

## **Chapter – 4**

### **Surveys and Investigations**

#### **4.0 General**

Surveys and Investigations provide field data required for planning and designing of various components of a Water Resources Development Project. A project can be designed optimally and economically, only when necessary field data of specified standards are available. As such, NWDA has taken up extensive field surveys and investigations in the project area for the collection of data required for the preparation of Detailed Project Report (DPR) of Par-Tapi-Narmada link project, during the years 2009 to 2014, as per the guidelines contained in “Terms of Reference for Preparation of Detailed Project Report of Inter Basin Water Transfer Proposals” approved by Ministry of Water Resources (MoWR). These guidelines are by and large in harmony with the updated Guidelines for the preparation of DPR of Irrigation and Multipurpose Projects of MoWR issued subsequently in 2010.

Detailed surveys and investigations such as topographical surveys, geological and geotechnical investigations including drilling bore holes on dam axes for obtaining rock cores, construction material investigations including borrow area surveys, socio-economic, ecological and environmental impact assessment studies, seismo-tectonic studies etc. have been undertaken departmentally through various specialized organizations in order to examine the feasibility of the scheme.

However, while carrying out the topographical surveys and geotechnical investigations at the proposed dam sites and along the canal alignment, resentment against the project by local people has been encountered forcing NWDA’s field engineers to abandon all field surveys and investigations. The subsequent efforts made by NWDA to convince the local people with the help of public representatives and State Government agencies could not yield the desired results. Thus, the detailed surveys and investigations planned at various locations of the link project could not be completed fully. Therefore, in

respect of the components for which the detailed surveys and investigations could not be taken up /completed at DPR stage, the information based on the surveys and investigations carried out at Feasibility Report (FR) stage of the link project have been compiled and supplemented for preparation of DPR, as found necessary.

The Feasibility Report (FR) of Par-Tapi-Narmada Link Project was prepared by NWDA during October, 2005. As per this FR, the project envisages construction of the following components:

- (i) A 773.50 m long composite earth - cum - concrete dam at Jheri across river Par in Peint taluka of Nasik district of Maharashtra State with FRL 246 m and corresponding gross storage capacity of 186 Mm<sup>3</sup>;
- (ii) A 947 m long composite earth - cum - concrete dam at Mohankavchali across river Par in Kaprada taluka of Valsad district of Gujarat State with FRL 158 m and corresponding gross storage capacity of 347 Mm<sup>3</sup>;
- (iii) A 1306 m long composite earth - cum - concrete dam at Paikhed across river Nar, a tributary of river Par in Dharampur taluka of Valsad district of Gujarat State with FRL 248 m and corresponding gross storage capacity of 217 Mm<sup>3</sup>;
- (iv) A 2837 m long composite earth - cum - concrete dam at Chasmandva across river Tan, a tributary of Auranga river in Dharampur taluka of Valsad district of Gujarat State with FRL 214 m and corresponding gross storage capacity of 79 Mm<sup>3</sup>;
- (v) A 1656 m long composite earth - cum - concrete dam at Chikkar across river Ambica in Ahwa taluka of Dang district of Gujarat State with FRL 210 m and corresponding gross storage capacity of 129 Mm<sup>3</sup>;
- (vi) A 1046 m long composite earth - cum - concrete dam at Dabdar across river Khapri, a tributary of Ambica river in Ahwa taluka of Dang district

of Gujarat State with FRL 169 m and corresponding gross storage capacity of 204 Mm<sup>3</sup>;

- (vii) A 1284 m long composite earth - cum - concrete dam at Kelwan across river Purna in Ahwa taluka of Dang district of Gujarat State with FRL 164 m and corresponding gross storage capacity of 255 Mm<sup>3</sup>;
- (viii) Construction of three diversion barrages one each in the downstream of Paikhed, Chasmandva and Chikkar dams;
- (ix) Six power houses: one each at the toe of Jheri, Paikhed, Chasmandva and Chikkar dams; and one each at the falls of the feeder canals connecting Dabdar and Kelwan reservoirs to the main canal;
- (x) A 400 km long link canal (including feeder canals and two tunnels of total about 5.5 km long).

During preparation of FR of the link project the surveys and investigations were carried out by NWDA for all the above components except Mohankavchali dam and tunnel connecting Mohankavchali dam and Paikhed Barrage. Survey for Mohankavchali dam and tunnel could not be carried out due to public hindrance in the project area.

In the light of the various surveys and investigation works and other technical studies that could be carried out as part of DPR. DPR was completed by NWDA during August 2015 and submitted to concerned State Governments of Gujarat and Maharashtra. Government of Gujarat has given certain suggestions on the DPR. DPR has been modified considering suggestions of Government of Gujarat. The link project will now envisage construction of the following components:

- i A 808.32 m long composite embankment (concrete face rock fill) cum concrete dam across river Par near village Jheri with FRL 246.00 m and corresponding gross storage capacity 206.03 Mm<sup>3</sup>. The length of concrete face rock fill portion of the dam is 663.32 m and the length of

concrete non-overflow section and spill way is 145.00 m. The dam axis is located at Latitude 20°22'25" N and Longitude 73°25'51" E.

- ii) A 1431.85 m long composite embankment (concrete face rock fill) cum concrete dam across river Nar (a tributary of Par river) near village Paikhed with FRL 248.00 m and corresponding gross storage capacity of 229.53 Mm<sup>3</sup>. The length of concrete face rock fill portion of the dam is 1310.85 m and the length of concrete non-overflow section and spill way is 121.00 m. The dam axis is located at Latitude 20°27'42" N and Longitude 73°23'37" E;
- iii) A power house of 9 MW installed capacity at the toe of Paikhed dam with 3 units each of 3 MW.
- iv) A 2781.00 m long composite embankment (concrete face rock fill) cum concrete dam across river Tan (a tributary of Auranga river) near village Chasmandva with FRL 214.00 m and corresponding gross storage capacity of 83.63 Mm<sup>3</sup>. The length of concrete face rock fill portion of the dam is 2703.00 m and the length of concrete non overflow section and spill way is 78.00 m. The dam axis is located at Latitude 20°37'02" N and Longitude 73°22'36" E.
- v) A power house of 2 MW installed capacity at the toe of Chasmandva dam with 2 units each of 1 MW.
- vi) A 1887.00 m long composite embankment (concrete face rock fill) cum concrete dam across river Ambica near village Chikkar with FRL 210.00 m and corresponding gross storage capacity of 141.99 Mm<sup>3</sup>. The length of concrete face rock fill portion of the dam is 1736.00 m and the length of concrete non overflow section and spill way is 151.00 m. The dam axis is located at Latitude 20°42'00" N and Longitude 73°30'50" E.
- vii) A power house of 2 MW installed capacity at the toe of Chikkar dam with 2 units each of 1 MW.

