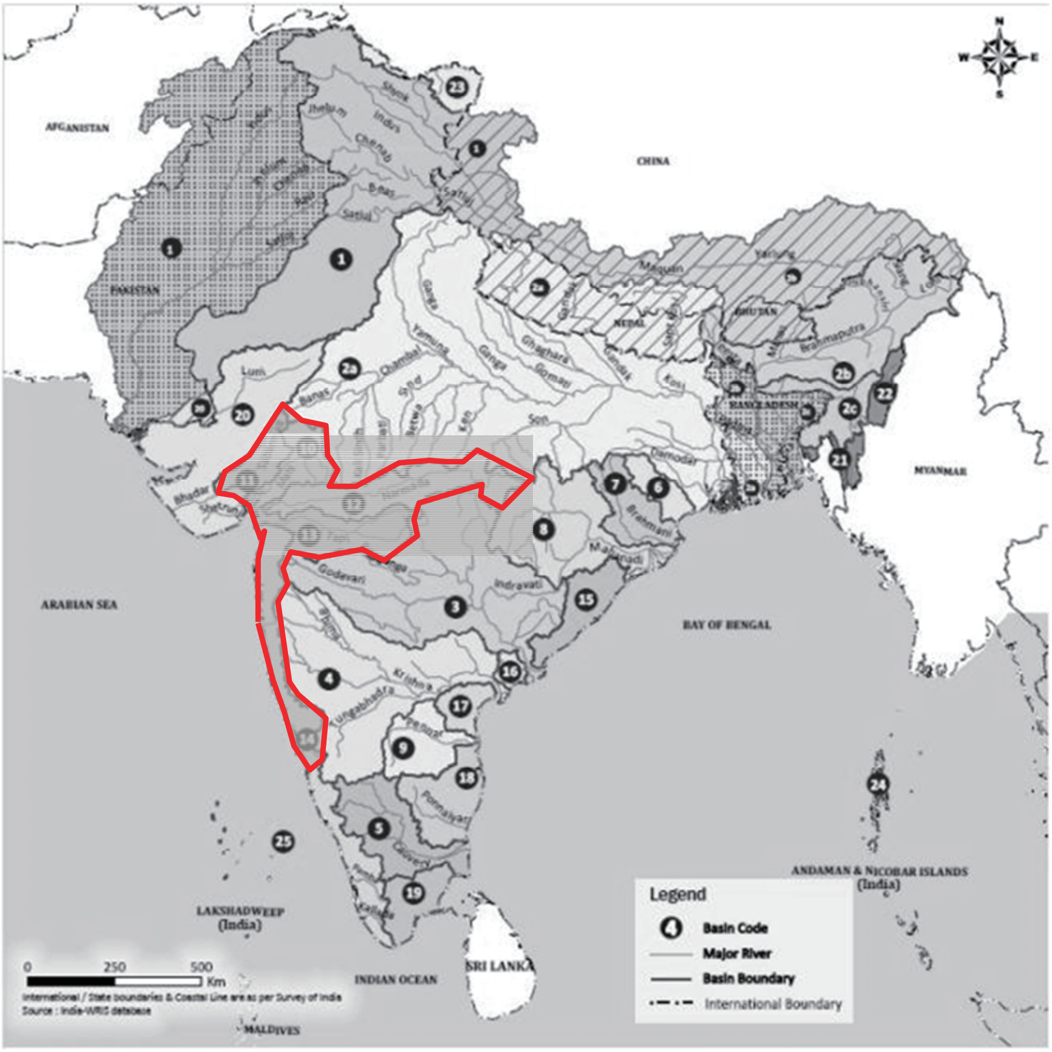
Narmada basin extends over states of Madhya Pradesh, Gujarat, Maharashtra and Chhattisgarh having an area of 98,796 Sq.km which is nearly 3% of the total geographical area of the country with maximum length and width of 923 & 161 km. It lies between 72°38' to 81°43' east longitudes and 21°27' to 23°37' north latitudes. It is bounded by the Vindhyas on the north, by the Maikala range on the east, by the Satpuras on the south and by the Arabian Sea on the west. The hilly regions are in the upper part of the basin, and lower middle reaches are broad and fertile areas well suited for cultivation.

4) Mahi Basin

Mahi basin extends over states of Madhya Pradesh, Rajasthan and Gujarat having total area of 34,842 Sq.km with a maximum length and width of about 330 km and 250 km. It lies between 72°21' to 75°19' east longitudes and 21°46' to 24°30' north latitudes. It is bounded by Aravalli hills on the north and the north-west, by Malwa Plateau on the east, by the Vindhyas on the south and by the Gulf of Khambhat on the west.

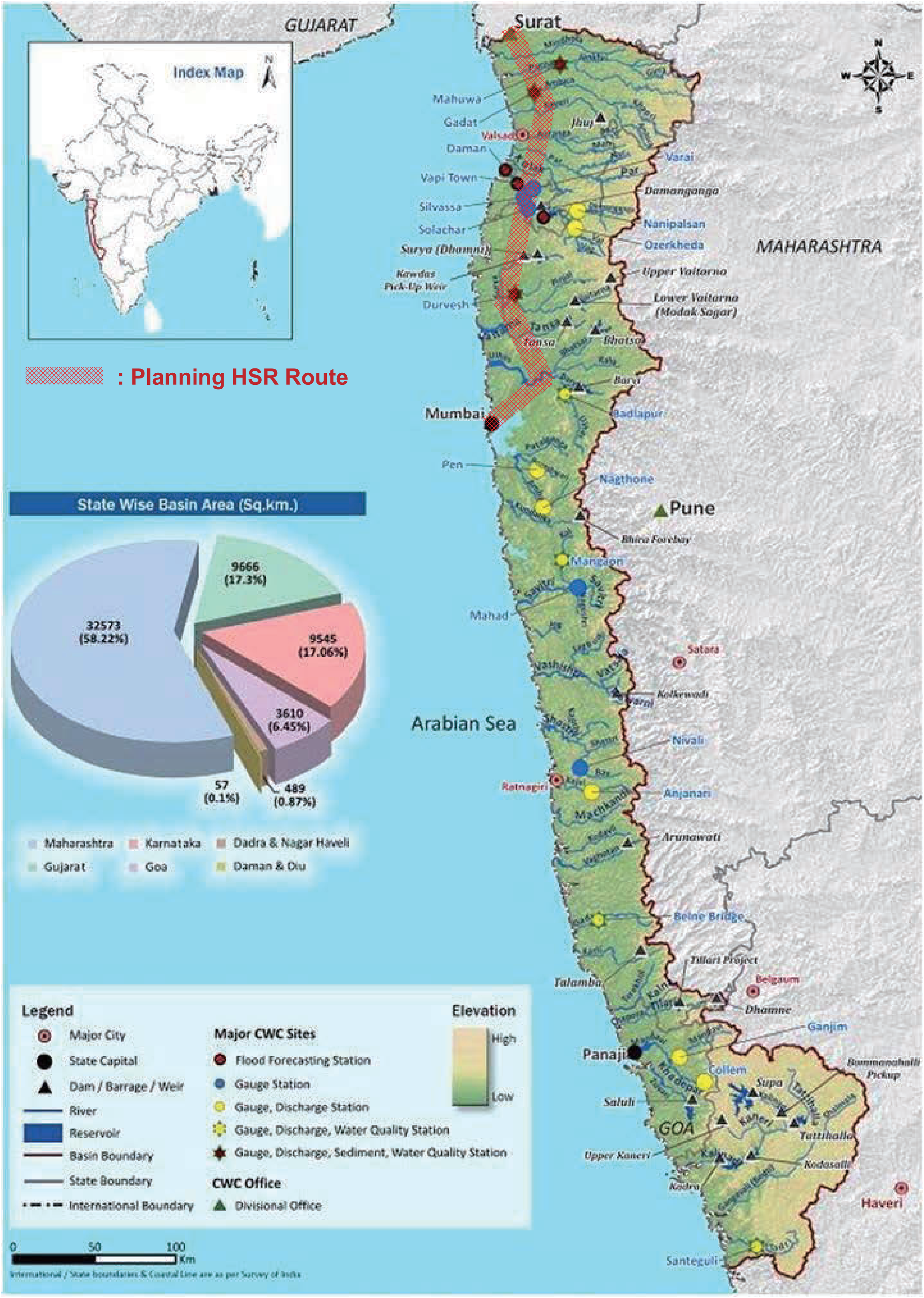
5) Sabarmati basin

Sabarmati basin extends over states of Rajasthan and Gujarat having an area of 21,674 Sq.km with maximum length and width of 300 km and 150 km. It lies between 70°58' to 73°51' east longitudes and 22°15' to 24°47' north latitudes. The basin is bounded by Aravalli hills on the north and north-east, by Rann of Kutch on the west and by Gulf of Khambhat on the south. The basin is roughly triangular in shape with the Sabarmati River as the base and the source of the Vatrak River as the apex point.



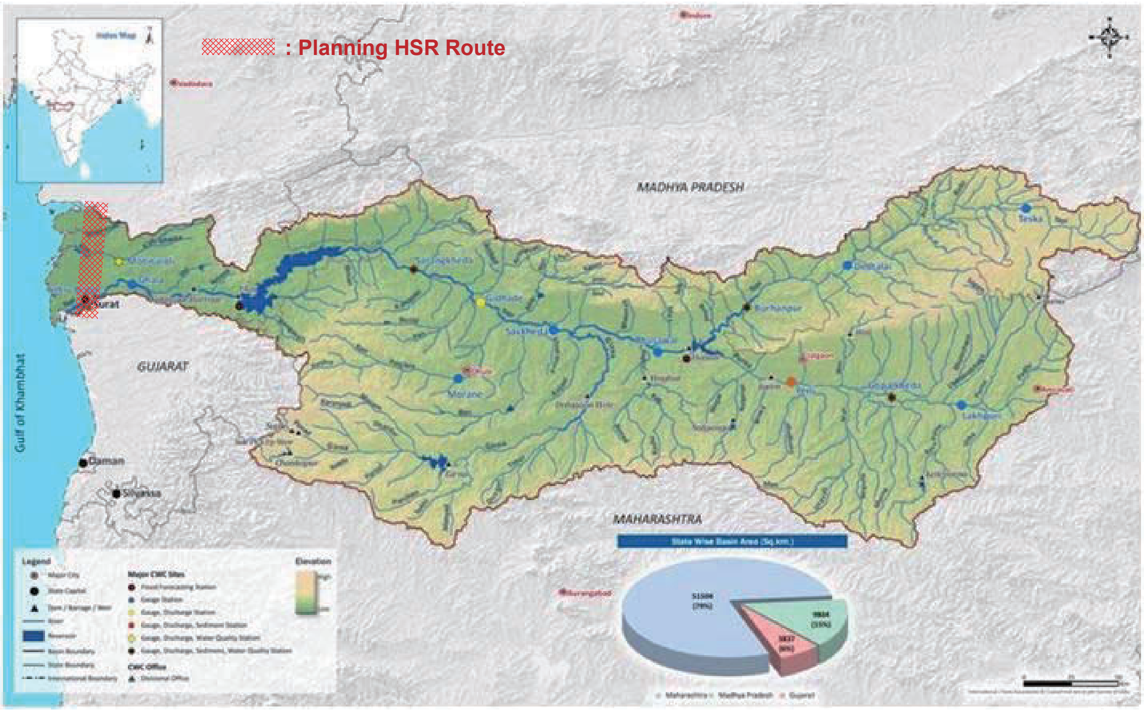
Source: River Basin Atlas of India

Figure 6.3-1 Basins Related to HSR Route



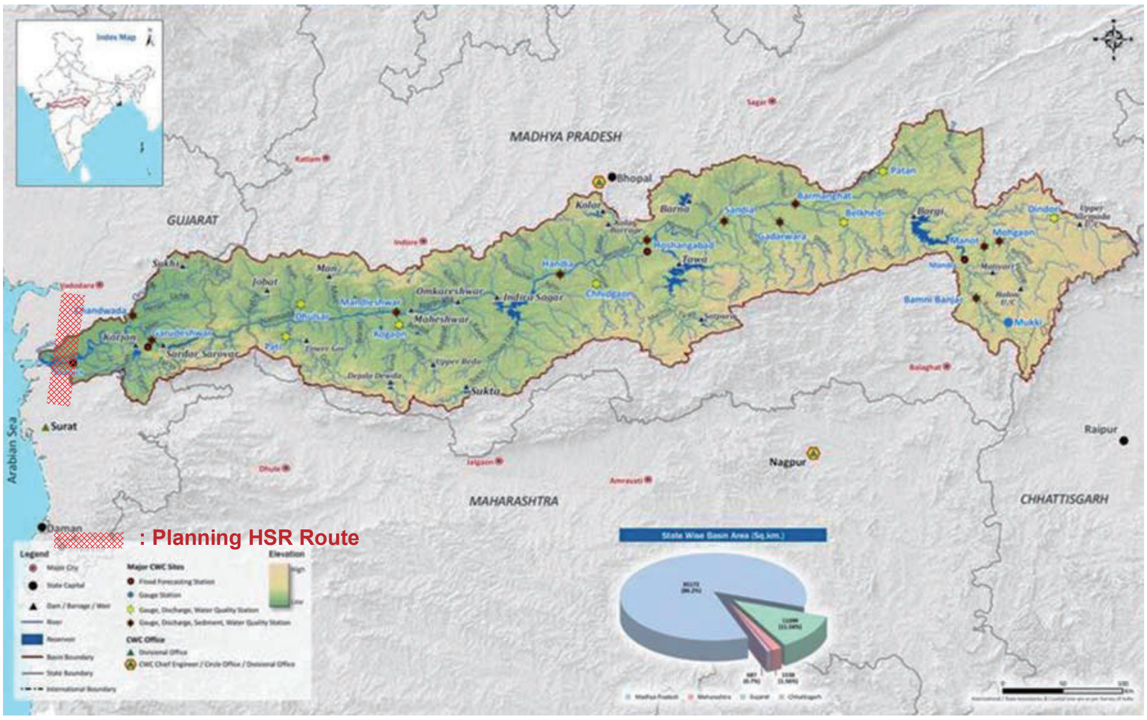
Source: River Basin Atlas of India

Figure 6.3-2 Basin of West Flowing Rivers from Tapi to Tadri



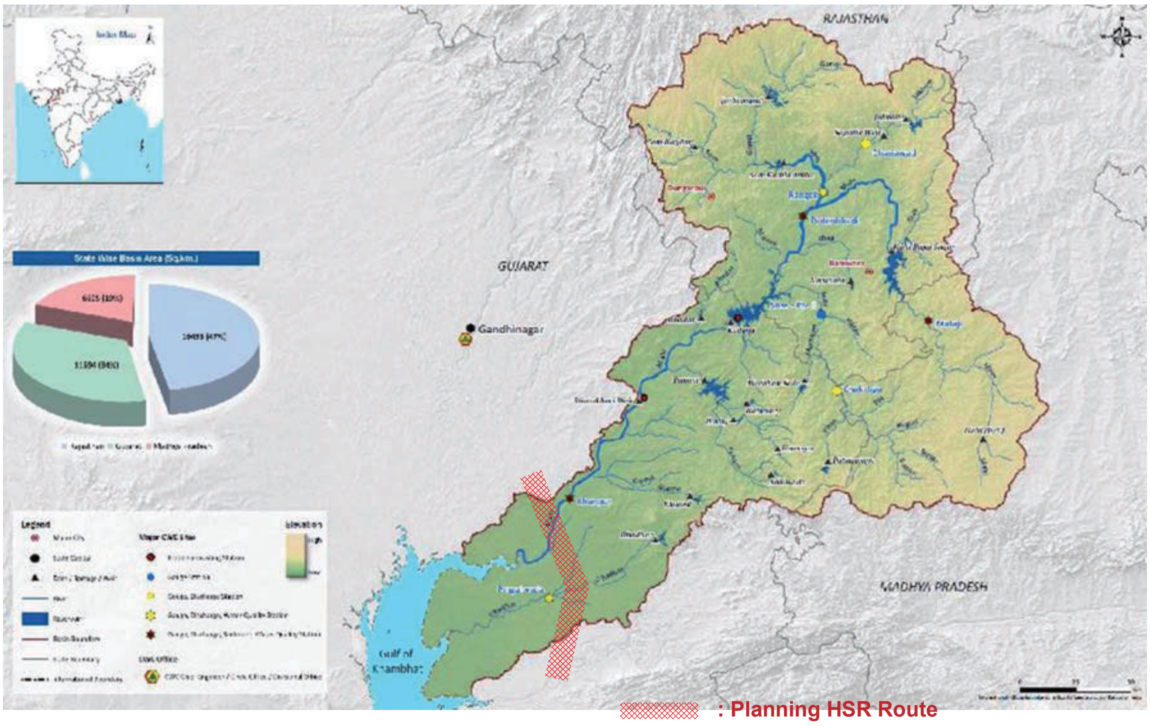
Source: River Basin Atlas of India

Figure 6.3-3 Tapi Basin



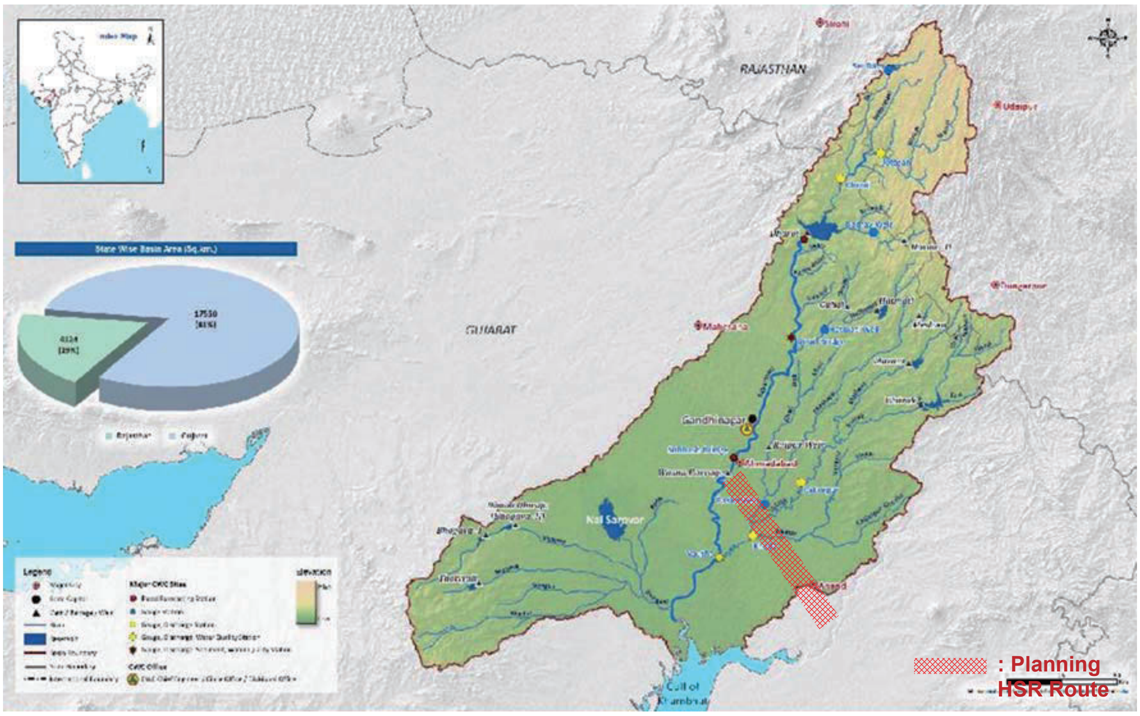
Source: River Basin Atlas of India

Figure 6.3-4 Narmada Basin



Source: River Basin Atlas of India

Figure 6.3-5 Mahi Basin



Source: River Basin Atlas of India

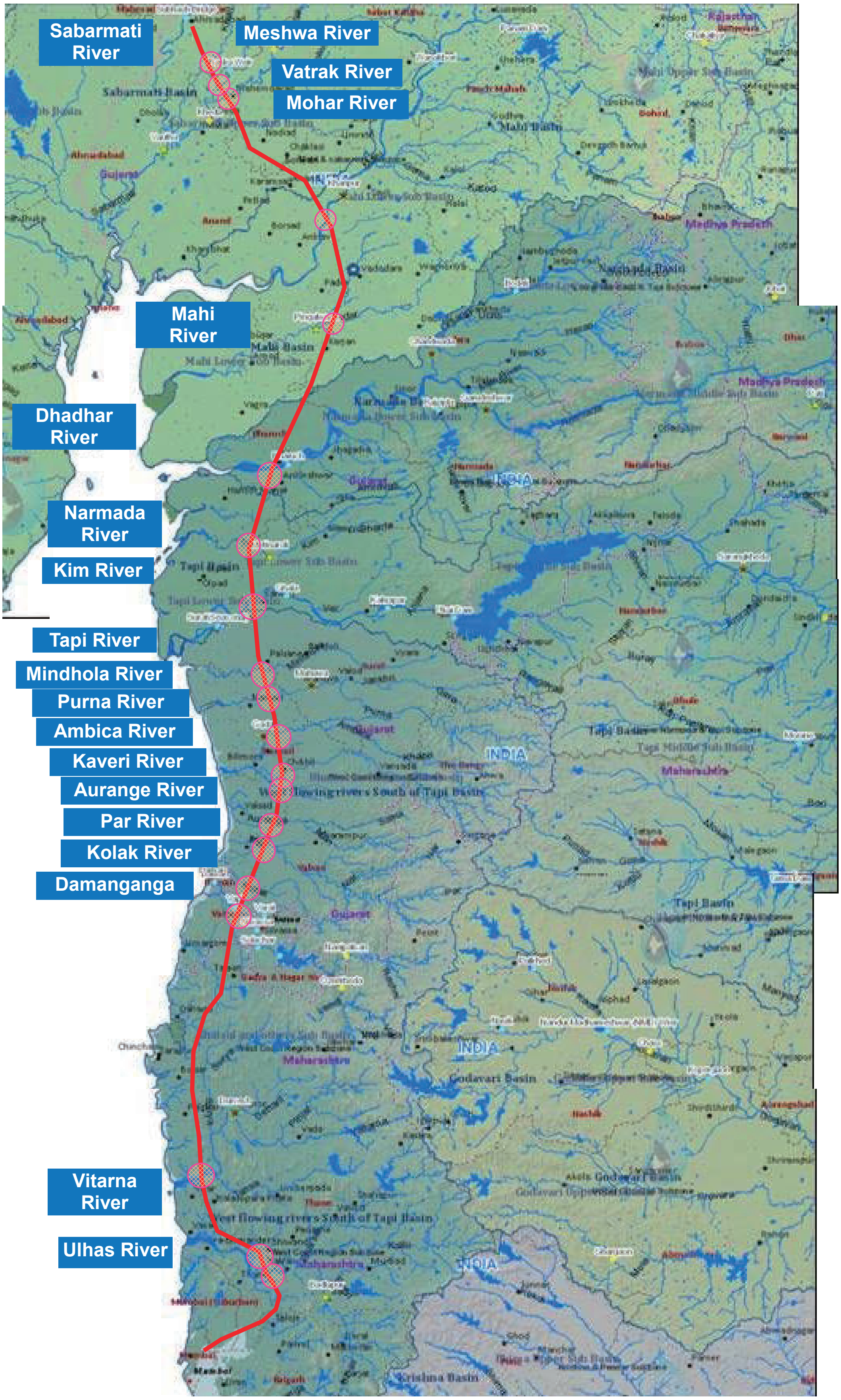
Figure 6.3-6 Sabarmati Basin

The basins are composed from various kinds of independent rivers and its tributaries including several large rivers which catchment area and river length is large.
The scale of large rivers such as catchment area, river length and the chainage of HSR route at the crossing, the distance from river mouth to HSR crossing, the river width at crossing point are shown in Table 6.3-1.