- viii) A 1170.00 m long composite embankment (concrete face rock fill) cum concrete dam across river Khapri (a tributary of Ambica river) near village Dabdar with FRL 169.00 m and corresponding gross storage capacity 222.38 Mm<sup>3</sup>. The length of concrete face rock fill portion of the dam is 1035.00 m and the length of concrete non overflow section and spill way is 135.00 m. The dam axis is located at Latitude 20°48'58" N and Longitude 73°32'05" E.
- ix) A power house of 3.2 MW installed capacity at the toe of Dabdar dam with 2 units each of 1.60 MW.
- x) A 1330.00 m long composite embankment (concrete face rock fill) cum concrete dam across river Purna near village Kelwan with FRL 164.00 m and corresponding gross storage capacity of 282.17 Mm<sup>3</sup>. The length of concrete face rock fill portion of the dam is 1141.00 m and the length of concrete non overflow section and spill way is 189.00 m. The main dam is located at Latitude 20°55'30" N and Longitude 73°32'00" E.
- xi) A power house of 2.5 MW installed capacity at the toe of Kelwan dam with 2 units each of 1.25 MW.
- xii) A power house of 2 MW installed capacity at the fall of feeder pipe line connecting Kelwan dam with main link canal with 2 units each of 1 MW.
- xiii) A tunnel of about 12.70 km long with 3.00 m diameter (D shape) and bed slope of 1:875 connecting Jheri reservoir with Paikhed reservoir.
- xiv) A 147.50 m long barrage in the downstream of Paikhed dam with crest level of 136.00 m
- xv) A 128.00 m long barrage in the downstream of Chasmandva dam with crest level of 123.00 m.
- xvi) A 369.043 km long link canal off-taking from Paikhed barrage at FSL 142.80 m.

- xvii) A 100 m long tunnel No.1 at RD 14.650 to 14.750 km; A 350 m long tunnel No.2 at RD 24.000 to 24.350 km; A 200 m long tunnel No.3 at RD 32.350 to 32.550 km; A 50 m long tunnel No.4 at RD 37.750 to 37.800 km; and A 450 m long tunnel No.5 at RD 51.500 to 51.950 km;
- xviii) A 2.859 km feeder pipe line connecting main canal with Chasmandva barrage.
- xix) A 14.342 km open pipe line inter connecting Chikkar and Dabdar reservoirs.
- xx) A 12.258 km feeder pipe line connecting main canal with Dabdar dam.
- xxi) A 7.616 km feeder pipe line connecting main canal with Kelwan dam.
- xxii) Cross Drainage / Cross Masonry works including regulators, escapes, road / railway bridges (469 No).

The various surveys and investigation works carried out at FR and DPR stages are described in the following paragraphs.

#### **4.1 Topographical Surveys**

The Great Trigonometrical Survey (GTS) Bench Mark (BM) of Survey of India (SOI) located at Rankuwa with Reduced Level (RL) of 41.61 m has been transferred to Chikkar, Dabdar and Kelwan dam axes and various locations along the alignment of Par-Tapi portion of Par-Tapi-Narmada link canal, Bench Mark (BM) of Survey of India (SOI) located at Dharampur with Reduced Level (RL) of 74.67 m has been transferred to Paikhed, Chasmandva, Jheri and Mohankavchali dam axes and Bench Mark (BM) of Survey of India (SOI) located at Mandavi with Reduced Level (RL) of 47.71 m has been transferred to various locations along the alignment of Tapi-Narmada portion of Par-Tapi-Narmada link canal by conducting Double Tertiary (DT) levelling of about 141 km. Adequate numbers of permanent/ temporary bench marks (PBM/TBM) at different locations of the project area were established with

reference to this GTS Bench mark. The details of various PBM/TBM established in the project area are given at Annexure – 4.1.1 and 4.1.2 in Volume-II.

#### **4.1.1 Rivers**

##### **i Par River**

At the DPR stage, the river survey along Par river across which Jheri dam is proposed could not be carried out due to resistance by local people. As such, the data of river survey carried out at the time of FR has been utilised in the preparation of the DPR. During preparation of the Feasibility Report of Par-Tapi-Narmada link project, topographical survey along fair weather deep channel of Par river was carried out. The longitudinal section of Par river has been surveyed for 17.70 km u/s and 10.60 km d/s of the Jheri dam axis at 100 m interval upto RLs of 272.870 m and 140.655 m respectively. The Longitudinal section of Par river in scale of 1: 10000 H and 1: 100 V and Cross section of Par river at proposed Jheri dam site in the scale of 1:1000 H and 1: 1000 V based on the surveys carried out at FR stage are appended at Plate 4.1 and 4.10 in Volume - VII.

##### **ii Nar River**

Paikhed dam has been proposed across river Nar, a tributary of river Par. At the DPR stage, the river survey along Nar river could not be carried out due to resistance by local people. As such, the data of river survey carried out at the time of FR has been utilised in the preparation of the DPR. During FR stage, the river survey was carried out along the fair weather deep channel of Nar river. The longitudinal section along the Nar river has been surveyed for 18.45 km upstream and 5.55 km d/s of the Paikhed dam axis at 100 m interval upto RL of 257.075 m and 141.945 m respectively. At DPR stage cross section survey of Nar river at proposed Paikhed dam site could be carried out as part of dam axis area grid survey. The Longitudinal section of Nar river near proposed Paikhed dam site in scale of 1: 10000 H and 1: 100 V based on the surveys carried out at FR stage and Cross section of Nar river at proposed Paikhed dam

site in the scale of 1:1000 H and 1: 1000 V based on the surveys carried out at DPR stage are appended at Plate 4.2 and 4.11 in Volume - VII.

Longitudinal section survey had also been carried out along Nar river in the vicinity of Paikhed barrage for a length of 8.42 km. The Longitudinal section has been taken for 1.60 km upstream and 6.82 km downstream of Paikhed barrage at 30 m interval upto RL 143.330 m and 112.095 m respectively The Longitudinal section of Nar river near proposed Paikhed barrage site in scale of 1: 10000 H and 1: 100 V and Cross section of Nar river at proposed Paikhed barrage site in the scale of 1:1000 H and 1: 1000 V based on the surveys carried out at FR stage are appended at Plate 4.3 and 4.12 in Volume - VII.

### **iii Tan River**

The Chasmandva dam has been proposed across river Tan, a tributary of river Auranga. During FR stage, the river survey was carried out along the fair weather deep channel of Tan river. The longitudinal section has been surveyed for a length of 15.88 km of the river reach between Chasmandva dam site and Barrage site covering from RL 174.305 m to 91.025m. At DPR stage the river cross section survey of Tan river at proposed Chasmandva dam site has been carried out as part of dam axis area grid survey. The Longitudinal section of Tan river in scale of 1: 10000 H and 1: 100 V based on the surveys carried out at FR stage; Cross section of Tan river at proposed Chasmandva dam site in the scale of 1:1000 H and 1: 1000 V based on the surveys carried out at DPR stage; and Cross section of Tan river at proposed Chasmandva barrage site in the scale of 1:1000 H and 1: 1000 V based on the surveys carried out at FR stage are appended at Plate 4.4 , 4.13 and 4.14 in Volume - VII.

### **iv Ambica River**

Chikkar dam is proposed across the river Ambica. During FR stage the longitudinal section of the Ambica river has been surveyed for 6.860 km upstreams and 6.280 km downstream of the proposed Chikkar dam site covering upto RL 181.507 m and 139.937 m. At DPR stage the river cross section survey

of Ambica river at proposed Chikkar dam site has been carried out as part of dam axis area grid survey. The river survey (both longitudinal section and cross section survey) of Ambica river has been carried out at DPR stage for about 80.0 km in the reach from the confluence of Ambica and Khapri rivers upto the outfall point of Ambica river in the Arabian sea. The Longitudinal section of Ambica river in scale of 1: 10000 H and 1: 100 V based on the surveys carried out at FR/ DPR stage and Cross section of Ambica river at proposed Chikkar dam site in the scale of 1:1000 H and 1: 1000 V based on the surveys carried out at DPR stage are appended at Plate 4.5, 4.6 and 4.15 in Volume -VII.

#### **v Khapri River**

Dabdar dam is proposed across the river Khapri, a tributary of river Ambica. During FR stage river survey has been carried out along the Khapri river. The longitudinal section of the river has been surveyed for 7.950 km upstream and 10.53 km downstream of the Dabdar dam covering upto RL of 145.040 m and 89.97 m respectively. At DPR stage the river cross section survey of Khapri river at proposed Dabdar dam site has been carried out as part of dam axis area grid survey. The Longitudinal section of Khapri river in scale of 1: 10000 H and 1: 100 V based on the surveys carried out at FR stage and Cross section of Khapri river at proposed Dabdar dam site in the scale of 1:1000 H and 1: 1000 V based on the surveys carried out at DPR stage are appended at Plate 4.7 and 4.16 in Volume -VII.

#### **vi Purna River**

The river survey has been carried out during the FR stage along the river Purna on which Kelwan dam is proposed. The longitudinal section of the river has been surveyed for 14.250 km upstream and 5.19 km downstream of the Kelwan dam site covering upto RL of 143.625 m and 96.115 m respectively. At DPR stage the river survey (both longitudinal section and cross section survey) of Purna river has been carried out for about 85.80 km in the reach from the downstream of Waghai – Vyara road bridge (about 3 km downstream of proposed Kelwan dam site) upto the outfall point of Purna river in the Arabian sea. The Longitudinal section of Purna river in scale of 1: 10000 H and 1: 100

V based on the surveys carried out at FR/ DPR stage and Cross section of Purna river at proposed Kelwan dam site in the scale of 1:1000 H and 1:1000 V based on the surveys carried out at FR stage are appended at Plate 4.8, 4.9 and 4.17 in Volume -VII.

#### **4.1.2 Reservoirs**

During FR stage the reservoir submergence surveys of two reservoirs namely Jheri and Paikhed reservoirs were carried out departmentally by NWDA; survey of Chasmandva reservoir was got carried out by NWDA through Survey of India (SoI). Reservoir surveys of three reservoirs: Chikkar, Dabdar and Kelwan reservoir were earlier got done by Government of Gujarat through Survey of India and the same data was used by NWDA during preparation of Feasibility Report. The reservoir submergence area survey of Mohankavchali reservoir could not carried out due to resistance from local people. Since this aspect was viewed during the meeting of Director General, NWDA with the concerned Chief Engineer of CWC on dated 18.02.2012 regarding completion of various design consultancy works for preparation of Detailed Project Report. It was decided that the NWDA shall examine the possibility of transfer of water directly from Jheri reservoir to Paikhed reservoir /barrage by avoiding Mohankavchali dam. As such, the Mohankavchali dam has not been considered in the present planning of Par – Tapi – Narmada link. A copy of the minutes of the meeting circulated by head office vide letter No. NWDA/Tech-I/200/44-14/meeting/09/Vol.I/126-32 dated 26.06.2012 is placed at Annexure-4.1.3