Table 6.3-1 Large Rivers Crossing with HSR Route

Basin	Name	Catchment Area (km2)	Length of the River (km)	Chainage of HSR route at Crossing (km)	Distance from River mouth (km)	River width at Crossing (m)
West flowing rivers from Tapi to Tadri	Ulhas River	4,637	122	28.0	38	400
	Branch of Ulhas River			37.6	28	100
	Vaitarna River (S)	3,637	120	71.4	9	400
	Vaitarna River (N)			72.6	9	800
	Daman Ganga	2,318	131	166.6	18	300
	Kolak River	584	50	175.5	17	100
	Par River	907	51	190.1	10	300
	Aurange River	Not obtained		198.0	13	200
	Kaveri River (S)	Not obtained		212.6	20	80
	Kaveri River (N)			214.8	22	100
	Ambica River	2,715	136	228.1	31	200
	Purna River	2,431	180	240.3	29	150
	Mindhola River	1,518	105	249.8	36	50
Tapi	Tapi River	63,859	724	275.7	47	500
	Kim River	1,286	107	292.5	45	50
Narmada	Narmada River	98,796	1,312	320.1	42	1000
Mahi	Dhadhar River	3,423	142	372.3	93	30
	Mahi River	31,419	583	416.0	88	600
Sabarmati	Mohar River	Tributary of Sabarmati River		461.8	120	30
	Vatrak River			472.0	118	200
	Meshwa River			475.4	119	100
	Sabarmati River	21,674	371	-	139	300

Note) Based on the MLIT Proposed Route / ALT1 Route.
Source: India-WRIS Wiki, etc



Source: India-WRIS wiki

Figure 6.3-7 Large Rivers Crossing with HSR Route

(2) Features of the Rivers

The feature of rivers such as geographical condition, tributaries at upper reaches and the condition at HSR crossing point are different in each rivers. It is also effected from various factor such as existing bridges at neighbor and dams located at upper reaches of the river.
The one of important feature is the water discharge such as maximum discharge and frequency of flood in past to be obtained from observed data at CWC hydrological station for some major rivers.
The feature of major rivers such as Ulhas River, Vaitarna River, Daman Ganga, Tapi River, Narmada River, Mahi River and Sabarmati River is summarized.

a) Ulhas River

・Geographical feature of Ulhas River

The Ulhas River is one of the West Flowing Rivers in Maharashtra falling into the Arabian Sea. The boundary of the basin consists of the main Sahyadri hills on the East, Westerly off shoots on the North and South and on the West, a narrow opening at the end leading to the sea. The Ulhas basin lies between North latitudes of 18º 44' to 19º 42' and East longitudes of 72º 45' to 73º 48'.

The Ulhas drains an area of 4,637 sq km which lies completely in Maharashtra. The Thane, Raigad and Pune districts fall in the basin. The Ulhas rises from Sahyadri hill ranges in the Raigad district of Maharashtra at an elevation of 600 meter above M.S.L. The total length of this West flowing river from its origin to its outfall in to the Arabian Sea is 122 km.

The important tributaries of the Ulhas River are Pej, Barvi, Bhivapuri, Murbari, Kalu, Shari, Bhasta, Salpe, Poshir and Shilar. The Kalu and Bhasta are the major right bank tributaries which together accounts for 55.7% of the total catchment area of Ulhas.

・Major dams across Ulhas River

Bhatsa dam is situated across Bhasta River and Barvi dam is situated across Barvi River respectively, which are tributary of Ulhas River at upper reaches.
According to obtained information, future plan such as two dams across Kalu River and one dam across Ulhas River have been proposed in past, although the implementation schedule is unsure.

Table 6.3-2 Major Dams across Ulhas River and Ttributaries

Name	Location	Purpose	Constructed Year	Dam Type	Gross Storage Capacity	Spillway Capacity
Bhatsa Dam	In Bhasta River at 48km up- stream from the confluence of kalu River	Irrigation and water supply	1983	Earthfill / Gravity	976 Mm3	5,342 m3/s
Barvi Dam	In Barvi River at 18km up-stream from the confluence of Ulhas River	Water supply	1978	Earthfill	179 Mm3	1,585 m3/s

(Source: India-WRIS wiki, National Register of Large Dams-2009, etc)

・CWC Hydrological Observation Station

Badlapur station is situated at 6km upstream from the confluence of Barvi tributary in Ulhas River. Badlapur station observes Gauge, Discharge and Water quality. The discharge observation at the station was started in 1981.
According to Integrated Hydrological Data Book issued by Central Water Commission, the maximum discharge at the station is observed as 4,440m3/s in 16.07.1988.

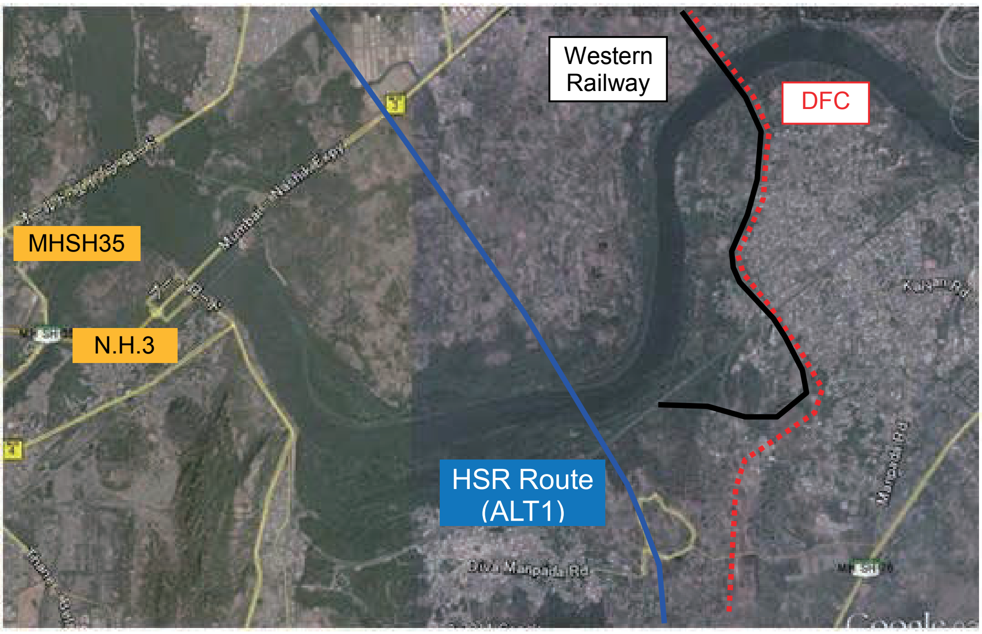
・Neighbor bridges in Ulhas River

Existing and Planned Railway bridge / Road bridge at around HSR route (ALT1) crossing with the River are as follows.

Table 6.3-3 Neighbor Bridges in Ulhas River

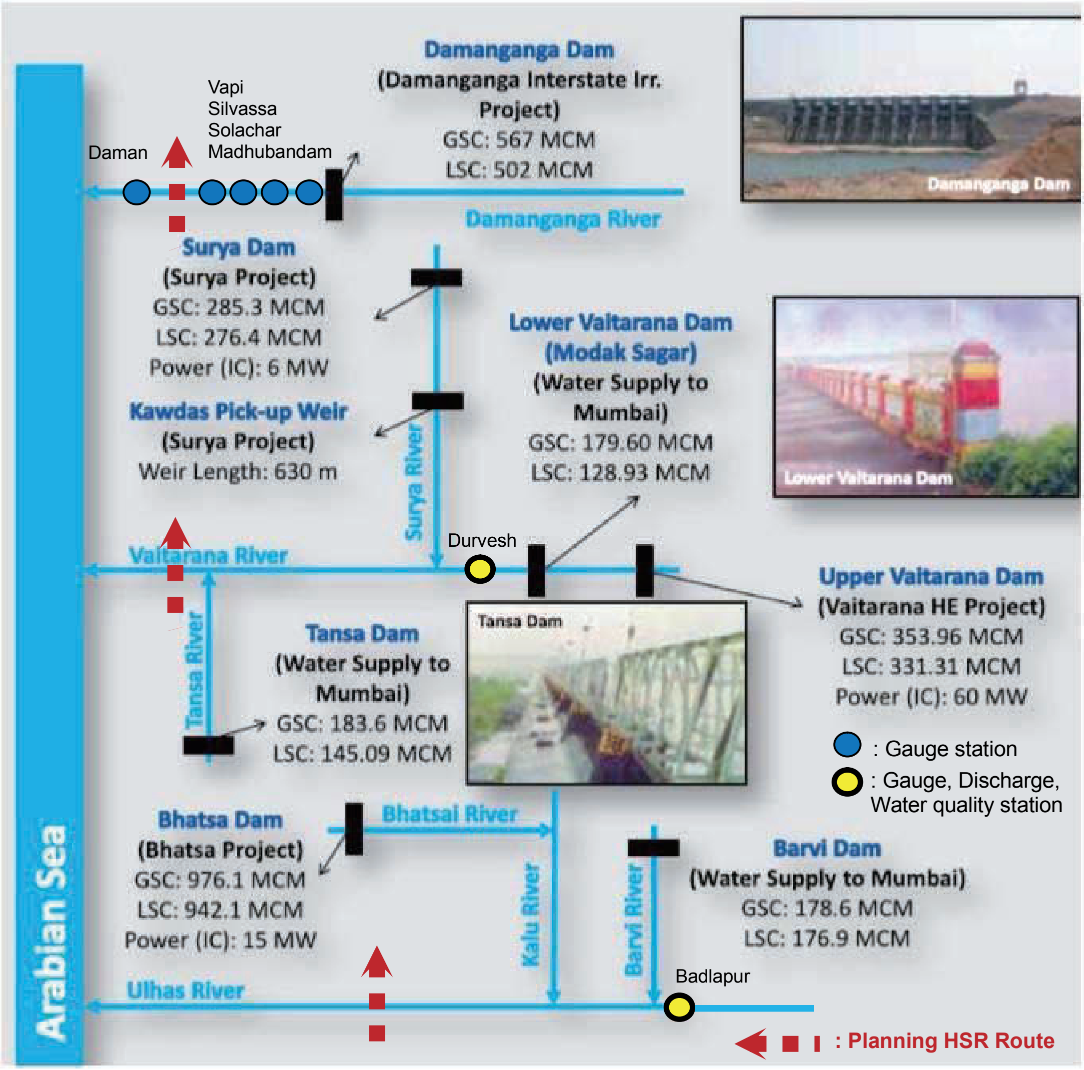
Name of Railway / Road	Distance from HSR ALT1 (km)	Remarks
N.H.3	-5.8 (DN)	
MHSH35	-7.5 (DN)	
N.H.8	-23.1 (DN)	
Western Railway (Bhayandar Bridge)	-30.3 (DN)	Bridge No.73 28x48.5m + 1x20.6m Girder : PSC Girder, Foundation : Well
		Bridge No.75 11x48.5m Girder : PSC Girder, Foundation : Well
Central Railway (Ulhas Bridge)	5.0 (UP)	
DFC (planned)	5.0 (UP)	Span& Length : 6x79.98m (480m) Girder : Open Web Welded Through Truss, Foundation : Well / Pile
N.H.222	10.7 (UP)	

Source: Study Team



Source: Google Earth

Figure 6.3-8 HSR Crossing Point in Ulhas River



Source: River Basin Atlas of India

Figure 6.3-9 River Flow Line Diagram for West Flowing Rivers from Tapi to Tadri

・<u>HSR crossing point with Ulhas River</u>

- HSR route crosses over Ulhas River at approx. 38 km upstream from mouth of the River.
-The width of river at HSR crossing point is approx. 400m.
- The river forms meandering shape with sharp curve at up and down streams.
-Flood plain extends widely at both side of the river. The land use of waterfront at nearby HSR route is mostly agriculture or natural forest.
-At south of the river, HSR cross over western railway line cross which is situated south-west to north-east direction.
-It is reference information from DFC project that the designed water discharge at DFC route crossing is 11,200 m3 in approximate. Also, the designed water depth from River Bed to High Flood Level at DFC route crossing is 9m in approximate.

b) Vitarma River

・Geographical feature of Vitarna River

The river Vaitarna originates from hilly terrain of Maharashtra at Trimbak in Nasik district. After running for 120 km in Maharashtra towards west, it falls into the Arabian Sea. The catchment area of the basin is 3,637 sq.km. This drainage area is located between east longitudes of 72° 45' and 73° 35' and north latitudes of 19° 30' and 20° 20'. The main tributaries of this river are Pinjal, Garjal, Surya, Daharji and Tansa. There are some irrigation projects under construction namely Surya and Wandri on the tributaries of the Vaitarna river.

・Major dams across Vitarna River

Two dams are situated across Vaitarna River at upper reaches, namely Upper Vaitarna dam and Lower Vaitarna dam. Also Surya dam is situated across Surya River and Tansa dam is situated across Tansa River, which are tributary of Vaitarna River respectively.

Middle Vaitarna Dam is under construction, which will be the second tallest dam in Maharashtra, India, planned to be built on the Vaitarna river in Thane's Kochale village by 2012.

According to obtained information, future plan such as two dams across Pinjai River have been proposed in past, although the implementation schedule is unsure.

Table 6.3-4 Major Dams across Vaitarna River and Tributaries

Name	Location	Purpose	Constructed Year	Dam Type	Gross Storage Capacity	Spillway Capacity
Upper Vaitalna Dam	In Vaitarna River at 164km up- stream from the mouth of River	Irrigation, Hydro-electric	1973	Earthen / Masonry	332 Mm3	1,440 m3/s
Lower Vaitalna Dam (Modak Sagar)	In Vaitarna River at 107km up- stream from the mouth of River	Drinking, Water supply	1954	Masonry	205 Mm3	5,660 m3/s
Surya Dam (Dhamni Dam)	In Surya River at 50km up-stream from the confluence of Vaitarna River	Hydro-elecric, Irrigation	1987	Masonry	285 Mm3	2,696 m3/s
Kawdas Pick up Weir	In Surya River at XXkm up-stream from the confluence of Vaitarna River	Irrigation	-	Earthen	14 Mm3	-
Tansa Dam	In Tansa River at 54km up-stream from the confluence of Vaitarna River	Drinking, Water supply	1892	Earthen & Masonry	209 Mm3	1,189 m3/s

(Source: India-WRIS wiki, National Register of Large Dams-2009, etc)

・<u>CWC Hydrological Observation Station</u>
Durvesh station is situated at 14km upstream from the confluence of Surya tributary in Vaitarna River. Durvesh station observes Gauge, Discharge Sediment and Water quality. The discharge observation at the station was started in 1971.
According to Integrated Hydrological Data Book issued by Central Water Commission, the maximum discharge at the station is observed as 9,100m3/s in 17.09.1998.

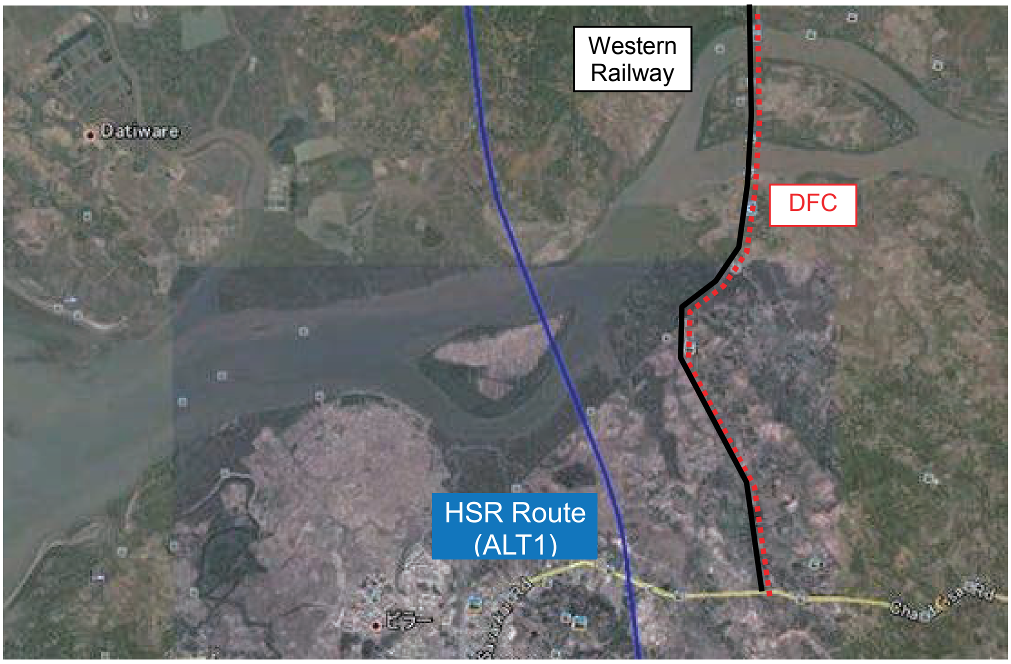
・<u>Neighbor bridges in Vitarna River</u>
Existing and planned Railway bridge / Road bridge at around HSR route (ALT1) crossing with the River are as follows.

Table 6.3-5 Neighbor Bridges in Vaitarna River

Name of Railway / Road	Distance from HSR ALT1 (km)	Remarks
Western Railway	4.4 (UP)	Bridge No.92, 19x18.02m + 1x8.86m Girder : RIVT PG, Foundatin : Pile
	5.2 (UP)	Bridge No.93 22x18.02m Girder : RIVT PG, Foundatin : Pile
DFC (Planned)	4.4 (UP)	Bridge No.92 (South), Span& Length : 20x19 (380m) Girder : PSC Box, Foundation : -
DFC (Planned)	5.2 (UP)	Bridge No.93 (North) Span& Length : 23x19 (437m) Girder : PSC Box, Foundation : -

Source: Study Team

・<u>HSR crossing point with Vaitarna River</u>
-HSR route crosses over Vaitarna River at approx. 9 km upstream from mouth of the River.
-The width of river at HSR crossing point is approx. 400m at south branch and apporx. 800m at north branch.
-No existing bridge is located at downstream of the river. Hence, HSR bridge will be nearest to the mouth of the river.
-HSR route pass a sandbank in center of the river. Another sandbank is also located at 4km upstream where the Western railway line is crossed. Hence, the direction of river flow in the section would be un-regular.
-Flood plain extends widely at both side of the river. The land use of waterfront at nearby HSR route is mostly agriculture or natural forest. Numerous small boats at anchor along the river are seen.
-At south of the river, HSR cross over western railway line cross which is situated south-west to north-east direction.
-It is reference information from DFC project that the designed water depth from River Bed to High Flood Level at DFC route crossing is 13m in approximate.



Source: Google Earth

Figure 6.3-10 HSR Crossing Point in Vaitarna River

c) Daman Ganga

・Geographical feature of Damanganga River

The Daman ganga originates from Sahyadri hills near Valveri village in Paint Taluka of Nasik district in Maharashtra State. It travels a distance of 131.30 km. before it drains to Arabian Sea at Daman. Daman ganga along with its tributaries mainly flows through the hilly areas of Maharashtra, Gujarat and Union Territory Dadra and Nagar Haveli and Daman. The major tributaries of the Daman ganga river are Dawan, Shrimant, Val, Rayate, Lendi, Wagh, Sakartong, Roshni, Dudhni and Piperiya. The basin is situated between 190 54'to 200 28'North latitude and 720 50'to 730 38'East longitude. The total drainage area of the basin is 2,318 sq.km.

・Major dams across Damanganga River

Damanganga dam is situated across Damanganga at middle reaches.
According to obtained information, future plan of two dams at upper reach of Damanganga have been proposed in past, although the implementation schedule is unsure.

Table 6.3-6 Major Dams across Damanganga and Tributaries

Name	Location	Purpose	Constructed Year	Dam Type	Gross Storage Capacity	Spillway Capacity
Daman ganga Dam	In Daman ganga at 42km up-stream from the mouth of River	Irrigation, water supply and power generation	1998	Compo-site	567 Mm3	22,040 m3/s

(Source: WRD Water Resources)

・CWC Hydrological Observation Station

-Nanipalsan station is situated at 13km upstream from the confluence of Vag tributary in Damanganga. Nanipalsan station observes Gauge and Discharge. The discharge observation at the station was started in 1982.

According to Integrated Hydrological Data Book issued by Central Water Commission, the maximum discharge at the station is observed as 9,500m3/s in 03.08.2004.

-Ozerkheda station is situated at 9km upstream from the confluence of Damanganga in Vag River. Ozerkheda station observes Gauge and Discharge. The discharge observation at the station was started in 1972.

According to Integrated Hydrological Data Book issued by Central Water Commission, the maximum discharge at the station is observed as 5,420m3/s in 04.08.2004.

-Gauge station such as Daman, Vapi, Silvassa, Solachar, Madhubandam is situated between the mouth of Damanganga and Madhubandam respectively.

・Neighbor bridges in Damanganga River

Existing and planned Railway bridge / Road bridge at around HSR route (ALT1) crossing with the River are as follows.

Table 6.3-7 Neighbor Bridges in Damanganga

Name of Railway / Road	Distance from HSR ALT1 (km)	Remarks
N.H.8	-4.4 (DN)	
Western Railway	-4.9 (DN)	
DFC (Planned)	-4.9 (DN)	Bridge No.19, Span& Length : 6x48.5m (291m) Girder : Open Web Welded Through Truss Foundation : Open Foundation with Micro (Anchor) Piles
Saily Rd	8.6 (UP)	

Source: Study Team

・HSR crossing point with Damanganga River

-HSR route crosses over Damanganga at approx. 18 km upstream from mouth of the River.
-The width of river at HSR crossing point is approx. 300m.
-Several sandbank are seen at up and down stream of HSR crossing point.
- The land use of waterfront at nearby HSR route is mostly natural forest.
-It is reference information from DFC project that the designed water discharge at DFC route crossing is 16,600 m^3 in approximate. Also, the designed water depth from River Bed to High Flood Level at DFC route crossing is 14m in approximate.