During DPR stage the work for carrying out topographical survey in the submergence areas of seven proposed reservoirs was out sourced to the private agencies. But due to public hindrance, the submergence area survey for the reservoirs could not be carried out. As such, the information based on reservoir submergence survey carried out at FR stage has been used in preparation of the DPR. The reservoir submergence area survey of Mohankavchali reservoir could not be carried out at FR and DPR stage as such, at the DPR stage the Par –Tapi–Narmada link has been planned without Mohankavchali reservoir. However, at later stage when the field investigations at Mohankavchali could

be carried out, this reservoir will also be dovetailed with the Par–Tapi–Narmada link project. The details of reservoirs submergence area survey are described below:

#### **i Jheri Reservoir**

The topographical survey for submergence area of Jheri reservoir was carried out departmentally by NWDA during the FR stage. The FRL of the Jheri reservoir has been fixed at 246 m and the MWL at 247 m. The reservoir submergence survey was carried out up to RL 270 m. The baseline was fixed by compassing, chaining, ranging and levels transferred by double levelling at 100 m interval. The cross sections have been taken at 300 m or less interval depending upon the topography and up to RL 270 m on both sides of the base line by using Theodolite / Engineering Levels. The submergence map of Jheri reservoir with 5m contour interval showing communication net work, settlements etc in the scale of 1:10000 prepared based on the survey carried out at FR stage is appended at Plate 4.18 in Volume -VII.

During DPR preparation the topographical and land use mapping of Jheri reservoir area was carried out through Bhaskaracharya Institute of Space Applications and Geo-informatics (BISAG) using remote sensing data/technology. The submergence map of Jheri reservoir prepared by BISAG, Gandhinagar is at Plate 4.19 in Volume -VII.

#### **ii Paikhed Reservoir**

The topographical survey for submergence area of Paikhed reservoir was carried out departmentally by NWDA during the FR stage. The FRL of the Paikhed reservoir has been fixed at 248 m and the MWL at 249 m. The reservoir submergence survey was carried out up to RL 280 m. The baseline was fixed by compassing, chaining, ranging and levels transferred by double levelling at 100 m interval. The cross sections have been taken at 300 m or less interval depending upon the topography and up to RL 280 m on both sides of the base line by using Theodolite / Engineering Levels. The submergence map of Paikhed reservoir with 5m contour interval showing communication net

work, settlements etc in the scale of 1:10000, prepared based on the survey carried out at FR stage is appended at Plate 4.20 in Volume -VII.

During DPR preparation the topographical and land use mapping of Paikhed reservoir area was carried out through Bhaskaracharya Institute of Space Applications and Geo-informatics using remote sensing data/technology. The submergence map of Paikhed reservoir prepared by BISAG is at Plate 4.21 in Volume -VII.

### **iii Chasmandva Reservoir**

The topographical survey for submergence area of Chasmandva reservoir was carried out by NWDA through Survey of India during the FR stage. The FRL of the Chasmandva reservoir has been fixed at 214 m and the MWL at 215 m. The reservoir submergence survey was carried out up to RL 230 m. The contour map of Chasmandva reservoir with 5m contour interval in the scale of 1:10000, prepared by the survey of India at FR stage is appended at Plate 4.22 in Volume -VII.

During DPR preparation the topographical and land use mapping of Chasmandva reservoir area was carried out through Bhaskaracharya Institute of Space Applications and Geo-informatics using remote sensing data/technology. The submergence map of Chasmandva reservoir prepared by BISAG is at Plate 4.23 in Volume -VII.

### **iv Chikkar Reservoir**

The topographical survey for submergence area of Chikkar reservoir was carried out by the Government of Gujarat through Survey of India and the same was used by NWDA during preparation of FR. The FRL of the Chikkar reservoir has been fixed at 210 m and the MWL at 212 m. The reservoir submergence survey was carried out up to RL 212.5 m. The contour map of Chikkar reservoir with 2.5 m contour interval in the scale of 1:15000, prepared by the survey of India at FR stage is at Plate 4.24 in Volume -VII.

During DPR preparation the topographical and land use mapping of Chikkar reservoir area was carried out through Bhaskaracharya Institute of Space Applications and Geo-informatics using remote sensing data/technology. The submergence map of Chikkar reservoir prepared by BISAG is at Plate 4.25 in Volume -VII.

#### **v Dabdar Reservoir**

The topographical survey for submergence area of Dabdar reservoir was carried out by the Government of Gujarat through Survey of India and the same was used by NWDA during preparation of FR. The FRL of the Dabdar reservoir has been fixed at 169 m and the MWL at 170 m. The reservoir submergence survey was carried out up to RL 190 m. The contour map of Dabdar reservoir with 5 m contour interval in the scale of 1:15000, prepared by the survey of India at FR stage is at Plate 4.26 in Volume -VII.

During DPR preparation the topographical and land use mapping of Dabdar reservoir area was carried out through Bhaskaracharya Institute of Space Applications and Geo-informatics using remote sensing data/technology. The submergence map of Dabdar reservoir prepared by BISAG is at Plate 4.27 in Volume -VII.

#### **vi Kelwan Reservoir**

The topographical survey for submergence area of Kelwan reservoir was carried out by the Government of Gujarat through Survey of India and the same was used by NWDA during preparation of FR. The FRL of the Kelwan reservoir has been fixed at 164 m and the MWL at 166 m. The reservoir submergence survey was carried out up to RL 180 m. The contour map of Kelwan reservoir with 5 m contour interval in the scale of 1:25000, prepared by the survey of India at FR stage is at Plate 4.28 in Volume -VII.

During DPR preparation the topographical and land use mapping of Kelwan reservoir area was carried out through Bhaskaracharya Institute of Space Applications and Geo-informatics using remote sensing data/

technology. The submergence map of Kelwan reservoir prepared by BISAG is at Plate 4.29 in Volume -VII.

### **4.1.3 Head Works**

#### **i Jheri Dam**

Jheri dam has been proposed across river Par, near village Jheri in Peint taluka of Nasik district of Maharashtra State. During preparation of Feasibility Report topographical grid survey of Jheri dam site area was carried out by NWDA. Total 10 cross section of the Par river in vicinity of proposed dam site were surveyed at 60 m interval and spot levels were taken along the cross sections at an interval of 20 m to 30 m. TBMs at 200m interval along the dam axis and also as per the site requirement were fixed. The detailed contour plan in the scale of 1: 2500 with 1 m contour interval covering the dam site area is at Plate - 4.30 in Volume -VII.