Source: Google Earth

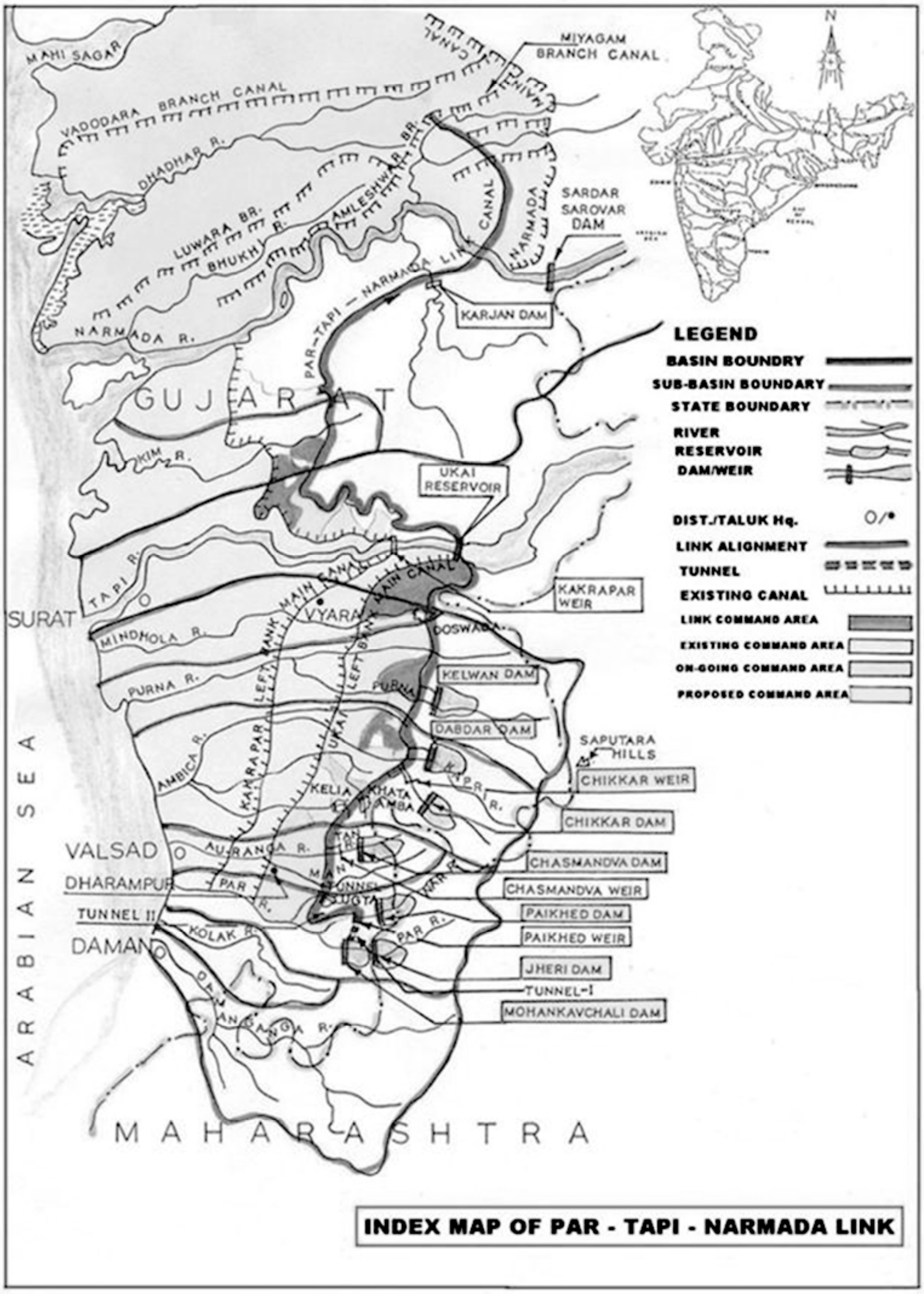
Figure 6.3-11 HSR Crossing Point in Damanganga

※Par Tapi Narmada Link

There is a plan of “Par Tapi Narmada Link” proposed by NWDA, which transfers surpluses available between Par and Tapi to water deficit areas in north Gujarat. It will transfer 1,350 Mcum of water through a canal of length 401 km. by gravity. The total enroute irrigation benefits envisaged are 1.63 lakh hectares in Gujarat by utilizing 460 Mcum and 190 Mcum for meeting the transmission losses. In addition to this, about 700 Mcum will also be provided to Saurashtra and Kutch areas of Gujarat. Besides this, there is also a provision for generation of about 32.5 MW of power.

However, it holds an environmental issue. The seven proposed reservoirs in this link would submerge an area of 7,559 ha of which 3,572 ha is forestland. Apart from this, 14,832 people and 9,029 livestock would be affected by the submergence. Provisions have been made to resettle the affected persons by providing them with attractive packages. Provision has also been made for compensatory afforestation.

The implementation of the project has not been confirmed.



Source: National Water Development Agency web-site

Figure 6.3-12 Map of Par Narmada Tapi Link

d) Tapi River

・<u>Geographical feature of Tapi River</u>

Tapi River is the second largest westward draining river of the Peninsula. It originates near Multai reserve forest in Betul district of Madhya Pradesh at an elevation of 752 m. The total length of the river from origin to outfall into the Arabian Sea is 724 km and its important tributaries are the Suki, the Gomai, the Arunavati and the Aner which joins it from right, and those joining from left are the Vaghur, the Amravati, the Buray, the Panjhra, the Bori, the Girna, the Purna, the Mona and the Sipna.

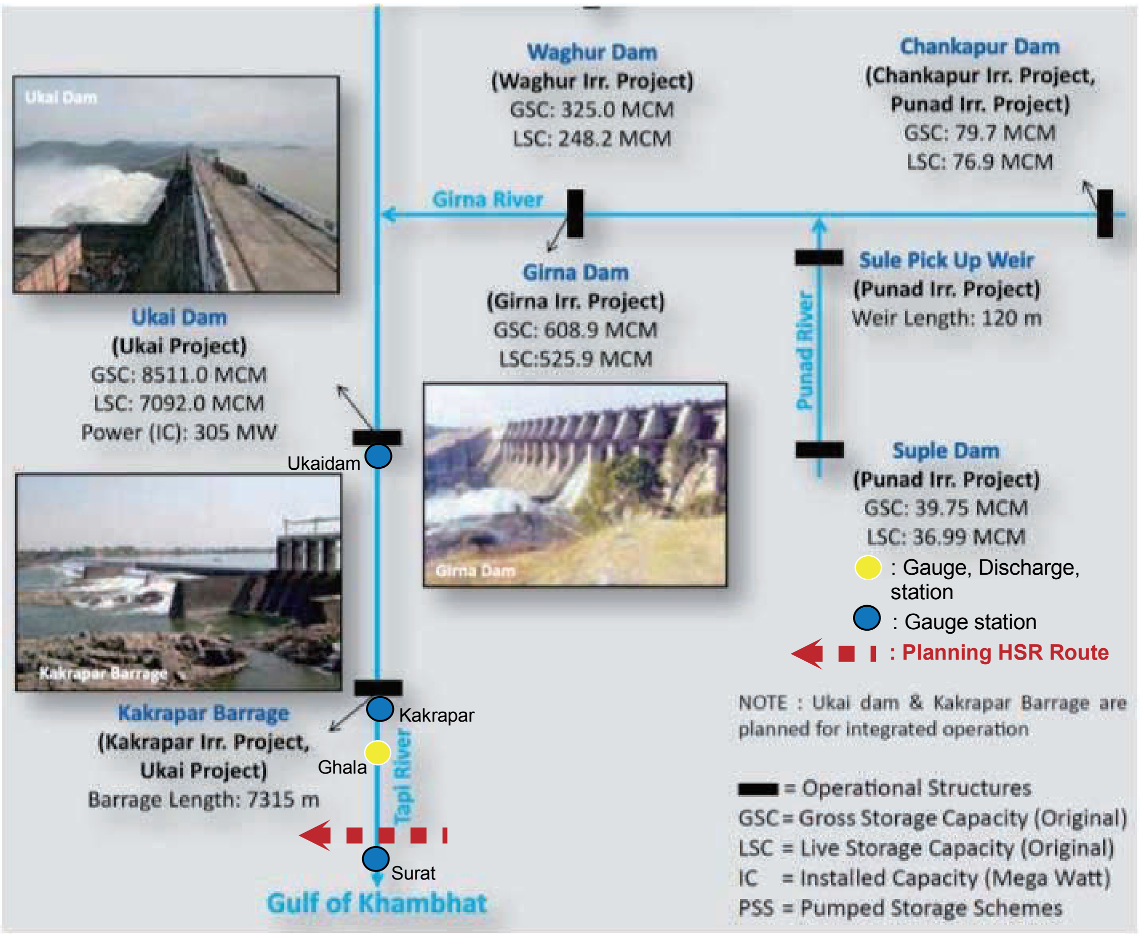
・Major dams across Tapi River

Ukai dam and Kakrapar Barrage is situated across Tapi River at middle reaches. Numerous dams are located at upper reaches of Tapi River and its tributaries.

Table 6.3-8 Major Dams across Tapi River and Tributaries

Name	Location	Purpose	Constructed Year	Dam Type	Gross Storage Capacity	Spillway Capacity
Ukai Dam (Vallabh Sagar)	In Tapi River at 128km up-stream from the mouth of River	Multi-purpose	1972	Earthen / Masonry	7,414 Mm^3	46,269 m^3/s
Kakrapar Barrage	In Tapi River at 105km up-stream from the mouth of River	Irrigation	1954	Masonry	52 Mm^3	38,228 m^3/s

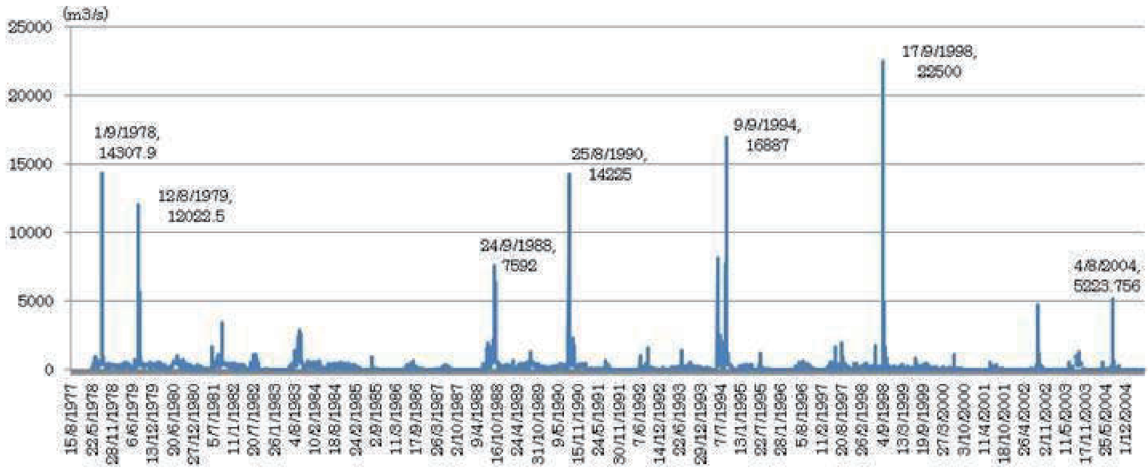
(Source: WRD Water Resources)



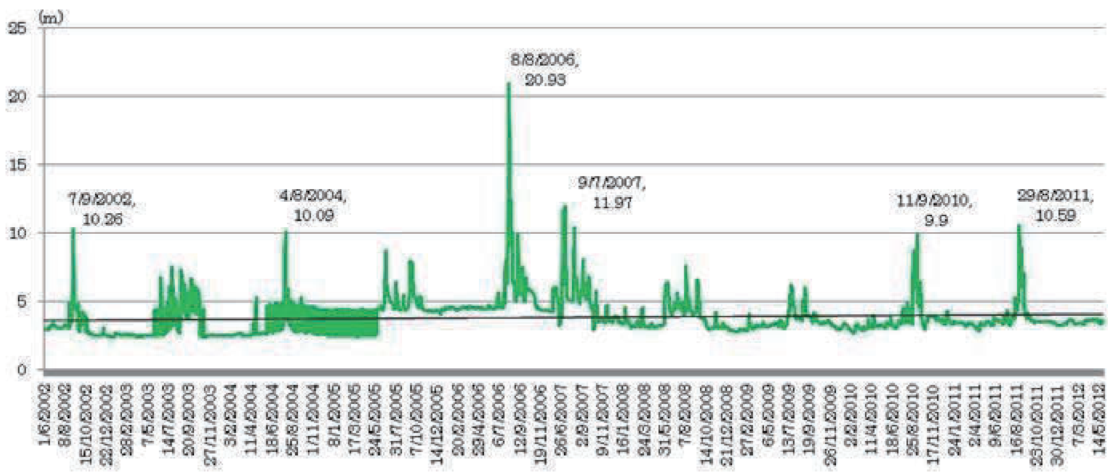
Source: River Basin Atlas of India

Figure 6.3-13 River Flow Line Diagram for Tapi River

・<u>CWC Hydrological Observation Station</u>
- Ghala station is situated at 40km from the mouth of Tapi River. Ghala Station observes Gauge and Discharge. The discharge observation at the station was started in 1977.
According to the data of Ghala station, the maximum discharge of 22,500m^3/s was obtained in 17.09.1998. The average in the period is calculated as 183m^3/s. Also, the minimum discharge except lowest 1% value becomes 5m^3/s. Hence, a coefficient of river regime is calculated as Max. /Min.≒4,600.
-Other CWC stations are located at middle-stream or upper-stream of Tapi River.



Source: Compiled from CWC observation data by Study Team
Figure 6.3-14 Discharge Observed at Ghala Station in 1977-2004



Source: Compiled from CWC observation data by Study Team
Figure 6.3-15 Water Level Observed at Ghala Station in 2002-2012

・<u>Neighbor bridges in Tapi River</u>
Existing and planned Railway bridge / Road bridge at around HSR route (ALT1) crossing with the River are as follows.

Table 6.3-9 Neighbor Bridges in Tapi River

Name of Railway / Road	Distance from HSR ALT1 (km)	Remarks
DFC (Planned)	-3.3 (DN)	Bridge No.240, Span& Length : 15x48.5m (728m) Girder : Open Web Welded Through Truss Foundation : Well / Pile
Savji-Korat Rd	-7.4 (DN)	
Kapodara-Utran Rd	-10.3 (DN)	
Western Railway	-12.0 (DN)	Bridge No.452, 10x57.15m Girder : TOWG, Foundation : Well
N.H.8	1.8 (UP)	

Source: Study Team

・<u>HSR crossing point with Tapi River</u>
-HSR route crosses over Tapi River at approx. 47 km upstream from mouth of the River.
-The width of river at HSR crossing point is approx. 500m. At upstream the river width is extended and sandbank in the river is seen.
- The land use of waterfront at nearby HSR route is mostly plant tree or natural bush.
-It is reference information from DFC project that the designed water discharge at DFC route crossing is 43,000 m3 in approximate. Also, the designed water depth from River Bed to High Flood Level at DFC route crossing is 19m in approximate.

Source: Google Earth

Figure 6.3-16 HSR Crossing Point in Tapi River

・Flood record / River improvement plan
Surat city has been affected by catastrophic flood once in every five years recently.
During 1994, 1998 and 2006, floods of the order of 14,870 m3/s, 19,820 m3/s and 28,315 m3/s were experienced. Specially, the flood 2006 was catastrophic and resulted in total losses of 21,000 Crores.
According to found article in the engineering journal※, the flood level with 28,315m3/s flood discharge are likely to be of the order of 10.6m near Bhata and industrial area around ONGC i.e. nearby about 2.0m above 1998 flood level.
Not only above but also several studies for flood of Tapi have been conducted by many research organizations such as CWC, GERI and CWPRS.
※Flood Water Surface Profile in Tapi River – Surat (G.I.Joshi, etc)

e) Narmada River

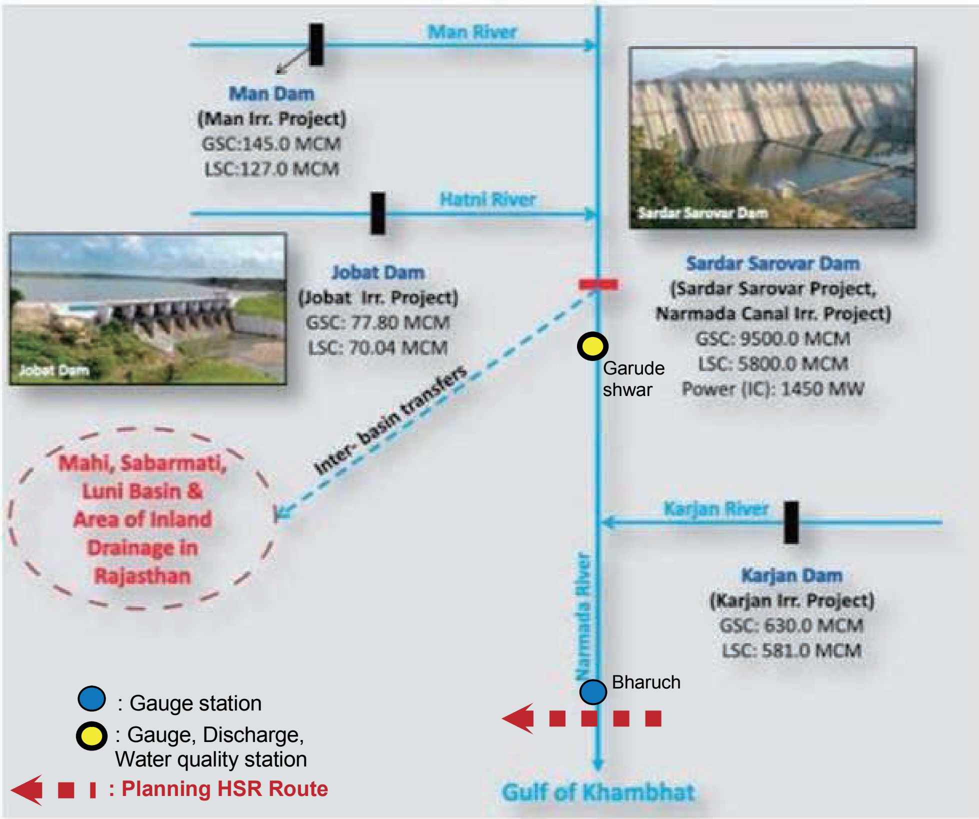
・Geographical feature of Narmada River
Narmada River is the largest west flowing river of the peninsular India. It rises from Maikala range near Amarkantak in Anuppur district of Madhya Pradesh, at an elevation of about 900 m. The total length of the river is 1,312 km and its important tributaries are the Burhner, the Banjar, the Sher, the Shakkar, the Dudhi, the Tawa , the Ganjal, the Kundi, the Goi and the Karjan which joins from left whereas the Hiran, the Tendoni, the Barna, the Kolar, the Man, the Uri, the Hatni and the Orsang joins from right. Narmada drains into the Arabian Sea through the Gulf of Khambhat.

・Major dams across Narmada River
Sardar Sarovar dam is situated across Narmada River at middle reaches. Karjan dam is situated across Karjan River which is tributary of Narmada River.
The project of Sardar Sarovar dam was taken from in 1979 and has still continued height increase until recent.
Numerous dams are located at middle and upper reaches of Narmada River and its tributaries.

Table 6.3-10 Major Dams across Narmada River and Tributaries

Name	Location	Purpose	Constructed Year	Dam Type	Gross Storage Capacity	Spillway Capacity
Sardar Sarovar Dam	In Narmada River at 146km up- stream from the mouth of River	Multi-Purpose	2008 (partially)	Concrete Gravity	9,500 Mm3	87,000 m3/s
Karjan Dam	In Karjan River at 26km up-stream from the confluence of Narmada River	Irrigation	1996	Masonry& Concrete	630 Mm3	17,286 m3/s

(Source: India-WRIS wiki, WRD Water Resources)



Source: River Basin Atlas of India

Figure 6.3-17 River Flow Line Diagram for Narmada River

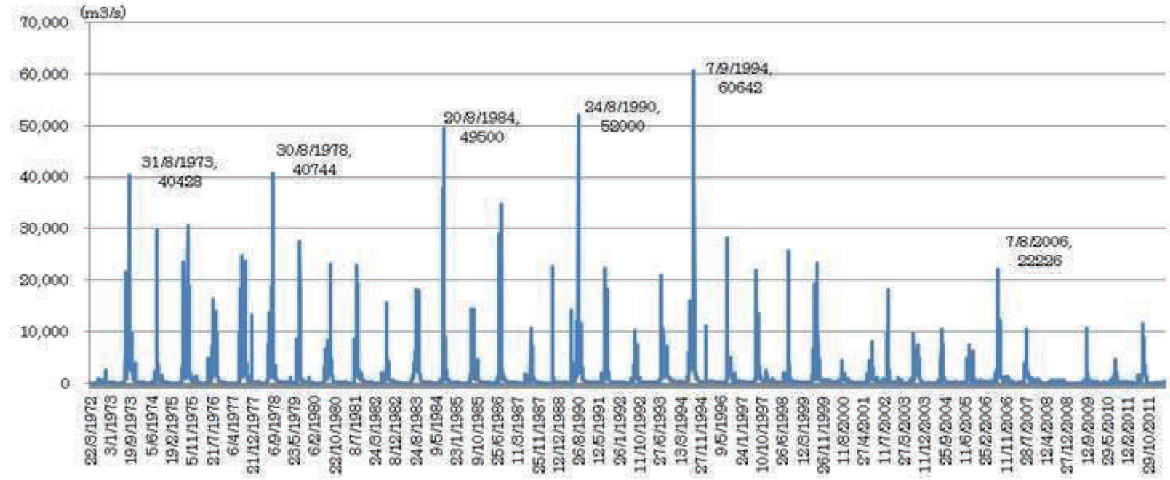
・<u>CWC Hydrological Observation Station</u>

-Bharuch station is situated at 18km from the mouth of Narmada River. Bharuch station observes Gauge.

-Garudeshwar station is situated at 12km downstream from Sardar Sarvor dam in Narmada River. Garudeshwar station observes Gauge, Discharge, Sediment and Water quality. The discharge observation at the station was started in 1972.