At Jheri dam 91 m long spillway has been proposed at the right side of the river by CMDD (NandW) Directorate of Central Water Commission for passing flood discharge of 6539 cumec computed by Hydrology (South) Directorate of Central Water Commission while carrying out the hydrological studies of Par – Tapi – Narmada Link project. The detailed layout plan of the Jheri dam axis showing the location of CFRD portion, spillway and non-over flow concrete portion is at Plate -6.2 and 6.8 in Volume –VIII (A).

#### **ii Paikhed Dam**

Paikhed dam has been proposed across river Nar (a tributary of river Par) near village Paikhed in Dharampur taluka of Valsad district in Gujarat State. The DPR level topographical survey work of Paikhed dam site area was carried out departmentally by National Water Development Agency during the year 2009-10. The topographical survey of the area covering 250 m upstream and 500 m downstream of the dam axis upto the elevation of MWL + 5 m on both the banks at 10 m X 10 m grid basis was carried out. The baseline fixed on right bank of the river, extended up to 250 m upstream and 500 m

downstream with fixing of concrete pillar @ 50m interval along the baseline thereafter cross sections perpendicular to the baseline were surveyed by chaining, compassing, ranging and levelling at 10 m interval up to MWL +5 m. TBM at 200 m interval along the dam axis and as per the site requirement were fixed. The detailed contour plan in the scale of 1:2500 with 2 m contour interval has been prepared and is appended at Plate 4.31 in Volume - VII.

At Paikhed dam 72 m long spillway has been proposed in the right flank of dam by CMDD (NandW) Directorate of Central Water Commission for passing flood discharge of 5307 cumec computed by Hydrology (South) Directorate of Central Water Commission while carrying out the hydrological studies of Par–Tapi–Narmada Link project. The detailed layout plan of the Paikhed dam axis showing the location of CFRD portion, spillway, non-over flow concrete portion and power block is at Plate – 6.26 and 6.32 in Volume – VIII(A).

### **iii Chasmandva Dam**

Chasmandva dam has been proposed across river Tan (a tributary of river Auranga) near village Chasmandva in Dharampur taluka of Valsad district in Gujarat State. The DPR level topographical survey work of Chasmandva dam site area was carried out departmentally by National Water Development Agency during the year 2009. The topographical survey of the area covering 250 m upstream and 500 m downstream of the dam axis upto the elevation of MWL + 5 m on both the banks at 10 m X 10 m grid basis was carried out. The baseline fixed on right bank of the river, extended up to 250 m upstream and 500 m downstream with fixing of concrete pillar @ 50m interval along the baseline thereafter cross sections perpendicular to the baseline were surveyed by chaining, compassing, ranging and levelling at 10 m interval up to MWL +5 m. TBM at 200 m interval along the dam axis and as per the site requirement were fixed. The detailed contour plan in the scale of 1:2500 with 1 m contour interval has been prepared and is appended at Plate 4.32 in Volume - VII.

At Chasmandva dam 44 m long spillway has been proposed in the right flank of the dam by CMDD (NandW) Directorate of Central Water

Commission for passing flood discharge of 2578 cumec computed by Hydrology (South) Directorate of Central Water Commission while carrying out the hydrological studies of Par–Tapi–Narmada Link project. The detailed layout plan of the Chasmandva dam axis showing the location of CFRD portion, spillway, non-over flow concrete portion and power block is at Plate - 6.50 and 6.56 in Volume –VIII(A).

#### **iv Chikkar Dam**

Chikkar dam has been proposed across river Ambica, near village Chikkar in Ahwa taluka of Dang district in Gujarat State. The DPR level topographical survey work of Chikkar dam site area was carried out departmentally by National Water Development Agency during the year 2009. The topographical survey of the area covering 250 m upstream and 500 m downstream of the dam axis upto the elevation of MWL + 5 m on both the banks at 10 m X 10 m grid basis was carried out. The baseline fixed on right bank of the river, extended up to 250 m upstream and 500 m downstream with fixing of concrete pillar @ 50m interval along the baseline thereafter cross sections perpendicular to the baseline were surveyed by chaining, compassing, ranging and levelling at 10 m interval up to MWL +5 m. TBM at 200 m interval along the dam axis and as per the site requirement were fixed. The detailed contour plan in the scale of 1:2500 with 1 m contour interval has been prepared and is appended at Plate 4.33 in Volume - VII.

At Chikkar dam 72 m long spillway has been proposed in the right flank of the dam by CMDD (NandW) Directorate of Central Water Commission for passing flood discharge of 5649 cumec computed by Hydrology (South) Directorate of Central Water Commission while carrying out the hydrological studies of Par–Tapi–Narmada Link project. The detailed layout plan of the Chikkar dam axis showing the location of CFRD portion, spillway, non-over flow concrete portion and power block is at Plate – 6.72 and 6.78 in Volume – VIII(A).

#### **v Dabdar Dam**

Dabdar dam has been proposed across river Khapri (a tributary of river Ambica) near village Dabdar in Ahwa taluka of Dang district in Gujarat State. The DPR level topographical survey work of Dabdar dam site area was carried out departmentally by National Water Development Agency during the year 2009-10. The topographical survey of the area covering 250 m upstream and 500 m downstream of the dam axis upto the elevation of MWL + 5 m on both the banks at 10 m X 10 m grid basis was carried out. The baseline fixed on left bank of the river, extended up to 250 m upstream and 500 m downstream with fixing of concrete pillar @ 50m interval along the baseline thereafter cross sections perpendicular to the baseline were surveyed by chaining, compassing, ranging and leveling at 10 m interval up to MWL +5 m. TBM at 200 m interval along the dam axis and as per the site requirement were fixed. The detailed contour plan in the scale of 1:2500 with 1 m contour interval has been prepared and is appended at Plate 4.34 in Volume - VII.