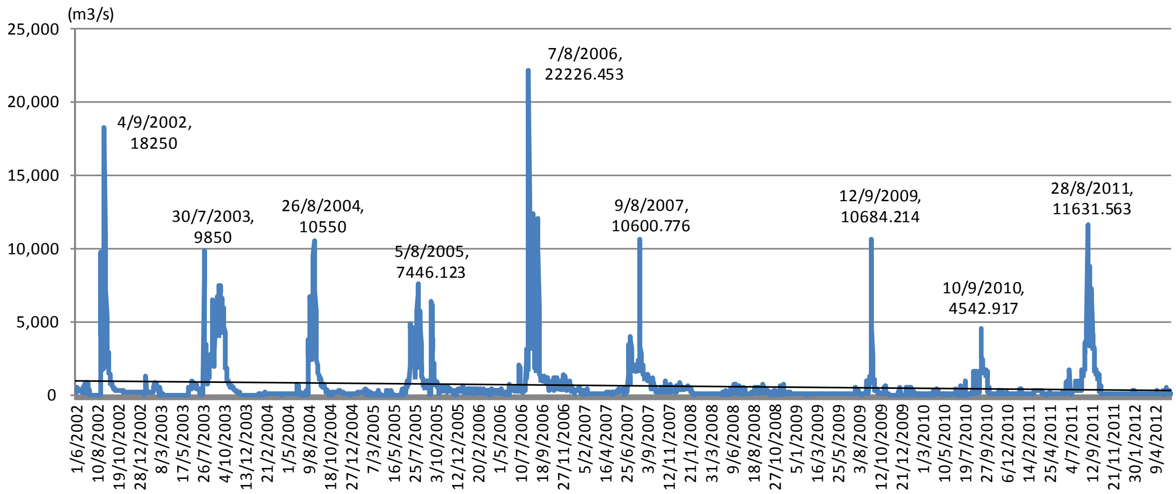
According to the data of Garudeshwar station, the maximum discharge of 60,642m3/s was obtained in 07.09.1994. The average in the period is calculated as 954m3/s. Also, the minimum discharge except lowest 1% value becomes 6m3/s. Hence, a coefficient of river regime is calculated as Max. /Min.≒9,400.

-Other CWC stations are located at middle-stream or upper-stream of Narmada River.



Source: Compiled from CWC observation data by Study Team

Figure 6.3-18 Discharge Observed at Garudeshwar Station in 1972-2012



Source: Compiled from CWC observation data by Study Team

Figure 6.3-19 Discharge Observed at Garudeshwar Station in 2002-2012

・<u>Neighbor bridges in Narmada River</u>

Existing and planned Railway bridge / Road bridge at around HSR route (ALT1) crossing with the River are as follows.

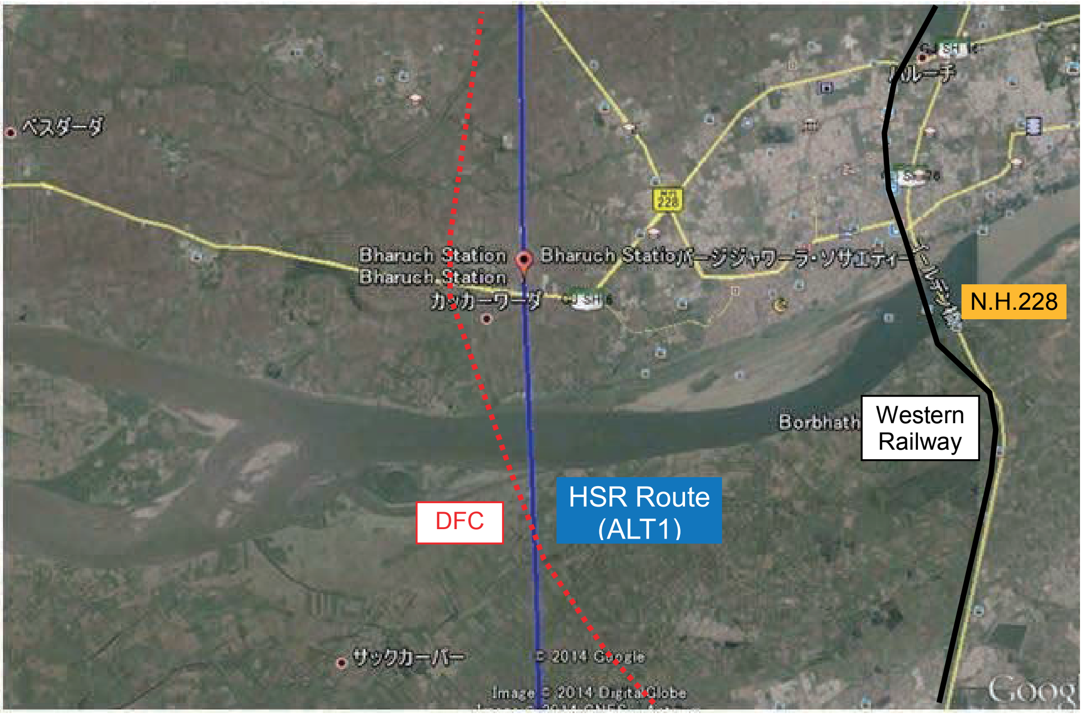
Table 6.3-11 Neighbor Bridges in Narmada River

Name of Railway / Road	Distance from HSR ALT1 (km)	Remarks
DFC (Planned)	0.7 (DN)	Bridge No.57, Span& Length : 29x48.15m (1396m) Girder : Underslung Truss With Composite RCC Deck Foundation : Well / Pile
N.H.228	6.6 (UP)	
Western Railway	6.4 (UP)	Bridge No.502 1x18.29m + 1x76.30m + 15x87.63m Girder : TOWG, Foundation : Well

Source: Study Team

・<u>HSR crossing point with Narmada River</u>

-HSR route crosses over Narmada River at approx. 42 km upstream from mouth of the River.
-The width of river at HSR crossing point is approx. 1000m.
-No existing bridge is located at downstream of the river except DFC bridge which will be constructed in near future.
-HSR route pass a sandbank in south side of the river. Another sandbank is also located at 4km downstream. Hence, the direction of river flow in the section would be un-regular.
-Flood plain extends at north side of the river. The land use of waterfront at nearby HSR route is mostly agriculture or natural bush.
-It is reference information from DFC project that the designed water discharge at DFC route crossing is 72,000 m3 in approximate. Also, the designed water depth from River Bed to High Flood Level at DFC route crossing is 16m in approximate.



Source: Google Earth

Figure 6.3-20 HSR Crossing Point in Narmada River

・<u>Recent flood record in Narmada River</u>

(Source: Readings and Case Studies on Disaster Management, Solanki Pravin K, IAS (Gujarat))
Bharuch is traditionally facing flood in Narmada River.
In August 2004, Bharuch city and surrounding rural areas were specially affected due to high intensity rainfall. Water was overflowing at the Sardar Sarovar dam on 2nd august. However, with the increasing rain activities in the Narmada Catchment area the water level at the dam had been increased which is at 113.62 meter. Similarly, at Garudeswar the water level was 18.62 and at the Golden Bridge 5.00 meter on 3rd August.
Moreover, human obstructions to natural water flow and heavy rainfall were two prime reasons to create a situation like flash floods at Bharuch.
Due to flooding in the major areas of the district, railways, roads and bridges were disturbed or damaged seriously. Railway traffic was disrupted in major way and many trains were cancelled. 22 Rural road links were affected. Six state highways in the district were totally blocked for traffic due to heavy water logging and flooding in the roads. 2 bridges and 22 culverts were damaged.

Out of affected 22 rural roads, traffic was restored in 14 links by the 5th august, and by 7th august traffic was back into normal. Bharuch-Dahej state highway and Ankleswar – Olpad - Surat, which were totally blocked are open for traffic. In two marooned villages i.e., Kothia and Sadadla in Vagra Taluka, approach roads had been opened. Railway was also restored to the normal.

f) Mahi River

・Geographical feature of Mahi River

Mahi River is one of the major interstate west flowing rivers of India. It originates from the northern slopes of Vindhyas at an altitude of 500 m near village Bhopawar, Sardarpur tehsil in Dhar district of Madhya Pradesh. The total length of Mahi is 583 km. The Som is its principal tributary which joins from right, and the Anas and the Panam joins the river from left. It drains into the Arabian Sea through the Gulf of Khambhat.

・Major dams across Mahi River

Wanakbori Weir and Kadana dam is situated across Mahi River at middle reaches. Panam dam is situated across Panam River which is tributary of Mahi River.
Numerous dams are located at middle and upper reaches of Mahi River and its tributaries.

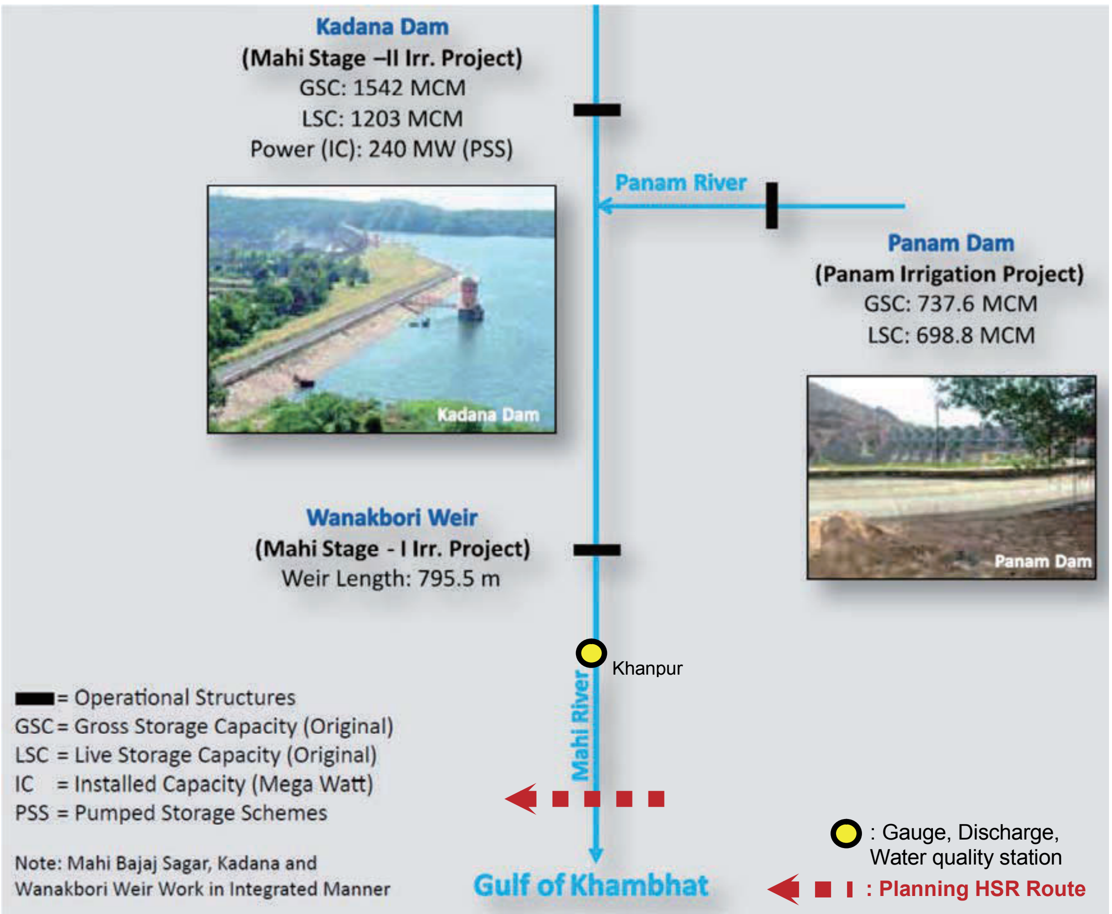
Table 6.3-12 Major Dams across Mahi River and Tributaries

Name	Location	Purpose	Constructed Year	Dam Type	Gross Storage Capacity	Spillway Capacity
Wanakbori Weir	In Mahi River at 114km up-stream from the mouth of River	Irrigation	1980	Compo-site	42 Mm3	46,978 m3/s
Kadana Dam	In Mahi River at 185km up-stream from the mouth of River	Irrigation, Hydro-power & Flood protection	1979	Earthen& Masonry	1,542 Mm3	49,497 m3/s
Panam Dam	In Panam River at 17km up-stream from the confluence of Mahi River	Irrigation, Water Supply, Power Generation, Fisheries	1999	Masonry	738 Mm3	10,075 m3/s

(Source: WRD Water Resources)

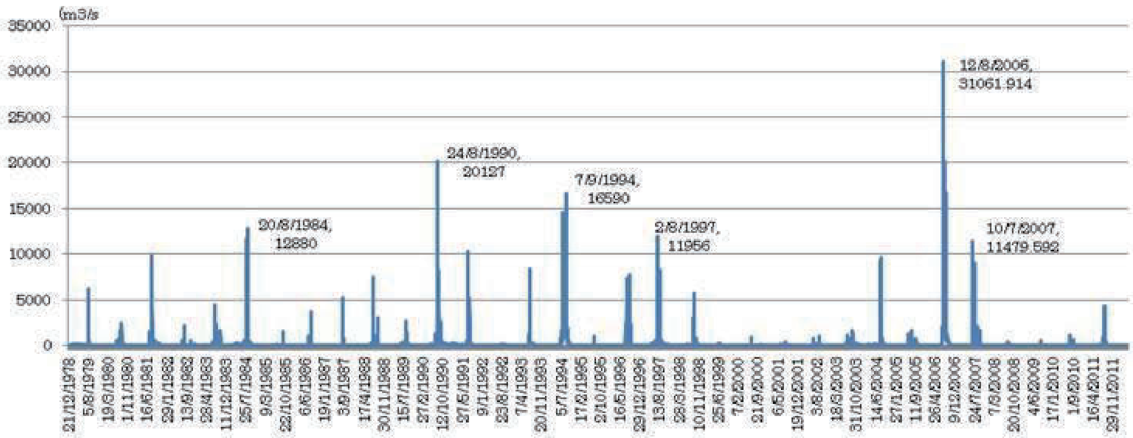
・CWC Hydrological Observation Station

-Khanpur station is situated at 52km from the mouth of Mahi River. Khanpur station observes Gauge, Discharge, Sediment and Water quality. The discharge observation at the station was started in 1978.
According to the data of Khanpur station, the maximum discharge of 31,062m3/s was obtained in 12.08.2006. The average in the period is calculated as 140m3/s. Also, the minimum discharge except lowest 1% value becomes 4m3/s. Hence, a coefficient of river regime is calculated as Max. /Min.≒8,900.
-Other CWC stations are located at middle-stream or upper-stream of Mahi River.



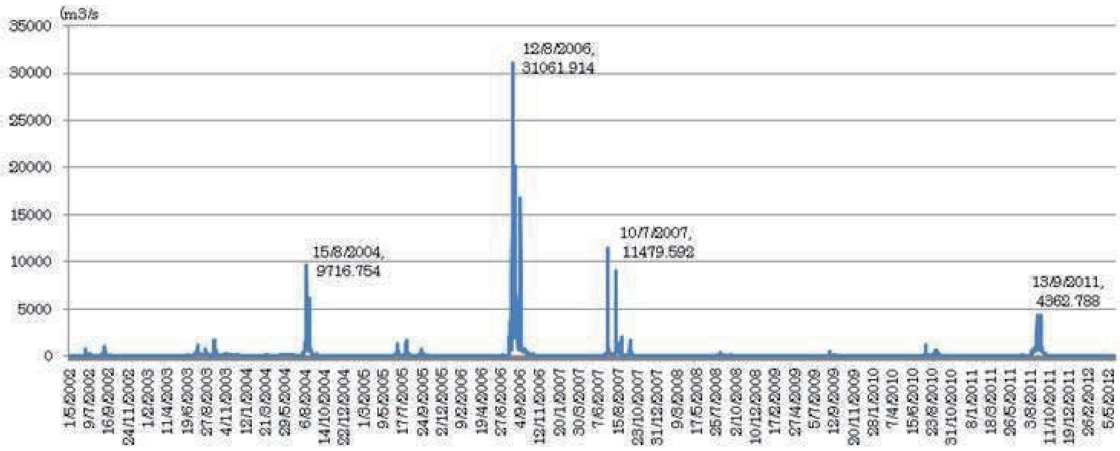
Source: River Basin Atlas of India

Figure 6.3-21 River Flow Line Diagram for Mahi River



Source: Compiled from CWC observation data by Study Team

Figure 6.3-22 Discharge Observed at Khanpur Station in 1978-2012



Source: Compiled from CWC observation data by Study Team

Figure 6.3-23 Discharge Observed at Khanpur Station in 2002-2012

・Neighbor bridges in Mahi River

Existing and planned Railway bridge / Road bridge at around HSR route (ALT1) crossing with the River are as follows.

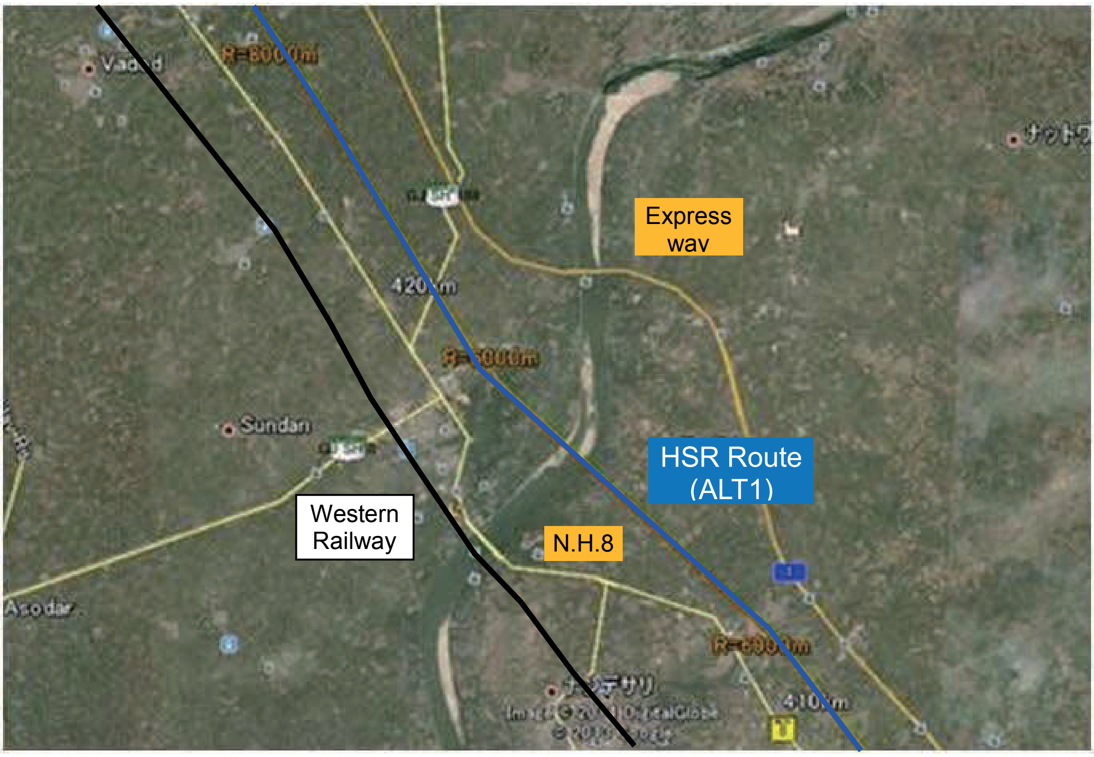
Table 6.3-13 Neighbor Bridges in Mahi River

Name of Railway / Road	Distance from HSR ALT1 (km)	Remarks
N.H.8	-2.2 (DN)	
Western Railway	-2.4 (DN)	Bridge No.624 (UP), Span& Length : 8x67.06m Girder : TOWG, Foundation : Well Bridge No.624 (DN), Span& Length : 16x33.75m Girder : PSC Girder, Foundation : Pile
DFC (Planned)	-9.7 (DN)	Span& Length : 12x48.75m (585m) Girder : Special steel truss Foundation : Well / In-situ Piles
GJSH 11	-14.0 (DN)	
N.H.228	-26.1 (DN)	
Expressway	3.3 (UP)	

Source: Study Team

・HSR crossing point with Mahi River

-HSR route crosses over Mahi River at approx. 88 km upstream from mouth of the River.
-The width of river at HSR crossing point is approx. 600m.
-HSR route pass a sandbank in center and north side of the river. Hence, the direction of river flow in the section would be un-regular.
-The land use of waterfront at nearby HSR route is mostly agriculture or natural bush.
-Numerous intake towers are situated at up and downstream of the crossing point.
-It is reference information from DFC project that the designed water discharge at DFC route crossing is 32,000 m3 in approximate. Also, the designed water depth from River Bed to High Flood Level at DFC crossing is 11m in approximate.



Source: Google Earth

Figure 6.3-24 HSR Crossing Point in Mahi River

・<u>Recent flood record in Mahi River</u>

Vadodara city has experienced a flash flood situation with most part of the city flooded due to the worst hit heavy rainfall in July 2005.

According to found article in a journal※, the heavy rain has left many of the major dams full while the medium and small dams are overflowing. The worst was the case of Pratap Pura lake in Vadodara district where nearly 100-feet long breach developed in check dam-cum-reservoir as it overflowed and water gushed out towards the villages downstream. Much of the overflowing water was been drained into the Vishwamitri river flowing through the Vadodara city. Also, heavy rainfall made Ajwa Dam necessitated opening of spillway gates to release water. Heavy rain and the release of water in the Vishwamitri River caused havoc in Vadodara.

The flood at most part of the city resided in less than 12 hours, except Northern-west part of the city where were built encroaching drainage channel on illegal land fill (Nizampura, Sama, Chani.) It was concluded that proper planning and management is required to mitigate the flood risk vulnerability in these area.

※BLOCKAGE OF NATURAL DRAINS DUE TO URBANISATION AND ITS AFTERFITS H. K. Shastri, etc

According to the obtained information by internet, Vadodara Municipal Corporation (VMC) plans to establish a body for the development of Vishwamitri river on the lines of the Sabarmati Riverfront Development. It might take a long time, may be even 20 to 25 years, to develop a riverfront.

g) Sabarmati River

・Geographical feature of Sabarmati River

Sabarmati River originates from Aravalli hills at an elevation of 762 m near village Tepur, in Udaipur district of Rajasthan. The total length of river from origin to outfall into the Arabian Sea is 371 km and its principal tributaries joining from left are the Wakal, the Hathmati and the Vatrak whereas the Sei joins the river from right.

・Major dams across Sabarmati River

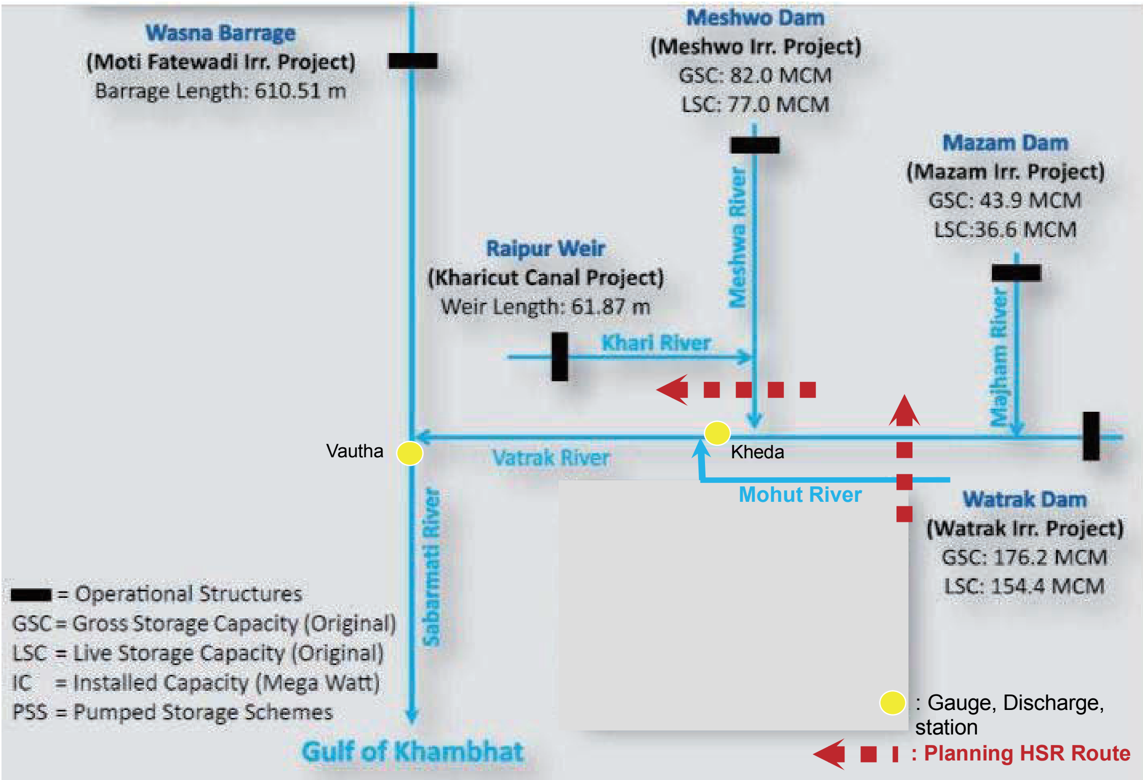
Wasna Barrage is situated across Sabarmati River at middle reaches. Watrak dam is situated across Vatrak River, Mazan dam is situated across Majham River and Meshwo dam is situated across Meshwo River, which are tributary of Sabarmati River.

Numerous dams are located at middle and upper reaches of Sabarmati River and its tributaries.

Table 6.3-14 Major Dams across Sabarmati River and Tributaries

Name	Location	Purpose	Constructed Year	Dam Type	Gross Storage Capacity	Spillway Capacity
Wasna Barrage	In Sabarmati River at XXkm up- stream from the mouth of River	To strengthen existing irrigation facility	1976	Barrage	-	21,000 m3/s
Watrak Dam	In Vatrak River at 180km up- stream from the confluence of Sabarmati River	Irrigation	1983	Composite	177 Mm3	5,669 m3/s
Mazam Dam	In Majham River at 71km up- stream from the confluence of Vatrak River	Irrigation	-	Composite Rolled filled zone type	44 Mm3	3,314 m3/s
Meshwo Dam	In Meshwa River at 191km up- stream from the confluence of Vatrak River	Irrigation & flood control	1972	Earthen	82 Mm3	2,067 m3/s

(Source: India-WRIS wiki, WRD Water Resources)



Source: River Basin Atlas of India

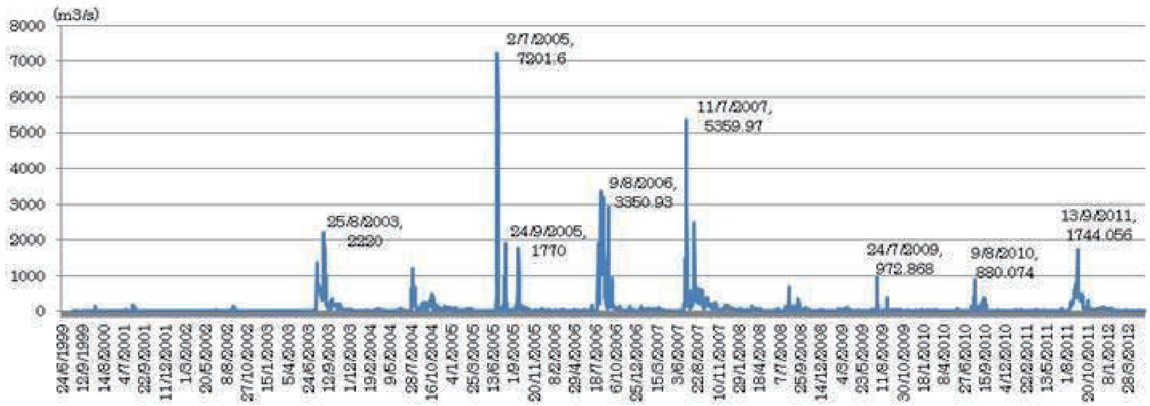
Figure 6.3-25 River Flow Line Diagram for Sabarmati River

・<u>CWC Hydrological Observation Station</u>

-Vautha station is situated at little downstream from the confluence between Sabarmati River and Vatrak tributary. Vautha station observes Gauge, Discharge and Water quality. The discharge observation at the station was started in 1999.

According to the data of Vautha station, the maximum discharge of 7,202m3/s was obtained in 02.07.2005. The average in the period is calculated as 88m3/s. Also, the minimum discharge except lowest 1% value becomes 1m3/s. Hence, a coefficient of river regime is calculated as Max. /Min.≒7,200.

-Other CWC stations are located at middle-stream or upper-stream of Sabarmati River.



Source: Compiled from CWC observation data by Study Team

Figure 6.3-26 Discharge Observed at Vautha Station in 1999-2012

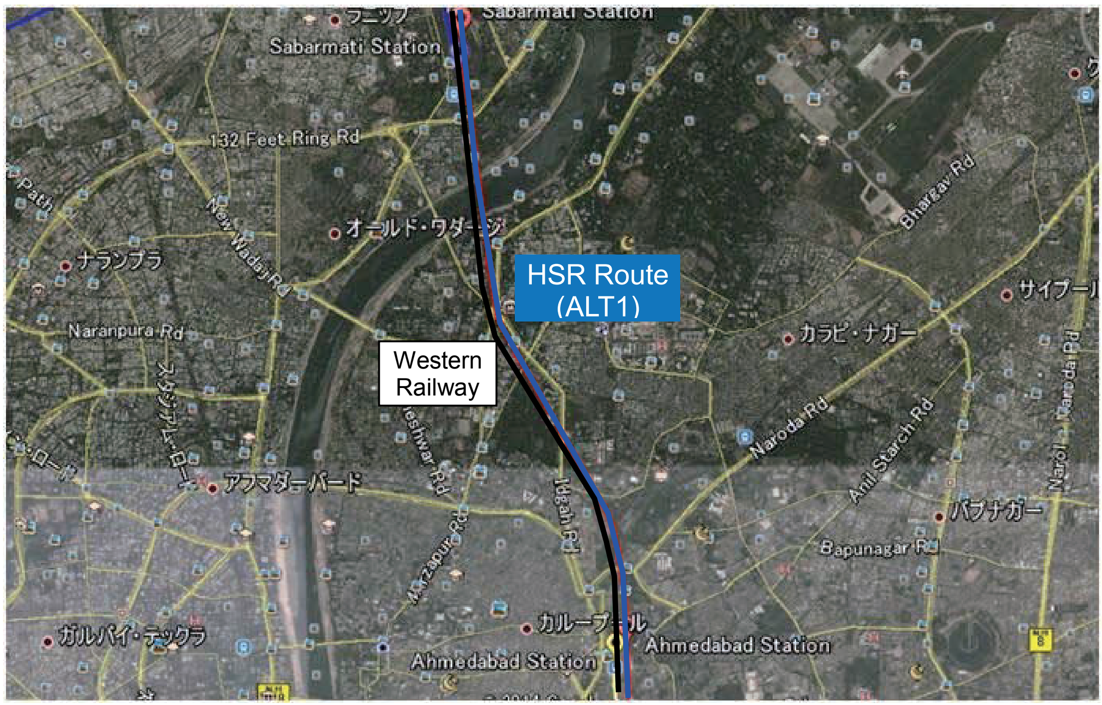
・<u>HSR crossing point with Sabarmati River</u>

-There are two options of Terminal Station location with HSR ALT1 plan which are at near existing Ahmedabad Station or at near Sabarmati Station. In case of at near Sabarmati Station, HSR route needs to cross over Sabarmati River. In that case, HSR route crosses over Sabarmati River at approx. 139 km upstream from mouth of the River. The width of river at HSR crossing point is approx. 300m.

-HSR crossing point with Sabarmati River is planned at just next to Sabarmati Rail Bridge.

-Sabarmati Riverfront Walkway does exist along Sabarmati River at HSR crossing point.

-It is reference information from DFC project that the designed water discharge at DFC route crossing is 15,000 m3 in approximate. Also, the designed water depth from River Bed to High Flood Level at DFC route crossing is 9m in approximate.



Source: Google Earth

Figure 6.3-27 HSR Crossing Point in Sabarmati River

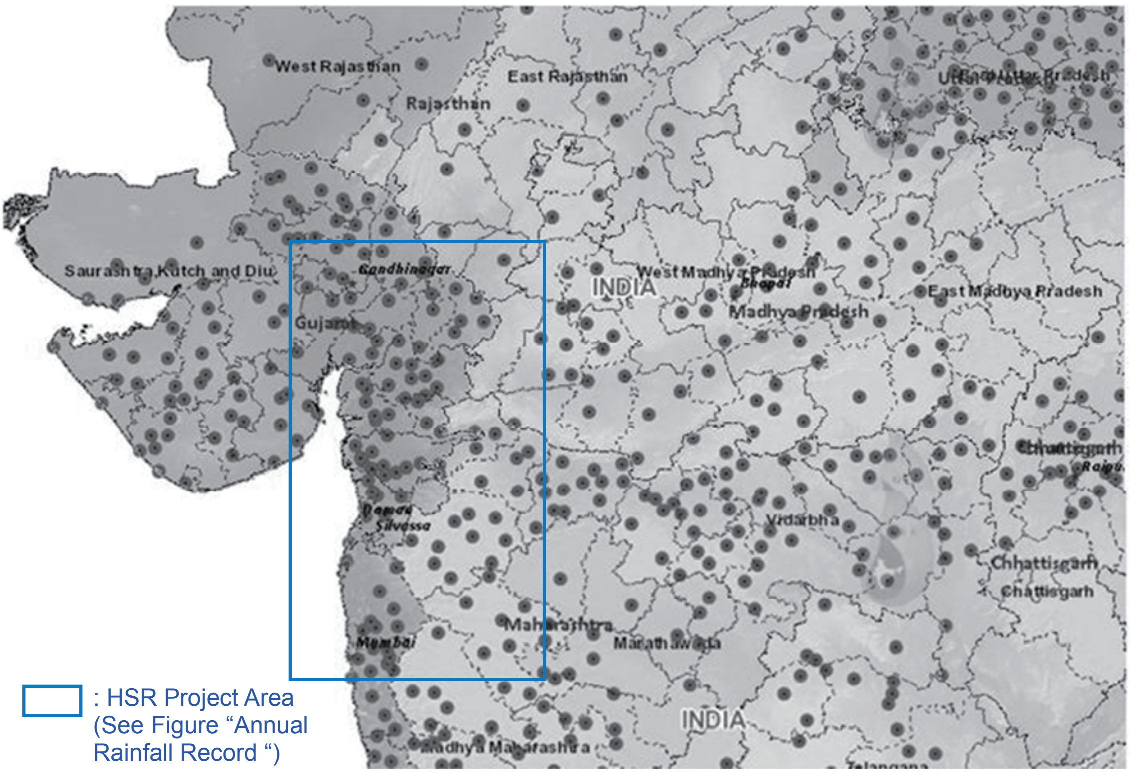
6.3.2 Meteorological Condition

(1) Meteorological observation in India

In India, there are three main organizations which records meteorological parameters viz., India Meteorological Department (IMD), Central Water Commission (CWC) and ISRO (Indian Space Research Organization).

IMD provides at 1,025 stations having data of monthly average precipitation and potential evapo-transpiration, average annual rainfall and potential evapo-transpiration for last 10 years. In addition, another 130 IMD sites having weekly data of rainfall, maximum and minimum temperature, wind speed, evaporation and sunshine hours are also being visualized.

CWC provides 851 meteorological stations with basic parameters details (CWC report, 2010). These data can be available by India-WRIS Web GIS system which is aimed as a Single window solution for comprehensive, authoritative and consistent data & information of India's water resources along with allied natural resources in a standardized national GIS framework with tools to search, access, visualize, understand and analyze the data for assessment, monitoring, planning, development and finally Integrated Water Resources Management..



Source: India-WRIS Web GIS

Figure 6.3-28 Distribution of IMD meteorological stations

(2) Rainfall Record at HSR project area

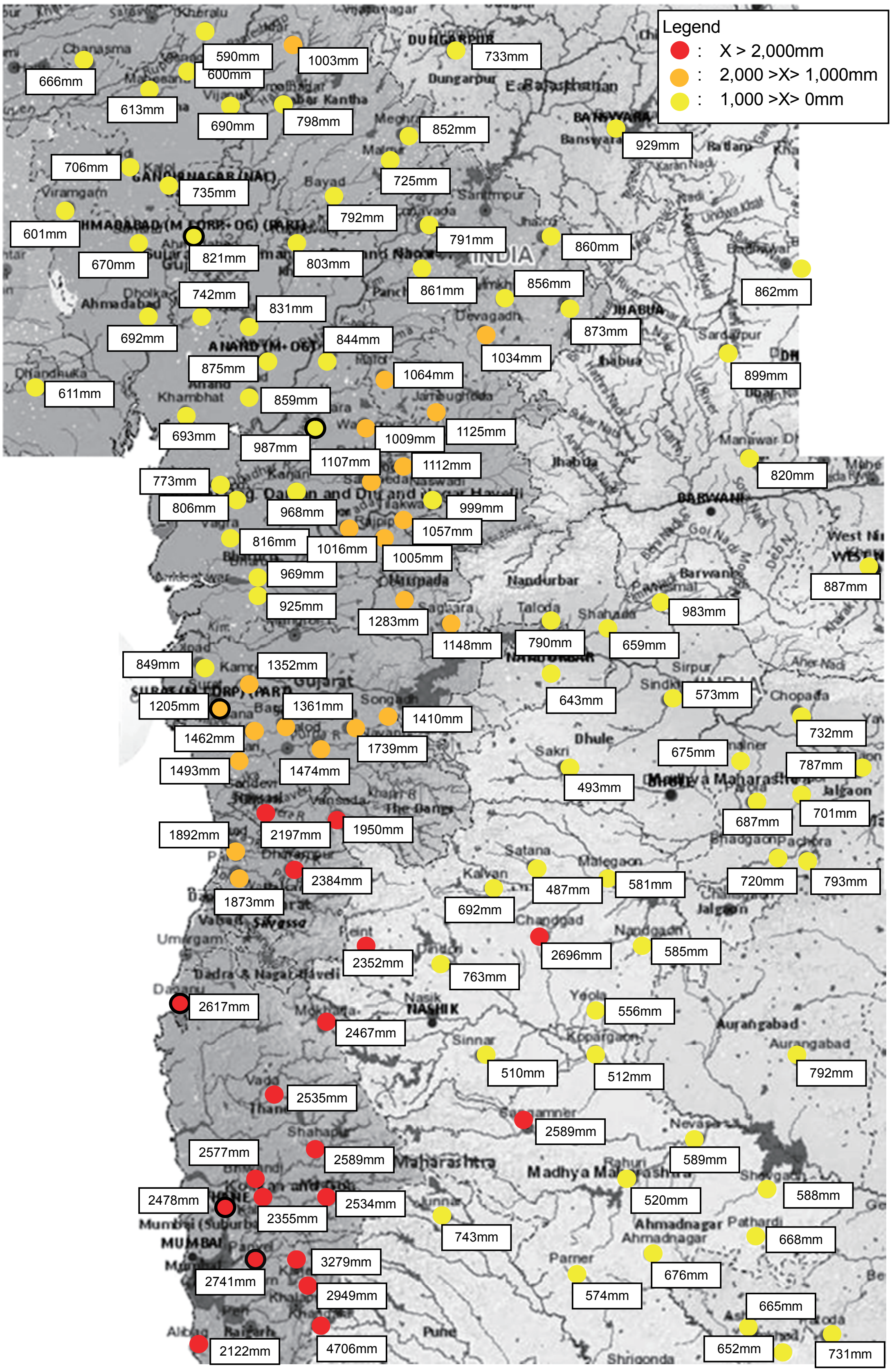
The annual rainfall record in average of last 10 years for wide range nearby HSR project area is shown in Figure 6.3-29. Also, the monthly rainfall in average of last 10 years for several major cities beyond HSR route is shown in Figure 6.3-30.
From these data, the characteristic of meteorological condition around HSR route can be considered as follows.

- The annual rainfall nearby Mumbai, known as tropical monsoon climate is comparably high among HSR project area. The averaged annual rainfall in last 10 years is 2,000-3,000 mm/year. It may cause of the dominant effect of the southwest monsoon.
- For Daman to Surat, the averaged annual rainfall in last 10 years is 1,000-2,000mm/year.
- The annual rainfall nearby Ahmadabad, known as semiarid steppe climate is comparably low among the project area. The averaged annual rainfall in last 10 years is below 1,000m.

- It is common for HSR project area that a rainy season is from June to September. Most of the annual rainfall is concentrated in this period.
- The monthly rainfall in July as a peak at nearby Mumbai is approximately 1,000mm/month.
- The monthly rainfall in July as a peak at nearby Surat to Ahmedabad is approximately 300-400mm /month.

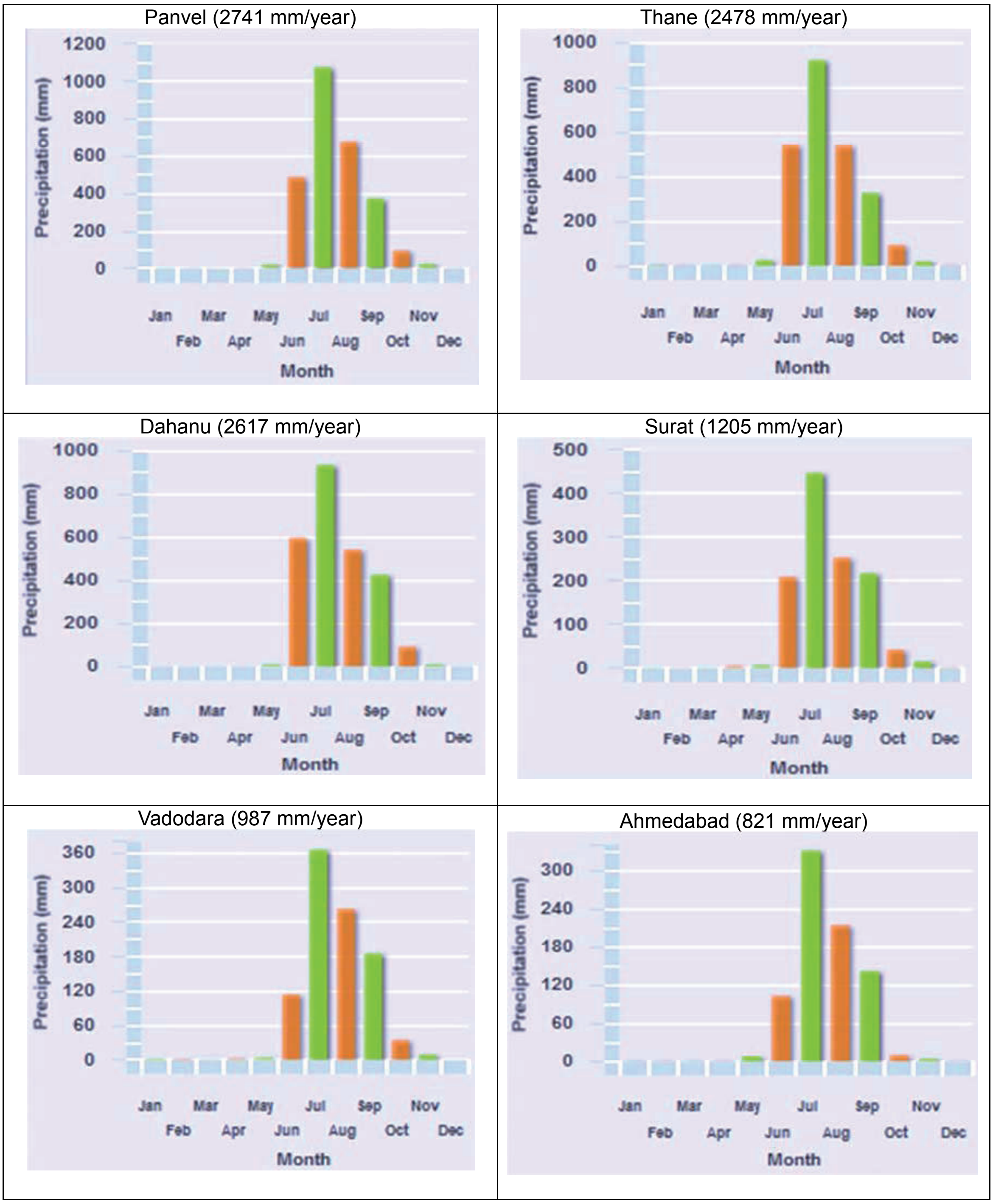
The contour map of 50year-24hour rainfall is commonly utilized for hydrological calculation for Railway /Road project implementation in India. The map has been prepared by joint work of IMD, CWC and Ministry of Railway in previous. The maps for HSR project area is shown in Figure 6.3-31 to Figure 6.3-33.

The map shows that the difference of hourly rainfall between Mumbai area and Ahmedabad area is not large as annual/monthly rainfall. The hourly rainfall nearby Mumbai is 360-400mm. The hourly rainfall nearby Ahmedabad is 320-360mm.