At Dabdar dam 91 m long spillway has been proposed in the right flank of the dam by CMDD (NandW) Directorate of Central Water Commission for passing flood discharge of 6683 cumec computed by Hydrology (South) Directorate of Central Water Commission while carrying out the hydrological studies of Par–Tapi–Narmada Link project. The detailed layout plan of the Dabdar dam axis area showing the location of spillway, non-over flow concrete portion, power block and CFRD portion is at Plate – 6.96 and 6.102 in Volume – VIII(A).

## **vi Kelwan Dam**

Kelwan dam has been proposed across river Purna, near village Kelwan in Ahwa taluka of Dang district in Gujarat State. During preparation of Feasibility Report topographical grid survey of Kelwan dam site area was carried out by NWDA. Total 8 cross section of the Purna river in vicinity of proposed dam site were surveyed at 60 m interval and spot levels were taken along the cross sections at an interval of 15 m. The detailed contour plan of the Kelwan dam axis area in the scale of 1: 2500 with 1 m contour interval covering the dam site area is at Plate - 4.35 in Volume -VII.

At Kelwan dam 91 m long spillway has been proposed in the left flank of the dam by CMDD (NandW) Directorate of Central Water Commission for passing flood discharge of 7979 cumec computed by Hydrology (South) Directorate of Central Water Commission while carrying out the hydrological studies of Par–Tapi–Narmada Link project. The detailed layout plan of the Kelwan dam axis area showing the location of CFRD portion spillway, non-over flow concrete portion and power block is at Plate – 6.120 and 6.126 in Volume – VIII(A).

#### **vii Paikhed Barrage**

Paikhed barrage is proposed across river Nar about 4.6 km in the downstream of proposed Paikhed dam near village Motikosbadi in Dharampur taluka of Valsad district in Gujarat State. The water released from Paikhed reservoir after power generation will be picked-up at Paikhed barrage from where the Par–Tapi–Narmada link canal will off takes. During preparation of Feasibility Report topographical grid survey of Paikhed barrage site area was carried out by NWDA. Total 5 cross section of the Nar river in vicinity of proposed Paikhed barrage site were surveyed at 50 m interval and spot levels were taken along the cross sections at an interval of 25 m. The detailed contour plan in the scale of 1: 2500 with 1 m contour interval covering the dam site area is at Plate – 4.37 in Volume -VII.

#### **viii Chasmandva Barrage**

Chasmandva barrage is proposed across river Tan about 8.5 km in the downstream of proposed Chasmandva dam near village Chikadi in Vandsa taluka of Navsari district in Gujarat State. The water released from Chasmandva reservoir after power generation will be picked-up at Chasmandva barrage from where a feeder pipe line will off take to release the water in to the Par – Tapi – Narmada link canal. During preparation of Feasibility Report topographical grid survey of Chasmandva barrage site area was carried out by NWDA. Total 5 cross section of the Tan river in vicinity of proposed Chasmandva barrage site were surveyed at 50 m interval and spot levels were taken along the cross sections at an interval of 25 m. The detailed

contour plan in the scale of 1: 2500 with 1 m contour interval covering the dam site area is at Plate -4.38 in Volume -VII.

#### **4.1.4 Plant and Colony Layout**

Detailed survey for plant and colony layout could not be carried out due to public hindrance in the project area. This will be carried out at pre-construction stage of the project. However, there are suitable locations available for installation of various plants near each dam site. An indicative map showing plant and colony layout is at Plate -4.39 in Volume -VII.

#### **4.1.5 Canal and Water Conductor System and Canal Structures**

The Par–Tapi–Narmada link canal will off take from proposed Paikhed barrage to carry the surplus waters of Jheri and Paikhed reservoirs. On its way the feeder pipe lines from Chasmandva barrage, Dabdar dam and Kelwan dam will join at RD 62.072 km, 108.250 km, 129.600 km respectively to release surplus water of Chasmandva reservoir, Chikkar and Dabdar reservoirs, and Kelwan reservoirs respectively in to the Par–Tapi–Narmada link canal. After traversing of 177.736 km the Par–Tapi–Narmada link canal will out fall in to Ukai reservoir. The link canal will further off take from the right side saddle dam of Ukai reservoir and out fall in to existing Miyagam Branch Canal of Narmada canal System at RD 16.70 km after traversing 191.307 km.

During preparation of Detailed Project Report the topographical survey along the canal alignment in Par – Ambica reach was outsourced. But due to public hindrance the agency could not take up the survey work. The topographical survey along the canal alignment in Ambica to Tapi reach and Tapi to Narmada reach except about 61.595 km from Ukai reservoir was carried out by outsourcing. The topographical survey for 61.595 km from Ukai reservoir was carried out by NWDA departmentally. The alignment survey was carried out covering an area of 250 m on either side of the proposed alignment. At the river/stream crossings and CD structures area of 300 m on either side of the alignment has been surveyed. The center line of the strip area has been surveyed by DT leveling at 50 m interval. The Cross sections are taken at 50 m interval and spot levels along the cross sections are taken at 50 m interval. The

TBMs are fixed at about 2 km intervals. The final alignment in Ambica to Tapi and Tapi – Miyagam branch canal has been marked on the ground by fixing CC pillars at 200 m interval except some length in the vicinity of Amravati river, where due to public hindrance CC pillars could not be fixed. In Par to Ambica reach the Survey carried out during preparation of Feasibility Report has been used at DPR stage. The canal alignment and longitudinal sections of Par – Tapi reach are at Plate - 6.250 to 6.308; Feeder pipe lines are at Plate – 6.309 to 6.321; and Tapi– Narmada reach are at Plate – 6.322 to 6.385 in Volume – VIII(C).

#### **4.1.5.1 Alternative Crossing of Tapi River without Dropping at Ukai Reservoir**

To delink the existing Ukai reservoir on Tapi river from Par-Tapi-Narmada link project as no water of Tapi river is proposed to be diverted under the link proposal and to reduce the length of the link canal and to derive power generation benefit along the canal alignment, an alternative canal alignment has been proposed to cross the Tapi rivers downstream of Ukai dam.