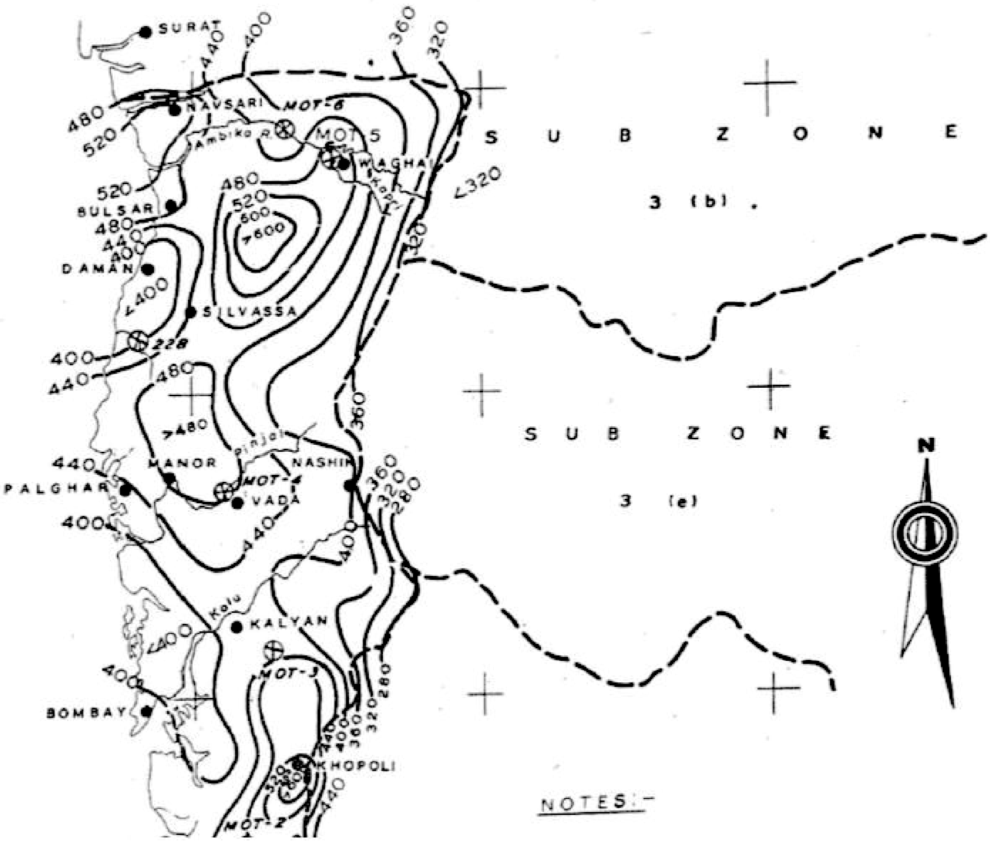
Source: Compiled by Study Team from India-WRIS Web GIS

Figure 6.3-29 Annual Rainfall Record (10 years average)



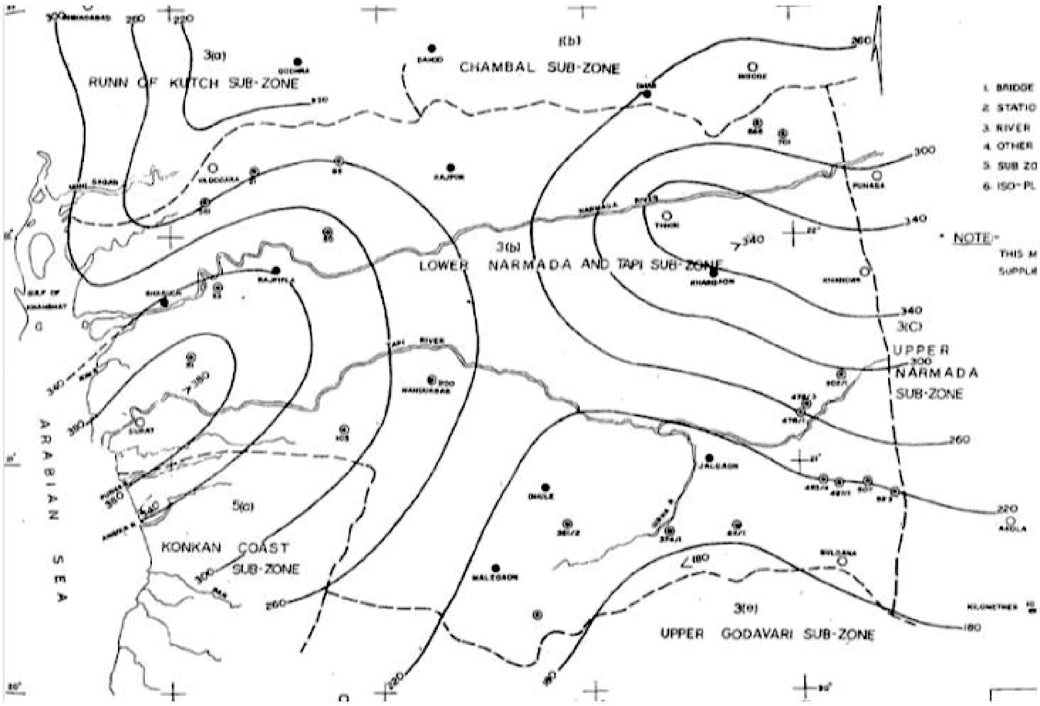
Source: Compiled by Study Team from India-WRIS Web GIS

Figure 6.3-30 Monthly Rainfall Record (10 years average)



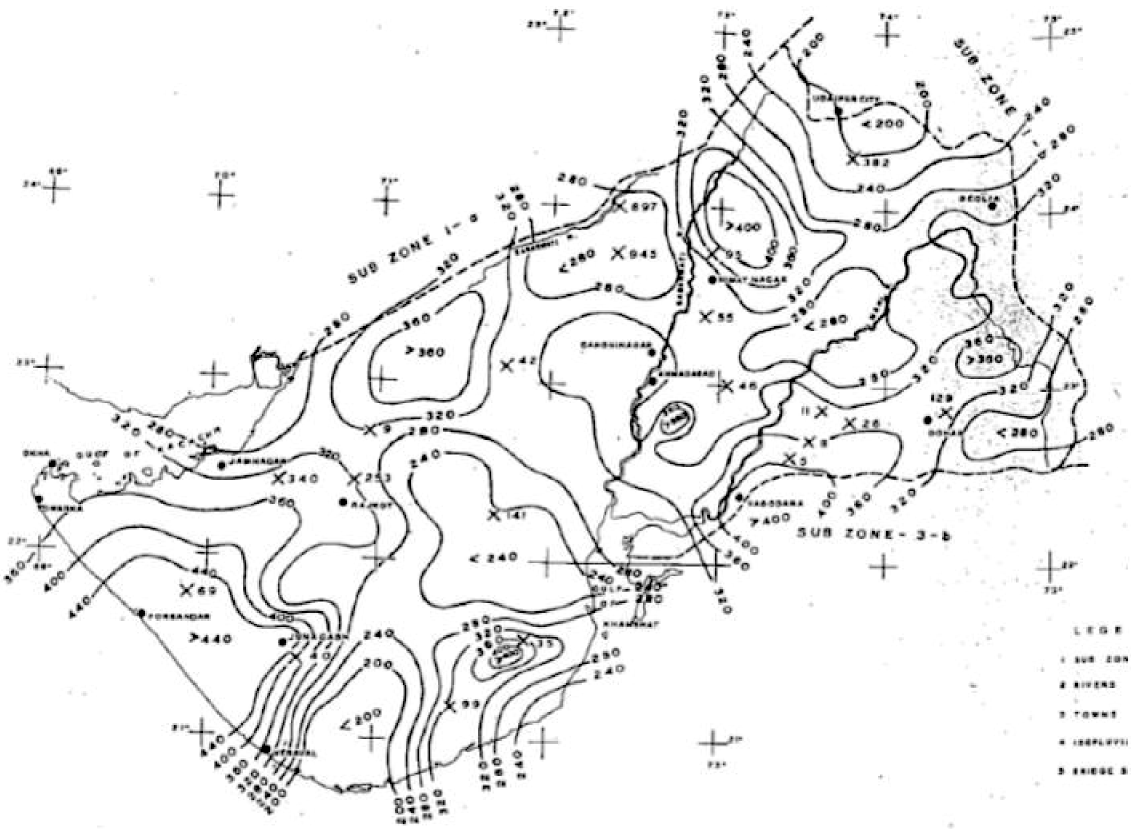
Source: Flood Estimation Report Sub-Zones 5a&5b

Figure 6.3-31 50year – 24hour Rainfall (Sub-zones 5a&5b)



Source: Flood Estimation Report Sub-Zone 3b

Figure 6.3-32 50year – 24hour Rainfall (Sub-zone 3b)



Source: Flood Estimation Report Sub-Zone 3a

Figure 6.3-33 50year – 24hour Rainfall (Sub-zone 3a)

6.3.3 Ground Water Level

(1) Ground Water Monitoring in India

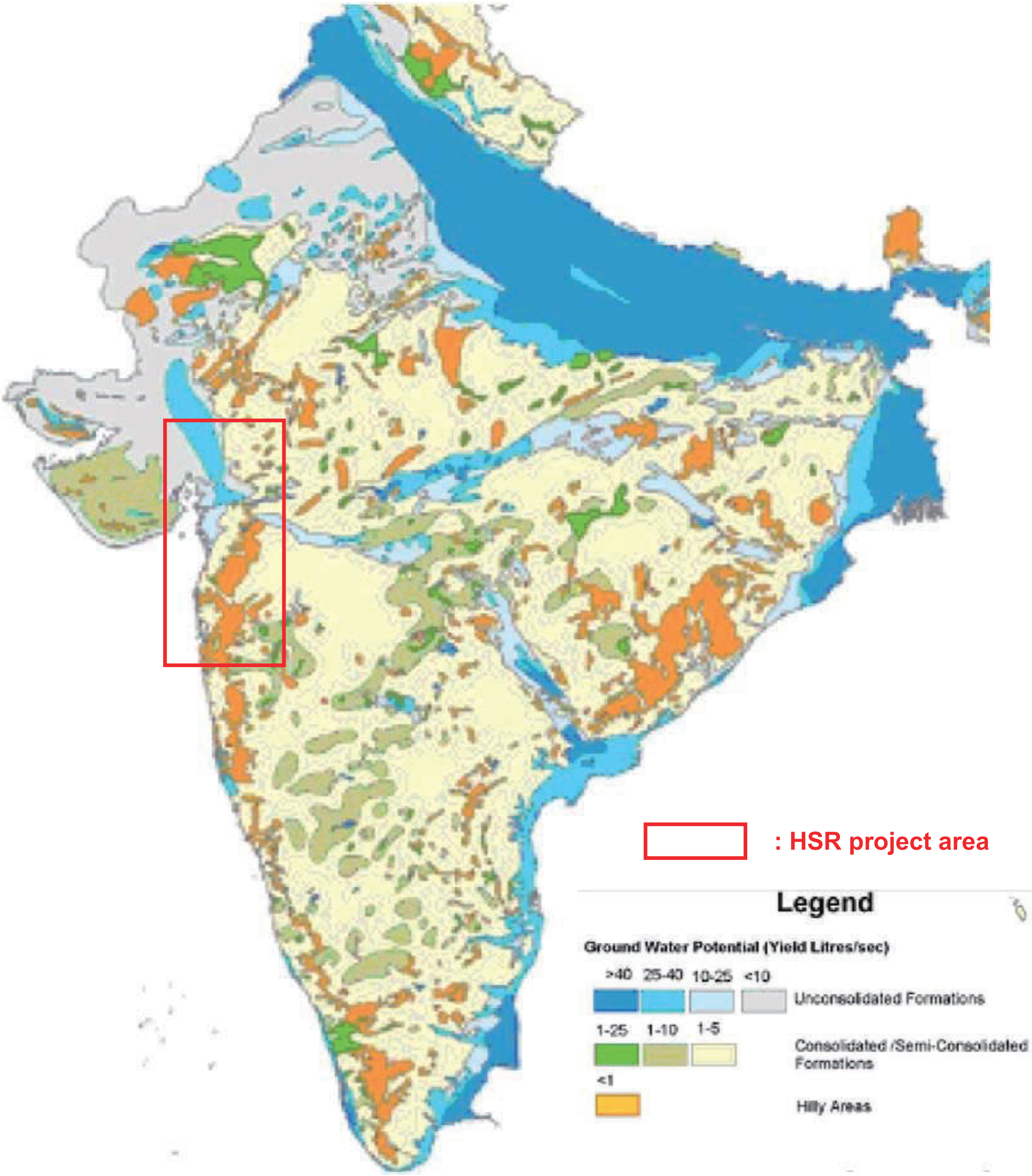
In India, the ground water behavior is highly complicated due to the occurrence of diversified geological formations with considerable lithological and chronological variations, complex tectonic framework, climatological dissimilarities and various hydrochemical conditions.
The aquifer system in India with their Ground water potential is given in Table 6.3-15.
Hydrogeological map of India is depicted in Figure 6.3-34.

In India, the regime monitoring has been started in the year 1969 by Central Ground Water Board. At present a network of 15,653 observation wells located all over the country is being monitored. The important attributes of ground water regime monitoring are ground water level, ground water quality and temperature. The primary objective of establishing the ground water monitoring network stations is to record the response of ground regime to the natural and anthropogenic stresses of recharge and discharge parameters with reference to geology, climate, physiography, land use pattern and hydrologic characteristics. The natural conditions affecting the regime involve climatic parameters like rainfall, evapotranspiration etc., whereas anthropogenic influences include pumpage from the aquifer, recharge due to irrigation systems and other practices like waste disposal etc.
Ground water levels are being measured four times a year during January, April/ May, August and November.

Table 6.3-15 Aquifer System in India

System	Coverage	Ground Water System
Unconsolidated formations- alluvial	Indo-Gangetic, Brahmaputra plains	Enormous reserves down to 600 m depth. High rain fall and hence recharge is ensured. Can support large-scale development through deep tube wells
	Coastal Areas	Reasonably extensive aquifers but risk of saline water intrusion
	Part of Desert area – Rajasthan and Gujarat	Scanty rainfall. Negligible recharge. Salinity hazards. Availability at great depths.
Consolidated/semiconsolidated formations - sedimentaries, basalts and crystalline rocks	Peninsular Areas	Availability depends on secondary porosity developed due to weathering, fracturing etc. Scope for GW availability at shallow depths (20-40 m) in some areas and deeper depths (100-200 m) in other areas. Varying yields.
Hilly	Hilly states	Low storage capacity due to quick runoff

Source: Ground Water Year Book India 2012-2013



Source: Ground Water Year Book India 2012-2013

Figure 6.3-34 Hydrogeological Map of India

(2) Recent Ground Water Level in Year2012 of Maharashtra & Gujarat

The ground water level at around HSR route ranged over Maharashtra and Gujarat for recent four seasons as Pre Monsoon 2012, August 2012, Post Monsoon 2012 and January 2013 is shown in Figure 6.3-35.

・The data for Pre Monsoon 2012 indicates that the ground water level in the west coast is mostly 5-10 m. Some isolated area of water level 2 -5m have been also observed at North of Mumbai. Also, some isolated pocket of depth 10-20m has been observed between Surat and Vadodara.
・The data for August 2012 indicates that the ground water level is generally less than 5 m in the west coast between West Maharashtra to South Gujatat. Specially northern of Mumbai and surrounding of Surat is water level less than 2 m has also been observed.
・The data for Pre Monsoon 2012 indicates that HSR route area the depth to ground water level varies under 10 meter. Generally, West Maharashtra is more shallow water level than South Gujarat.
・The data for January 2013 indicates that western coast of Maharashtra generally the depth to water level varies from 2-5 meter below ground level. At some part isolated pockets of water level less than 2m has also been observed. In the South Gujarat the water level varies under 10m.
・Generally, it is common for four season that the water level is more shallow at surrounding of Mumbai than Ahmedabad.

(3) Annual Water Fluctuation in Year2012 of Maharashtra & Gujarat

The annual water level fluctuation at around HSR route ranged over Maharashtra and Gujarat for recent four periods as Pre Monsoon 2011 to 2012, August 2011 to 2012, Post Monsoon 2011 to 2012 and January 2012 to 2013 is shown in Figure 6.3-36.

・A comparison of water level of Pre Monsoon 2011 with Pre Monsoon 2012 reveals that most of the wells have been showing fall of water level in the range of 0-2 m in West Maharashtra. Some isolated pockets are observed as fall more than 2m has been observed at West Maharashtra. South Gujarat both shows both of fall and rise less than 2m.
・A comparison of water level of August 2011 with August 2012 reveals that most of the wells at South Gujarat have been showing rise of water level in the range of 0-2 m.
Both of rise and fall in water level less than 2m has also been observed at West Maharashtra.
・A comparison of water level of November 2011 with November 2012 reveals that most of the wells at South Gujarat and West Maharashtra have been showing rise of water level in the range of 0-4 m. Some isolated pocket area of rise 2m has been observed at around Vadodara.
・A comparison of water level of January 2012 with January 2013 reveals that most of the wells at South Gujarat have been showing fall of water level in the range of 0-2 m. Rise in water level in the range of 0-2 m is observed in West Maharashtra.
・In general aspect for HSR route area, the water level in 2012 was higher than 2011 in August and Post Monsoon, whereas 2012 was lower in Pre Monsoon and January.

(4) Seasonal Water Level Fluctuations in Year2012 of Maharashtra & Gujarat

The seasonal water level fluctuation at around HSR route ranged over Maharashtra and Gujarat for recent three periods as Pre Monsoon 2012 to August 2012, Pre monsoon 2012 to November 2012, Post Monsoon 2012 to January 2013 is shown in Figure 6.3-37.

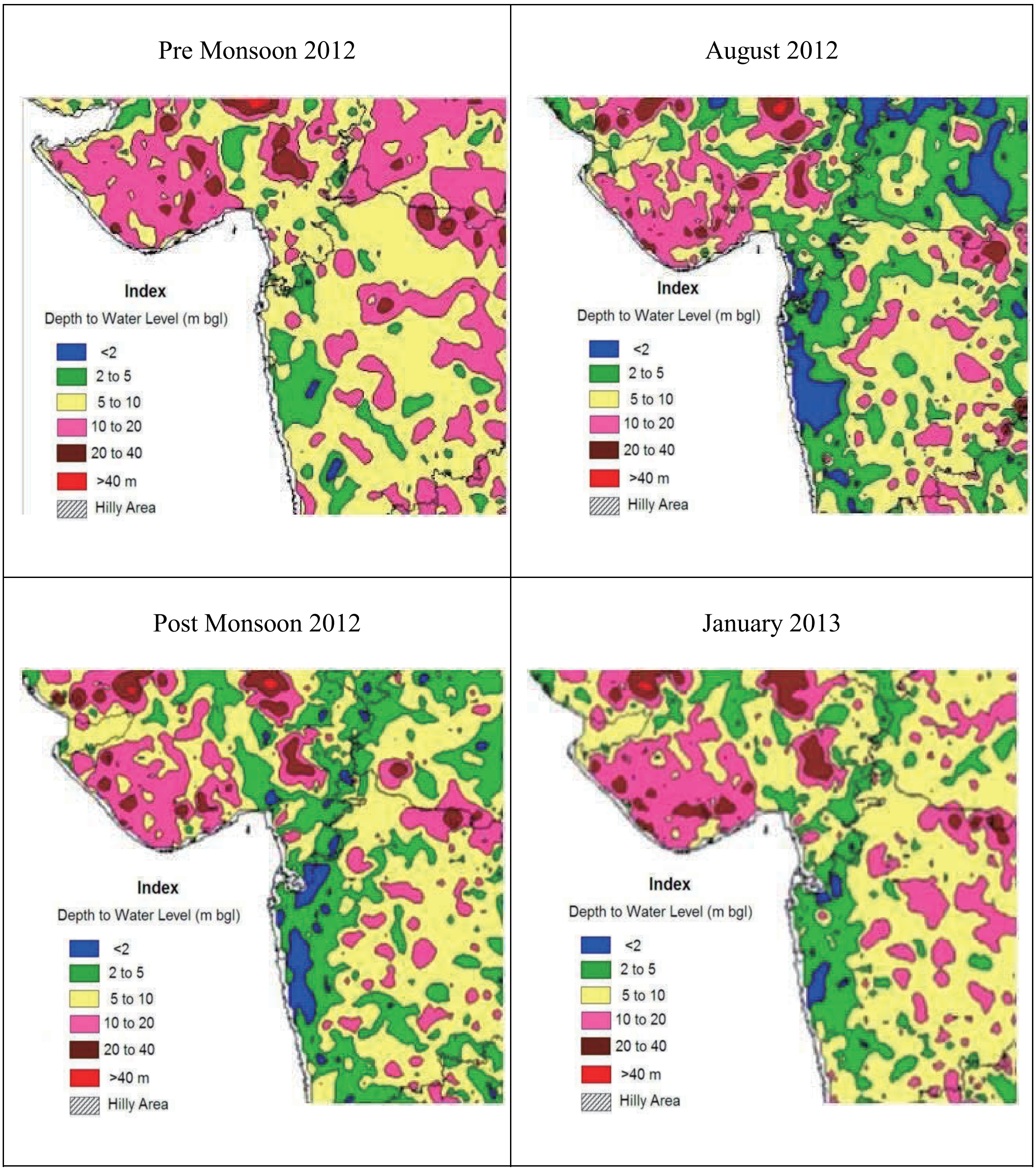
・A comparison of water level during Pre Monsoon 2012 with August 2012 reveals that almost all of South Gujarat and West Maharashtra is rise of water level. At West Maharashtra, more than 4m rise has been observed.

・A comparison of water level during Pre Monsoon 2012 with November 2012 reveals that most of South Gujarat and West Maharashtra is rise of water level. At West Maharashtra, more than 2m rise has been observed.
・A comparison of water level during Pre Monsoon 2012 with January 2013 reveals that mostly South Gujarat and West Maharashtra is rise of water level. At West Maharashtra, more than 2m rise has been observed.
・In general aspect for HSR route area, the ground water level is in Pre Monsoon was lowest among four season of Year2012.

(5) Decadal Water Level Fluctuations in Year2012 of Maharashtra & Gujarat

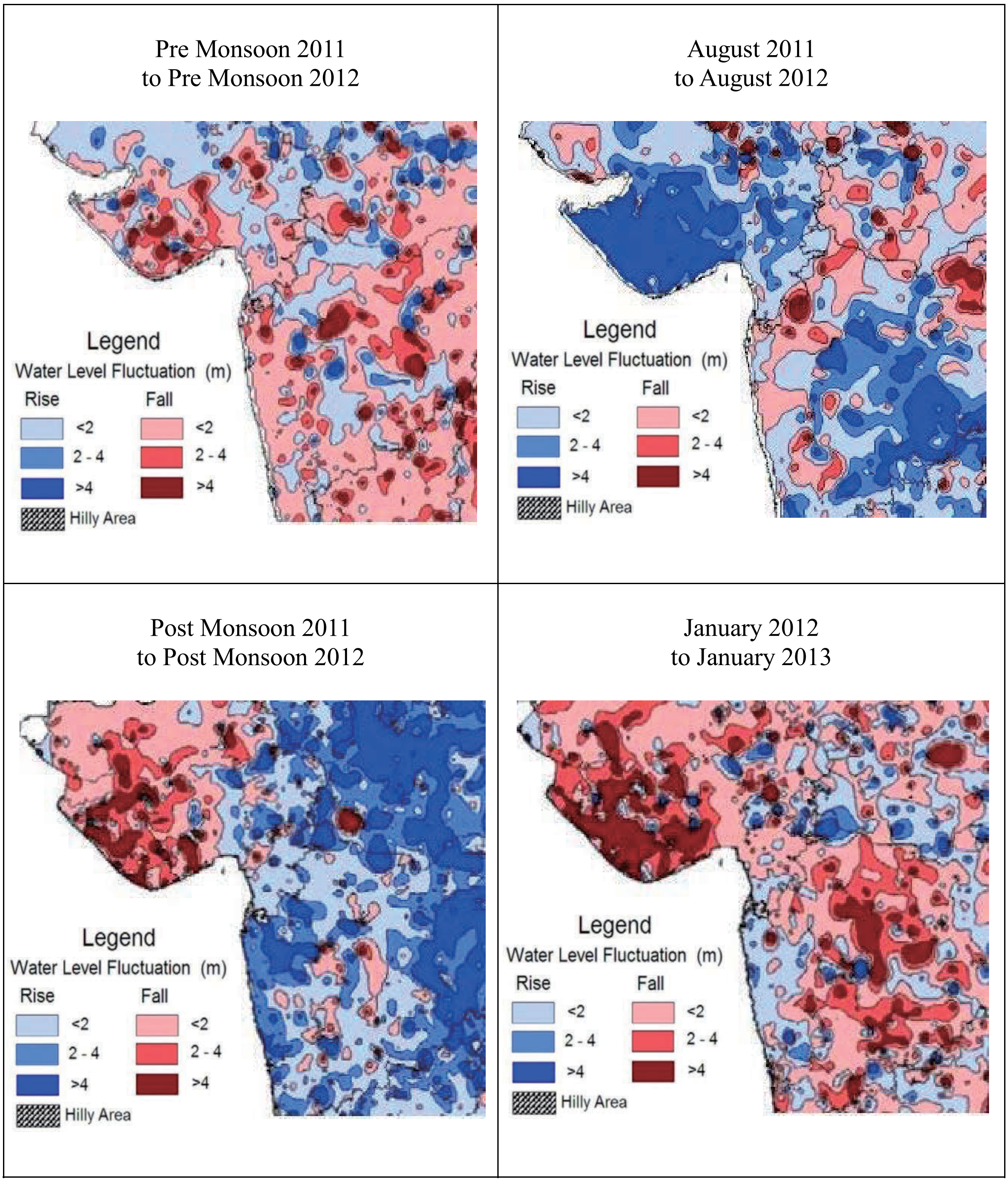
The decadal water level fluctuation at around HSR route ranged over Maharashtra and Gujarat for four periods as Pre Monsoon 2012 with decadal mean Pre Monsoon (2002-2011), August 2012 with decadal mean August (2002-2011), November 2012 with decadal mean November (2002-2011), January 2013 with decadal mean January (2003-2012) is shown in Figure 6.3-38.

・A comparison of water level of Pre Monsoon 2012 with decadal mean Pre Monsoon (2002-2011) reveals that there is both rise less than 2 m and fall less than 2m rise at South Gujarat and West Maharashtra. Surrounding of Mumbai is fall whereas surrounding of Ahmedabad is rise.
・A comparison of water level of August 2012 with decadal mean August (2002-2011) reveals that there is both rise less than 2 m and fall less than 2m rise at South Gujarat and West Maharashtra. Surrounding of Mumbai and Ahmedabad is fall whereas surrounding of Surat is rise.
・A comparison of water level of November 2012 with decadal mean November (2002-2011) reveals that there is both rise and fall with various depth at South Gujarat and West Maharashtra. Surrounding of Mumbai is rise whereas surrounding of Ahmedabad is rise.
・A comparison of water level of January 2013 with decadal mean January (2003-2012) reveals that there is both rise and fall with various depth at South Gujarat and West Maharashtra. Surrounding of Mumbai is rise whereas surrounding of Ahmedabad is fall.



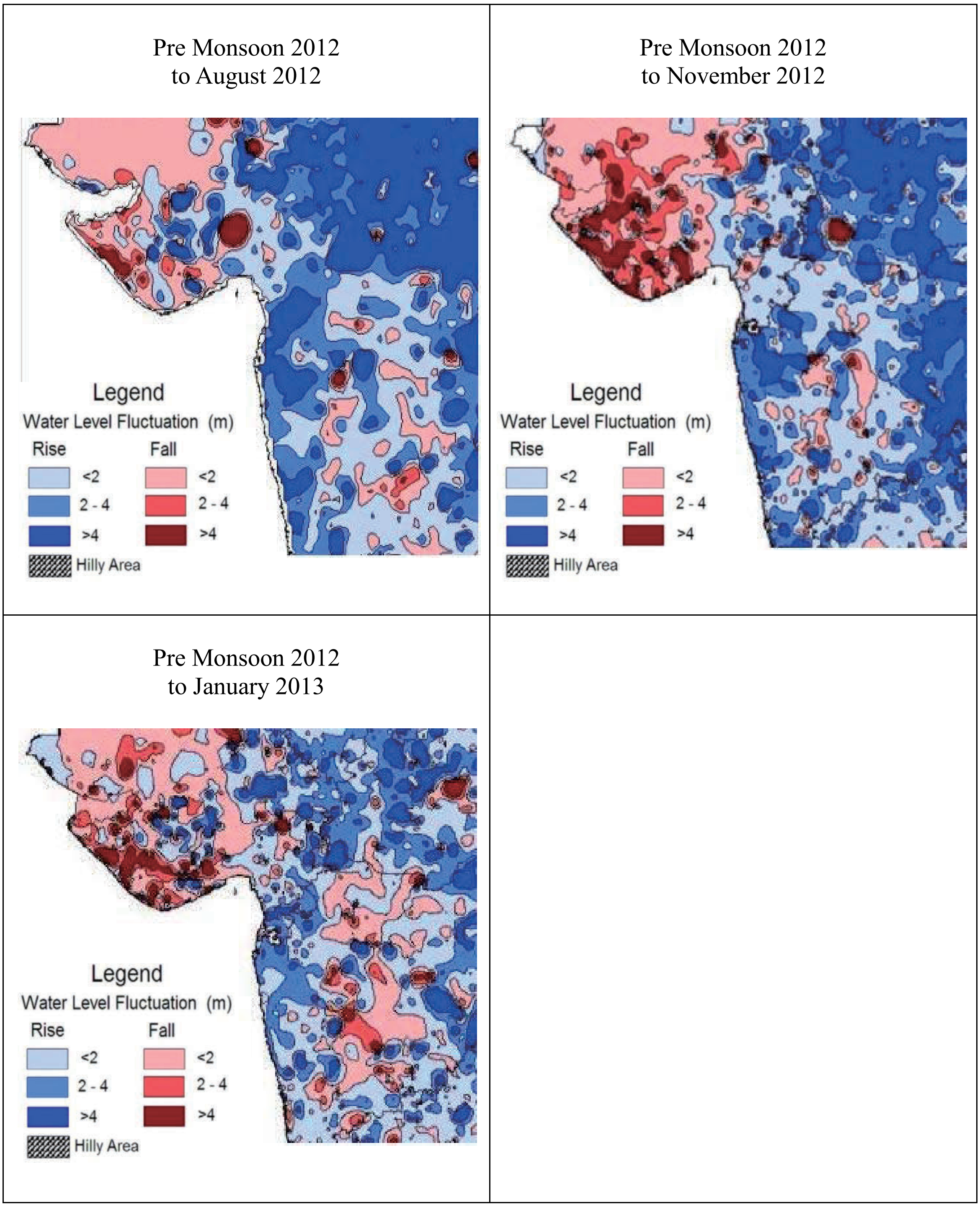
Source: Ground Water Year Book India 2012-2013

Figure 6.3-35 Recent Ground Water Level at a Glance



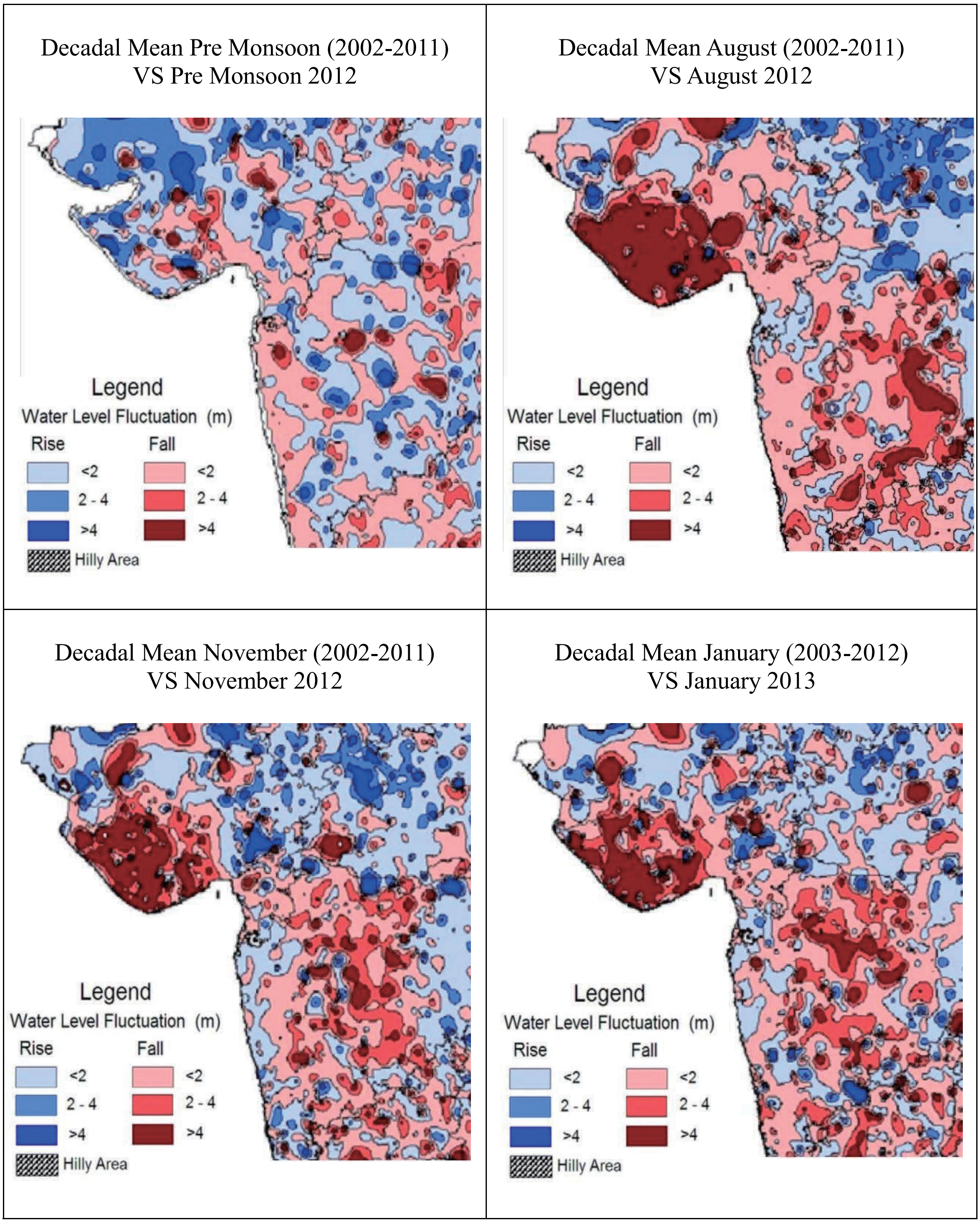
Source: Ground Water Year Book India 2012-2013

Figure 6.3-36 Annual Water Level Fluctuation at a Glance



Source: Ground Water Year Book India 2012-2013

Figure 6.3-37 Seasonal Water Level Fluctuation at a Glance



Source: Ground Water Year Book India 2012-2013

Figure 6.3-38 Decadal Water Level Fluctuation at a Glance

6.3.4 Water Quality

The observation stations for water quality in India are maintained by two apex organizations. Namely, Central Water Commission (hereafter called as CWC) and Central Pollution Control Board (Hereafter called as CPCB).

CWC is monitoring water quality at 390 locations covering all the major river basins of India. CWC is maintaining a three tier laboratory system for analysis of the parameters. The level-I laboratories are located at 258 field water quality monitoring stations on various rivers of India where physical parameters such as temperature, color, odor, specific conductivity, total dissolved solids, pH and dissolved oxygen of river water are observed. There are 23 level–II laboratories located at selected division offices to analyze 25 nos. physico- chemical characteristics and bacteriological parameters of river water.4 level-III/II+ laboratories are functioning at Varanasi, Delhi, Hyderabad and Coimbatore where 41 parameters including heavy metals/toxic parameters and pesticides are analyzed.
The water quality data by CWC observation are disseminated by India- WRIS Web GIS

On the other hand, CPCB established a nationwide network of water quality monitoring comprising 2,500 stations in 28 States and 6 Union Territories. The monitoring is done on monthly or quarterly basis in surface waters and on half yearly basis in case of ground water. The monitoring network covers 445 Rivers, 154 Lakes, 12 Tanks, 78 Ponds, 41 Creeks/Seawater, 25 Canals, 45 Drains, 10 Water Treatment Plant (Raw Water) and 807 Wells. Among the 2500 stations, 1275 are on rivers, 190 on lakes, 45 on drains, 41 on canals, 12 on tanks, 41 on creeks/seawater, 79 on ponds, 10 Water Treatment Plant (Raw Water) and 807 are groundwater stations. Water samples are being analyzed for 28 parameters consisting of 9 core parameters, 19 other physico-chemical and bacteriological parameters apart from the field observations.
The water quality data by CPCB observation can be available by CPCW web-site.

In the water quality data actually obtained from CPCW web-site, eight parameters for water quality observed in 2011 for each monitoring location are available. The item of each parameter and its characteristic is explained in Table 6.3-16.

The data contains the records of water quality in several large rivers in Maharashtra and Gujarat where HSR route crosses. From these data, the monitoring location assumed to be closed to HSR route is selected and summarized in Table 6.3-17.

Table 6.3-16 Monitoring Parameters Available in CPCB Web-site

Parameters	Description
Temperature	Water temperature effects on the chemical change of obstacle dissolved in water or activity of organism. The amount of organism activities depends on the water temperature.
D.O. (Dissolved Oxygen)	D.O. indicates the amount of oxygen in water. The value become lower if the contamination by organic substance is larger.
PH	PH indicates acidity, neutrality or alkalinity of water. It shows high alkalinity when CO2 was decreased for photosynthesis of phytoplankton. Sudden change of PH value is seen if incoherent substance was mixed into the water.
Conductivity	Conductivity indicates the electric conductivity in water. Because high conductivity is caused from dissolve of various substance in water, the value is used to judge a contamination.
B.O.D. (Biochemical oxygen demand)	B.O.D. indicates the amount of oxygen consumed when organic substance is resolved by aerobic microorganism. The water causes bad-smelling if the value of B.O.D. become higher.
Nitrate	Nitrate induces algae and moss in the water. Also, it causes decrease of PH. It results in the change of water quality for the worse.
Fecal Coliform	Fecal coliform indicates the amount of bacteria parasiticed in enteric of human or animals. It directly shows contamination of water.
Total Coliform	Total coliform indicates the total amount of bacteria which includes not only fecal coliform but also all bacteria widely distributed in natural field such as water and soils.

Source: Study Team

Table 6.3-17 Water Quality for Major Rivers in 2011

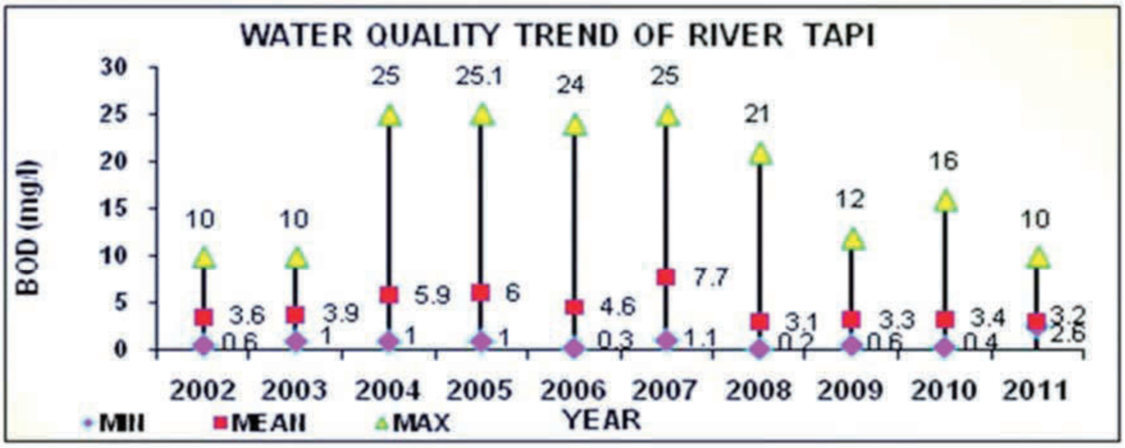
RIVER	LOCATIONS	TEMPERATURE °C			D.O. (mg/l)			pH			CONDUCTIVITY (µmhos/cm)			B.O.D. (mg/l)			NITRATE- N+ NITRITE-N (mg/l)			FECAL COLIFORM (MPN/100ml)			TOTAL COLIFORM (MPN/100ml)		
		Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean
Water Quality Criteria					> 4 mg/l			6.5-8.5						< 3 mg/l						< 2500 MPN/100ml			< 5000 MPN/100ml		
Ulhas River	At U/S of NRC bund at Mohane, Maharashtra	22.0	30.0	25.9	5.8	7.3	6.8	7.2	8.4	7.8	128	202	151	2.0	4.8	3.4	0.26	0.78	0.50	35	1800	601	110	1800	740
	At U/S of Badlapur	22.0	30.0	25.9	6.0	7.4	7.0	7.5	8.5	7.8	77	175	123	2.8	4.6	3.4	0.19	0.82	0.44	17	70	42	50	170	100
	At Jambhul Water Works	22.0	30.0	26.0	6.5	7.6	6.9	7.4	8.4	7.8	87	181	139	2.6	4.0	3.3	0.19	2.01	0.76	25	200	85	0	350	169
Vaitarna River	Near road bridge,Gandhare Village, Wada, Thane	22.0	30.0	26.9	5.7	7.6	6.8	7.3	9.4	8.2	77	930	313	3.0	10.0	4.0	0.08	1.15	0.49	11	140	49	40	250	99
Daman Ganga	At Vapi Weir, Vapi	27.1	28.3	27.7	6.6	6.7	6.7	8.0	9.0	8.5	196	273	235	N/A	N/A	N/A	2.80	3.40	3.10	N/A	N/A	N/A	N/A	N/A	N/A
	At D/S of M/S Surat Beverages, Village, Dadra	27.1	27.1	27.1	6.7	6.9	6.8	7.2	8.3	7.8	221	233	227	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	At Village Namdha, Vapi	27.0	27.0	27.0	4.2	4.2	4.2	8.2	8.2	8.2	2754	2754	2754	42.0	42.0	42.0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	At Kachigaon U/S at GIDC wier	25.0	30.0	27.6	6.8	7.4	7.1	7.0	8.3	7.3	120	350	212	0.7	5.0	1.4	0.04	2.29	0.84	3	4	3	3	11	6
Tapi River	At Mandavi	27.0	28.0	27.7	7.2	7.6	7.4	7.8	8.1	8.0	318	390	359	1.5	2.5	1.9	0.02	0.32	0.22	230	900	677	930	2100	1510
	At Kathore (NH-8 bridge)	26.0	29.0	27.5	7.0	7.4	7.2	7.2	8.0	7.7	495	563	535	1.7	2.1	2.0	0.30	0.40	0.30	33	900	566	930	2800	1908
	AT Surat U/S Kathore	26.0	29.0	27.5	6.9	7.3	7.1	7.8	8.1	8.0	472	585	525	1.5	2.2	1.9	0.20	0.30	0.30	900	1500	1058	2100	4300	2775
	At Rander Bridge, Surat	27.0	27.0	27.0	6.8	7.1	7.0	7.8	7.9	7.9	621	697	659	1.2	2.6	1.9	0.09	0.45	0.27	900	1500	1200	2000	2300	2150
	At NR Bardoli (KAPP Bridge)	27.0	31.0	29.0	5.5	6.7	6.1	7.8	7.9	7.9	339	364	352	2.1	2.7	2.4	0.17	0.28	0.23	400	4300	2350	2300	24000	13150
	AT ONGC Bridge, Surat	26.0	28.0	27.5	3.2	5.6	4.4	7.1	7.9	7.5	2417	41836	25418	2.5	9.0	4.9	0.10	0.40	0.20	430	9000	2815	1500	15000	5850
Narmada River	At Chandod	25.0	29.0	26.4	6.9	8.2	7.6	7.1	8.4	7.9	222	404	274	1.1	5.0	2.3	0.07	0.34	0.18	0.6	14	5	4	34	16
Mahi River	At Sevalia	25.0	28.0	26.6	6.9	8.3	7.6	7.4	8.7	8.1	291	490	418	0.9	5.0	3.3	0.00	0.92	0.22	2	6	3	7	17	9
	At Vasad	25.0	25.0	25.0	8.8	8.8	8.8	8.3	8.3	8.3	561	561	561	2.0	2.0	2.0	0.38	0.38	0.38	3	3	3	9	9	9
Sabarmati River	At Mahudi Jain Temple, 150m from Origin	22.0	22.0	22.0	7.1	7.1	7.1	8.1	8.1	8.1	506	506	506	4.0	4.0	4.0	0.47	0.47	0.47	90	90	90	430	430	430

Source : Basin Wise Water Quality Data 2011 by C.P.C.B

(1) Water Quality Trend of BOD

B.O.D. is one of parameters mostly referred for evaluation of water quality. B.O.D. indicates the amount of oxygen consumed when organic substance is resolved by aerobic microorganism.
In CPCB web-site, the trend of B.O.D. in a decade for each major rives of India is summarized. Here, the trend of B.O.D. in Tapi River, Narmada River, Mahi River and Sabarmati River depicting the data from 2002 to 2011 is selected as shown in Figures 6.3.39 – Figure 6.3.42.