The topographical surveys of alternative canal alignment for about 15 km to cross Tapi river downstream of Ukai dam and reservoir periphery survey at the out fall point, to fix the location of outfall point of Par-Tapi portion of the link canal at Ukai reservoir, have been carried out. The same can be utilized in future planning at construction and implementation stage if need arise.

#### **4.1.6 Power House, Switch Yard, Surge Shaft, Tailrace etc.**

Total six power houses, five power houses are proposed to be located at the toe of the Paikhed, Chasmandva, Chikkar, Dabdar and Kelwan dams and one power house is proposed at the fall on the feeder pipe line connecting Kelwan dam with Par–Tapi–Narmada link canal. The grid survey of the Paikhed, Chasmandva, Chikkar, and Dabdar dam site carried out at DPR stage and that for Kelwan dam site carried out at FR stage has been utilised for locating the power house and switch yard etc during preparation of DPR.

#### **4.1.7 Tunnel Survey**

The Par-Tapi-Narmada link involves a tunnel of about 12.7 km interconnecting the proposed Jheri and Paikhed reservoirs to transfer the surplus waters available at Jheri reservoirs to Paikhed reservoir. A 100 m long tunnel No.1 at RD 14.650 to 14.750 km; A 350 m long tunnel No.2 at RD 24.000 to 24.350 km; A 200 m long tunnel No.3 at RD 32.350 to 32.550 km; A 50 m long tunnel No.4 at RD 37.750 to 37.800 km; and A 450 m long tunnel No.5 at RD 51.500 to 51.950 km. The survey for the tunnel connecting Jheri and Paikhed reservoirs could not be conducted due to public hindrances. The topographical mapping of the tunnel alignments area with 10 m contour intervals has been carried out through BISAG by using remote sensing technology. Detailed survey and investigation of the tunnels alignments may be conducted during pre-construction stage.

#### **4.1.8 Command Area (Detailed and Sample)**

The topographical surveys of Command Area are proposed for identification of irrigable area under the link canal, for planning branch canals and distributaries etc. and to estimate the cost of Command Area Development.

The Command Area survey has been carried out by Block levelling on 50 m or less grid basis. Contour plan of the area shall be prepared to a scale of 1:10,000 with a contour interval of 0.5 m. Contour plan of specific sample area: a) Plains and plateau OFD works – Contour plan of the area to a scale of 1:2500 H with contour interval 0.25 m and b) Hilly terrain OFD works – contour plan to a scale of 1:1000 H with contour interval 0.50 m shall be prepared. Area covering about 10% of the Culturable Command Area (CCA) are to be carried out for planning On-Farm Development (OFD) Works.

The area envisaged for irrigation under the Par-Tapi-Narmada link canal project can be divided into seven components: i) The command area proposed en-route the link canal, ii) The command area proposed under the Feeder pipe lines and iii) The command area proposed by Government of Gujarat on the left side of canal iv) The command in tribal area on right side of canal v) The

command in tribal area in vicinity of six reservoirs vi) The command in tribal area on right side of Narmada main canal by lift in Chhota Udepur and Panchmahal districts vii) The part Command Area of existing Miyagam Branch Canal of Sardar Sarovar Project (SSP) to be taken over by the link canal. The work of demarcation of Command Area and preparation of Command Area maps in respect of the Command Area proposed en-route the link canal was got done through Regional Remote Sensing Centre, Jodhpur. The proposed Command Area under Feeder pipe line is very small as such no detailed surveys are conducted. The Command Area of existing Miyagam Branch Canal of Sardar Sarovar Project (SSP) to be taken over by the link canal is already under irrigation as such no topographical surveys are required. Sample and detailed command area survey of newly added command areas will be taken up at the time of construction. The details of topographical surveys carried out covering the Command Area proposed en-route the link canal are furnished below.

#### **4.1.8.1 Detailed Topographical Surveys for Identification of En-Route Command Area of Link Canal**

Before taking up the detailed field topographical surveys of the entire proposed Command Area, the Command Area maps which had been prepared by the Government of Gujarat through Survey of India (SoI) while firming up the Command Areas of adjacent projects, such as SSP, Ukai and Karjan, were collected and examined for their utility in the demarcation of Command Area en-route the link canal. It is observed that the Command Area maps of SSP prepared in 1962 to a scale of 4 Inches to 1 Mile (1:15840) with contour interval of 2 feet did not cover the new Command Area proposed en-route the link canal. The Command Area maps of Ukai High Level Canal prepared by SoI to a scale of 1:15000 with contour intervals of 0.5 m and 2.5 m in 1978, though cover the proposed Command area en-route the link canal in between the Tapi and the Narmada rivers, were prepared by enlarging the 1:50000 scale surveys and also corrected to the year 1974-76 only for major details. The Karjan Command Area maps prepared by Survey of India in 1970-71 to a scale of 1:15000 with contour intervals of 0.5 m and 1m, which cover some parts of

en-route Command Area of link canal in-between the Kim and the Amravati rivers, were based on surveys conducted in 1969-70.

So, the maps prepared earlier could not be used for the link project as they do not provide correct picture of the present land-use and land-cover and topographical features in the en-route Command Area of the link canal. Hence, detailed topographical surveys of the en-route Command Area of the link canal were taken up to assess the irrigable area and cost of Command Area Development.

About 69000 ha of area need to be surveyed for finalizing the Command Area en-route the link canal. Since field survey of such a large area was time consuming, it was decided to demarcate en-route Command Area under the link canal with Remote Sensing techniques.

The work of demarcation of Command Area and preparation of Command Area map to a scale of 1:10000 with contour interval of 1.0 m in respect of the link canal by using Remote Sensing techniques was got done through Regional Remote Sensing Centre (RRSC), Jodhpur. IRS P6 LISS IV satellite data was used for land-use/land-cover mapping. IRS P6 LISS IV scenes were geo-referenced with respect to Survey of India toposheets by identifying common similar control points on toposheet as well as satellite image. SRTM DEM data at 90 m posting was used in the study to find out elevation values at different locations. Contours were generated at 10 m, 5 m and 1 m interval from SRTM DEM data. The heights shown by contour are above WGS 84 datum. The Index map of the Command Area identified en-route the link canal, prepared to a scale of 1:50,000, is appended as Plates 4.40(total 5 sheets) in Volume -VII.