These figures show different trend in each river as below;
-Tapi River: B.O.D value has been increased till year 2007 and it felt back as before after 2008.
-Narmada River: B.O.D value has kept low in a decade, although it little goes up recently.
-Mahi River: B.O.D. value has been gone-up and gone-down but basically settled under 2.5.
-Sabarmati River: B.O.D. value was quite high till year 2007. The value has been largey decreased from 2004 to 2007.



Source: Central Pollution Control Board web-site

Figure 6.3-39 Water Quality Trend of Tapi River

Source: Central Pollution Control Board web-site

Figure 6.3-40 Water Quality Trend of Narmada River

Source: Central Pollution Control Board web-site

Figure 6.3-41 Water Quality Trend of Mahi River

Source: Central Pollution Control Board web-site

Figure 6.3-42 Water Quality Trend of Sabarmati River

6.3.5 Hydrological Data Collection for Preliminary Survey of Alignment

Hydrological Data were collected from DFC (Dedicate Freight Corridor).
Table 6.3-18 shows large river crossing with HSR route.

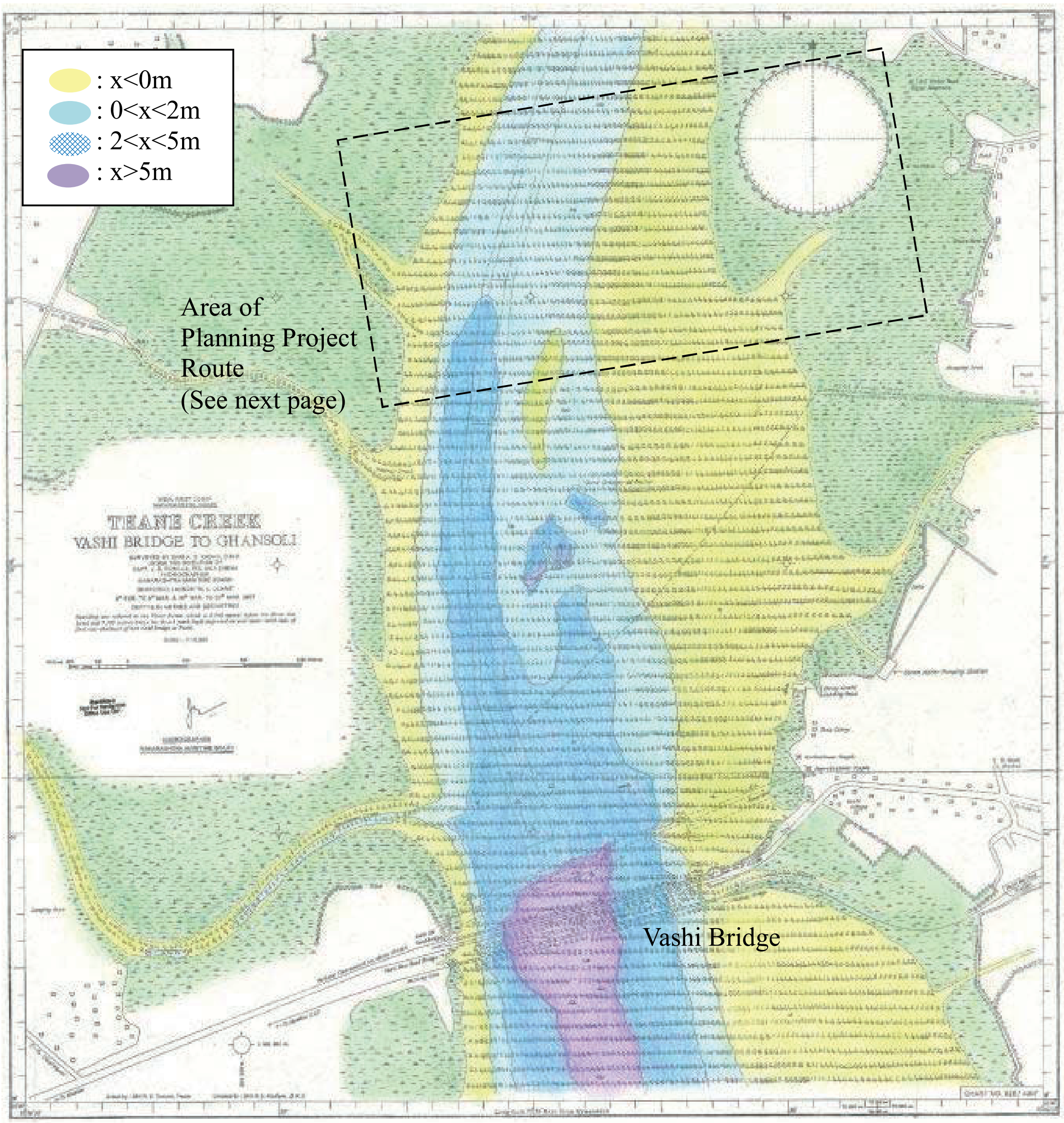
Table 6.3-18 Large Rivers Crossing with HSR Route

Name	
Ulhas River	Purna River
Branch of Ulhas River	Mindhola River
Vaitarna River (S)	Tapi River
Vaitarna River (N)	Kim River
Daman Ganga	Narmada River
Kolak River	Dhadhar River
Par River	Mahi River
Aurange River	Mohar River
Kaveri River (S)	Vatrak River
Kaveri River (N)	Meshwa River
Ambica River	Sabarmati River

6.4 Water Depth in Thane Creek

6.4.1 Mean Sea Level

The nautical chart of Thane Creek from Vashi bridge to Ghansoli was obtained.
The chart was surveyed by Shri A. S. Kadam, D.H.S. under the Direction of CAPT. J. B. Rohilla, FIS, MCA (INDIA), Hydrographer Maharashtra Maritime Board on 9th Feb to 8th Mar and 16th Mar to 20th Mar 2007.
The chart indicates reduced depth of water in each interval with contour line. Figure 6.4-1 shows the chart drawn by different colors in each contour layer for easy understanding.



Source : Thane Creek Vashi Bridge to Ghansoli (Added info. by Study Team)

Figure 6.4-1 Nautical Chart for Thane Creek

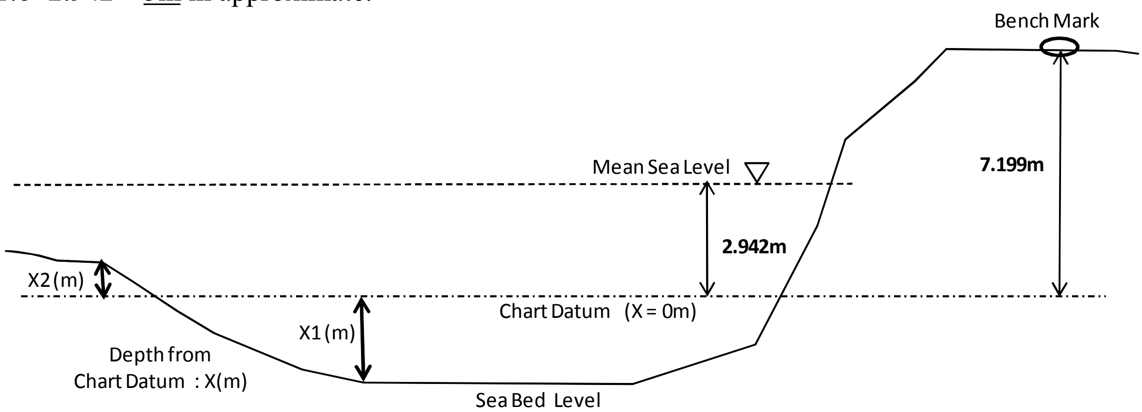
As a notification, it is mentioned on the chart that “Sounding are reduced to the Chart Datum which is 2.942 metres below the Mean Sea Level and 7.199 metres below the Bench mark B_M engraved on wall stone north side of first east abutment of new road bridge at Vashi.”

Therefore, the relation between Bench Mark, Mean Sea Level and Chart Datum (X=0m) in the chart can be understood as Figure 6.4-2 below.

According to the Figure 6.4-1, the reduced depth at around center of Vashi Bridge can be read approximately 8m. By considering the relation above, the depth from Mean Sea Level to Sea Bed Level at around center of Vashi Bridge should become 8+2.942 ≒11m in approximate.

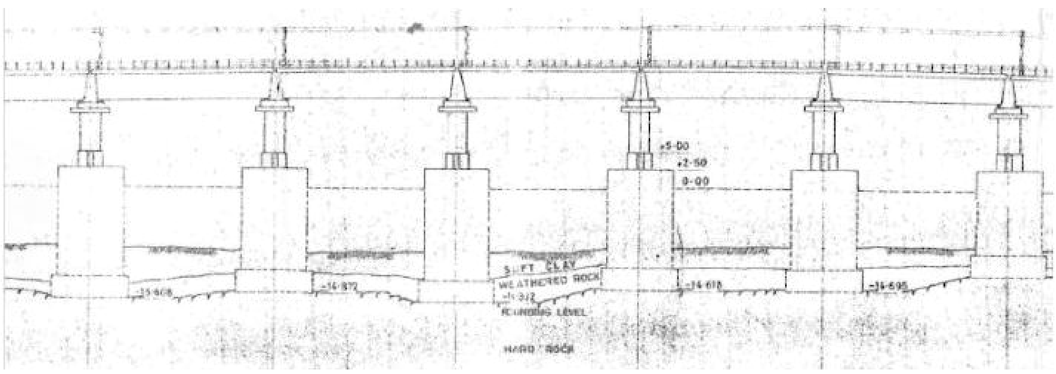
The reliability of the depth also could be confirmed by the design drawing of Vashi Railway Bridge sanctioned in 1983 (Figure 6.4-3.) The depth at around Vashi Bridge is consistency with the drawing which shows the depth from the Water Level to Sea Bed Level at around center of Vashi Bridge as about 10m.

Figure 6.4-4 shows also the chart but extracted neighbor of planning project route. The reduced depth along the route can be read as the range between -2m and 1.8m. By considering the relation above, the depth from Mean Sea Level to Sea Bed Level at deepest point along the route should be 1.8+2.942≒<u>5m</u> in approximate.



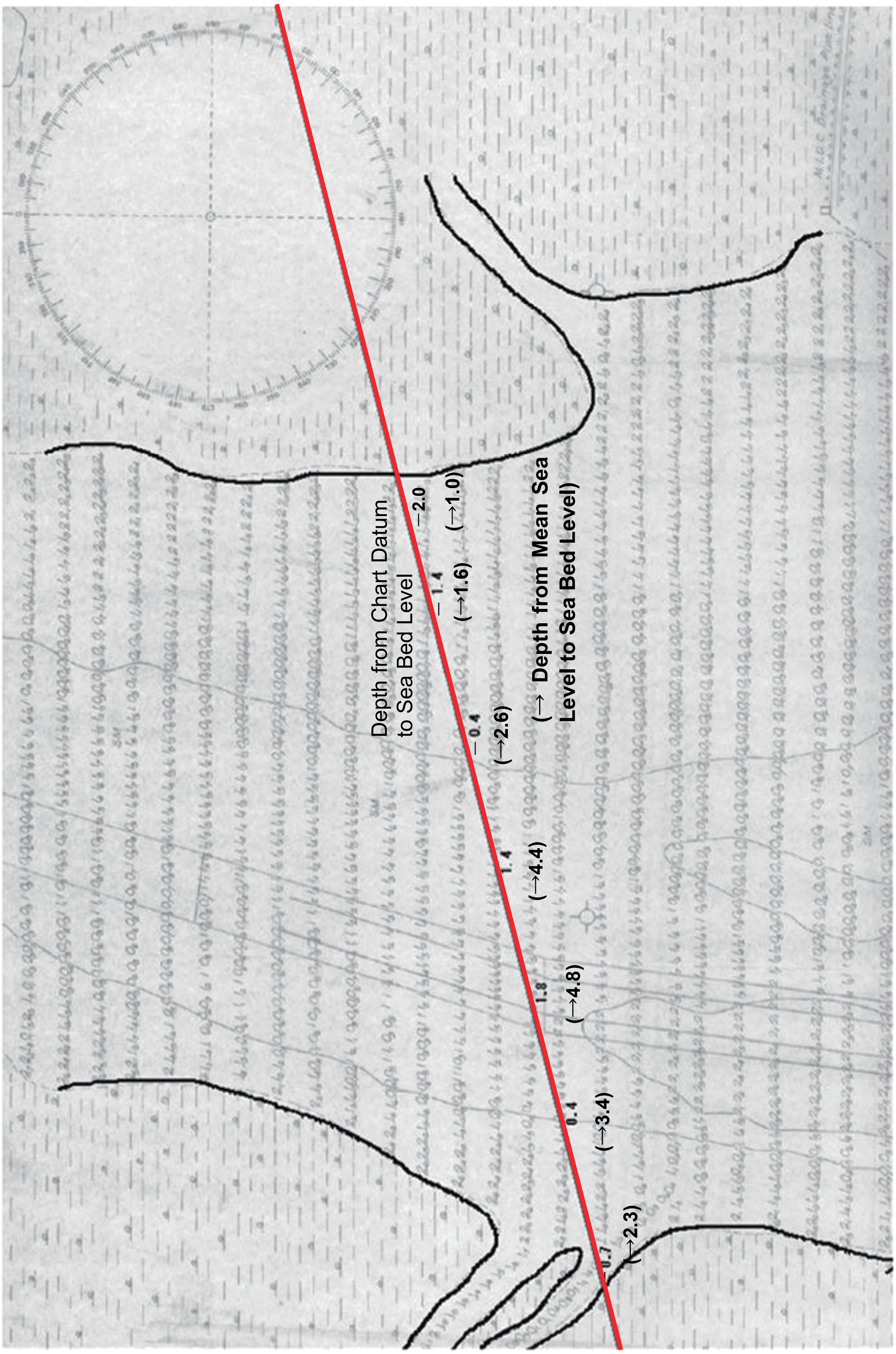
Source : Study Team

Figure 6.4-2 Relation between Bench Mark, Mean Sea Level and Chart Datum



Source : Extension of Railway Line

Figure 6.4-3 Vashi Railway Bridge



Source : Thane Creek Vashi Bridge to Ghansoli (Added info. by Study Team)

Figure 6.4-4 Nautical Chart around planning project route

6.4.2 Tidal Level

The table of "Harmonic Tidal Constants and Tidal Levels of Minor-Ports of Maharashtra" was obtained as shown in Table 6.4-1.

According to Table 6.4-1, the harmonic tidal constants which compose the tidal level majorly in India are such as M2, S2 and K2. By harmonic of these factors, the astronomical tidal level such as M.H.W.S., M.L.W.S, M.H.W.N., M.L.W.N. and etc. is obtained as in Table 6.4-1. Arbitration for harmonic tidal constant is shown in Table 6.4-2.

In Table 6.4-1, the port of Vashi Bridge is one of nearest location for the planning project route. Hence, the relation of each tidal level at Vashi Bridge port is figured as Figure 6.4-5.

As is seen in Figure 6.4-5, Mean spring Range indicates the difference between M.H.W.S. and M.L.W.S.. and valued as 3.7306m. If the Mean Sea Level was defined as the average between M.H.W.S and M.L.W.S., it become to 3.7306/2 + 1.0767 =2.942m. It results in the exact consistency with the depth from Mean Sea Level to Chart Datum explained in Chapter 6.4.1.

Here, the difference between Mean Sea Level and M.H.W.S. can be calculated as 4.8073 – 2.942 = 1.8653m. Also, the difference between Mean Sea Level and H.H.W. can be become 5.3559 – 2.942 =2.4139m.

Because the depth from Mean Sea Level to Chart Datum along the planning project route is about 5m in deepest point, Sea Water Level in maximum case of H.H.W. along the route can be calculated as 5+2.4≒7.5m.

Table 6.4-1 Harmonic Tidal Constants and Tidal Level of Minor Ports of Maharashtra

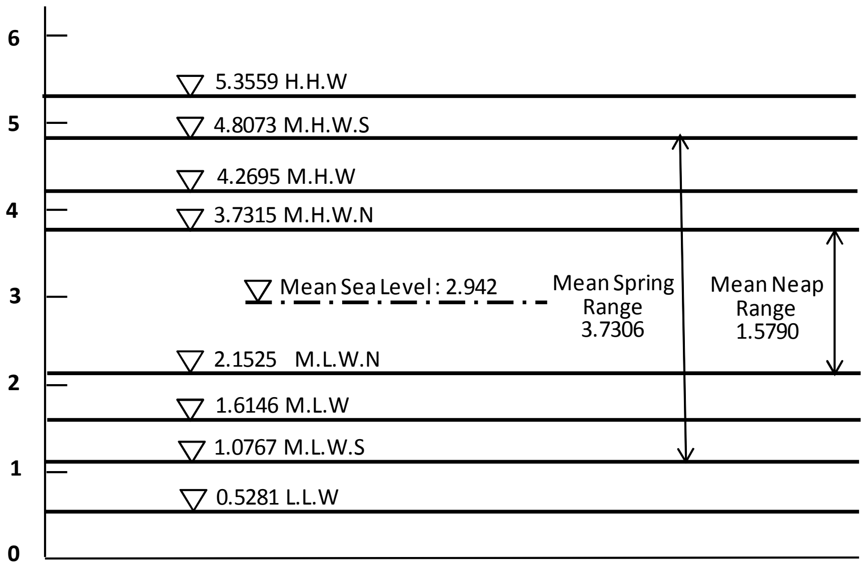
Sl. No	Ports	So	Zo	M_2	S_2	K_2	H.H.W.	L.L.W	M.H. W.S.	M.L. W.S.	M.H W.N.	M.L. W.N.	M.H.W.	M.L.W.	Mean spring range	Mean Neap range
1	DAHANU	1.960	2.835	1.449	0.594	0.162	5.4810	0.1890	4.878	0.792	3.690	1.980	4.284	1.386	4.086	1.710
2	SATPATI	4.941	3.091	1.304	0.513	0.140	5.4394	0.7426	4.908	1.274	3.882	2.300	4.395	1.787	3.634	1.582
3	KELVA-MAHIM	3.095	2.860	1.267	0.530	0.144	5.1892	0.5308	4.657	1.063	3.597	2.123	4.127	1.593	3.594	1.474
4	ARNALA	5.277	2.700	1.228	0.482	0.131	4.9092	0.4908	4.410	0.990	3.446	1.954	3.928	1.472	3.420	1.492
5	BASSIEN	2.029	2.530	1.200	0.440	0.119	4.6408	0.4192	4.170	0.890	3.290	1.770	3.730	1.330	3.280	1.520
6	VERSOVA	3.554	2.509	1.143	0.462	0.126	4.5862	0.4318	4.114	0.904	3.190	1.828	3.652	1.366	3.210	1.362
7	BANDRA	5.510	2.499	1.147	0.434	0.118	4.5378	0.4602	4.080	0.918	3.212	1.786	3.646	1.352	3.162	1.426
8	BOMBAY (AP.B)	3.124	2.515	1.227	0.479	0.130	4.7182	0.3118	4.221	0.809	3.263	1.767	3.742	1.288	3.898	1.496
9	THANE (S.B.)	3.251	2.819	1.407	0.542	0.148	5.3354	0.3026	4.768	0.870	3.684	1.954	4.226	1.412	3.898	1.730
10	VASHI BRIDGE	2.0762	2.9420	1.3274	0.5379	0.1463	5.3559	0.5281	4.8073	1.0767	3.7315	2.1525	4.2695	1.6146	3.7306	1.5790
11	KASHELI BRIDGE	2.726	2.357	1.165	0.386	0.105	4.3442	0.3698	3.908	0.806	3.136	1.578	3.522	1.192	3.102	1.558
12	MORA	1.583	2.592	1.267	0.495	0.134	4.8672	0.3168	4.354	0.830	3.364	1.820	3.859	1.325	3.524	1.544
13	REVAS	5.096	2.636	1.233	0.499	0.136	4.8776	0.3944	4.368	0.904	3.370	1.902	3.869	1.403	3.464	1.468
14	DHARAMTAR	4.5266	2.9577	1.3198	0.5363	0.1459	5.3601	0.5553	4.8138	1.1016	3.7412	2.1742	4.2775	1.6379	3.7122	1.5670
15	REVADANDA	2.938	2.225	1.031	0.393	0.107	4.0622	0.3878	3.649	0.801	2.863	1.587	3.256	1.194	2.848	1.276
16	ALIBAG	4.520	2.439	1.048	0.411	0.112	4.3242	0.5538	3.898	0.980	3.076	1.802	3.487	1.391	2.918	1.274
17	MURUD	3.966	2.164	0.987	0.383	0.104	3.9328	0.3952	3.534	0.794	2.768	1.560	3.151	1.177	2.740	1.208
18	AGARDANDA	2.5622	2.3804	1.0336	0.3876	1.054	5.3506	0.5898	3.920	0.9592	3.0264	1.7344	3.414	1.3468	2.8424	1.292
19	DIGHI	2.4836	2.2838	0.9934	0.3782	0.1029	4.0532	0.5144	3.6554	0.9122	2.899	1.6686	3.2772	1.2904	2.7432	1.2304
20	SHRIWARDHAN	4.081	2.018	0.909	0.350	0.095	3.6428	0.3932	3.277	0.759	2.577	1.459	2.927	1.109	2.518	1.118
21	BANKOT	2.318	1.960	0.845	0.307	0.084	3.4432	0.4768	3.112	0.808	2.498	1.422	2.805	1.115	2.304	1.076
22	HARNAI	3.391	1.853	0.842	0.329	0.089	3.3650	0.3410	3.024	0.682	2.366	1.340	2.695	1.011	2.342	1.026
23	DABHOL	4.228	1.676	0.792	0.372	0.0074	3.0416	0.3104	2.740	0.612	2.196	1.156	2.468	0.884	2.128	1.040

Source : Harmonic Tidal Constants and Tidal Levels of Minor Ports of Maharashtra

Table 6.4-2 Arbitrations for Harmonic Tidal Constants

	Arbitration	Description
Tidal level	H.H.W.	Higher High Water
	L.L.W.	Lower Low Water
	M.H.W.S.	Mean High Water Spring
	M.L.W.S.	Mean Low Water Spring
	M.H.W.N.	Mean High Water Neap
	M.L.W.N.	Mean Low Water Neap
	M.H.W.	Mean High Water
	M.L.W.	Mean Low Water
Harmonic tidal constants	M2	Principal lunar semi-diurnal tide
	S2	Principal solar semi-diurnal tide
	K2	Luni solar semi-diurnal tide

Source : Study Team



Source : Harmonic Tidal Constants and Tidal Levels of Minor-Ports of Maharashtra

Figure 6.4-5 Tidal Levels at Vashi Bridge Port