For analysis the en-route Command Area is divided into two reaches viz. i) Par-Tapi reach and ii) Tapi-Narmada reach. The link canal is plotted over the land-use/land-cover map and possible outlet points to cover the un-irrigated agriculture land are identified. Thirty nine Off-take points are identified in Par-Tapi reach and twenty two Off-take points are identified in Tapi-Narmada reach. The Command Area maps prepared by RRSC, Jodhpur to a scale of

1:10000 with contour intervals at 10 m, 5 m and 1m showing proposed Branch canals/Distributaries/Outlet and the report on “Demarcation of Command Area en-route Par-Tapi-Narmada link” is at Appendix 4.1 in Volume – III.

The areas which are already proposed under projects contemplated by Government of Gujarat are excluded from the command area identified by the RRSC Jodhpur for firming up of en-route command area of the link canal.

However, as per water planning, around 232175 ha area has been identified as Culturable Command Area (CCA) under the link project. The total Culturable Command Area (CCA) identified is 61190 ha for enroute command, out of which the CCA identified in Par-Tapi reach is 10100 ha; in Tapi-Narmada reach is 49820 ha; and 1270 ha identified under Dabdar and Kelwan Feeder pipe lines are firming up of en-route command area of the link canal. The command area of project proposed by Government of Gujarat on the left side of canal is about 45561 ha to be irrigated by gravity through link canal. Tribal area right side of canal is 36200 ha will be irrigated by lift. About 12514 ha tribal area will also be irrigated directly by lift from proposed six reservoirs of this project. In addition to this tribal area on right side of Narmada main canal 23750 ha of Chhota Udepur dist. and 10592 ha of Panchmahal dist. will also be irrigated through lift directly from Narmada main canal on substitution basis. Project will also take over an area of 42368 ha CCA with annual irrigation of 42368 ha. under the command area of existing Miyagam branch canal of Narmada canal system. Narmada Water so saved will be utilized to provide irrigation facilities in Saurashtra region of Gujarat.

#### **4.1.8.2 Sample Command Area Surveys for OFD Works**

Sample Command area surveys were taken up departmentally in the proposed en-route Command Area of the link canal for planning and cost estimation of OFD works during 2011-12 and 2012-13. But, due to public hindrance no sample Command Area surveys could be carried out in the Par-

Tapi reach. However, in the Tapi-Narmada reach Sample Command Area surveys were carried out at three locations viz. i) Mandvi, ii) Wankal and iii) Valia to an extent of 1300 ha, 1750 ha and 1150 ha respectively, covering a total area of about 4200 ha. The topographical survey had been carried out at 50 m grid basis and the Command Area maps were prepared to a scale of 1: 15000 with contour interval of 1 to 2 m. The maps are appended as Plates 4.41 to 4.43 in Volume –VII. No sample command area survey has been carried out in the newly added command through lift in the right side of canal, in Chhota Udepur and Panchamahar districts, Command added in the vicinity of reservoirs and command of State Government projects. However command area map have been prepared on the basis of contour map of that area collected from BISAG and interpolation contour available in the survey of India toposheets of that area. The same are appended in Volume- 8(C). Detailed survey of newly added command area will be carried out at the time of pre construction stage.

#### **4.1.9 Soil Conservation**

M/s Water and Power Consultancy Services (WAPCOS), Gandhinagar has carried out the Environmental Impact Assessment (EIA) studies of Par-Tapi-Narmada link project which includes Environmental Monitoring Plan (EMP), Catchment Area Treatment (CAT) Plan and Rehabilitation and Resettlement (RandR) Packages for the project affected people. In order to minimise the soil erosion in the catchment areas and reduce the silt deposition at the proposed reservoirs being carried by various streams and nallas and also to compensate the loss of forest land likely to be submerged under the proposed reservoirs, soil erosion measures and afforestation plan have been suggested to be taken up and are duly included in the EMP plan. Necessary provisions for all these works have been kept in the project estimate.

## **4.2 Other Surveys**

### **4.2.1 Archaeological Survey in the Reservoir Area**

The Archaeological Survey of the Par–Tapi–Narmada link project area has been carried by Archaeological Survey of India (ASI), Vadodara. The

Superintending Archaeologist, ASI, Vadodara vide their letter No.36/10/MIS/08-09/4078 dated 19<sup>th</sup> June, 2009 (Annexure - 4.2.1 in Volume -II) have informed that no antiquarian archaeological remains have been noticed and none of the centrally protected monuments are located in the area likely to be submerged due to construction of proposed dams viz Mohankavchali, Paikhed, Chasmandva, Chikkar, Dabdar and Kelwan dams. The Superintending Archaeologist, Archaeological Survey of India (ASI), Aurangabad. vide their letter No. F No.12/2009-10/Tech-3036 dated 17<sup>th</sup> Feb, 2011 (Annexure - 4.2.2 in Volume -II) have informed that no monuments or any remains of archaeological importance were noticed in the area likely to be submerged due to construction of proposed Jheri dam.

#### **4.2.2 Mineral Survey in the Catchments / Reservoir / Canals Area**

The Engineering Geology Division of GSI, Jaipur vide Letter No. 171/G-1/EG/WR/GSI/08-09 dated 9<sup>th</sup> April, 2009 (Annexure – 4.3 in Volume -II) informed that the area covered under Par–Tapi–Narmada link project in Valsad and Dang districts of Gujarat and Nasik district of Maharashtra are occupied by the different basaltic flows and associated rocks belonging to the Deccan Traps. No significant minerals have been reported from the area, except construction material and a few minor minerals like zeolites.

#### **4.2.3 Right of Way Survey for the Reservoirs**

Major road connecting Peint to Surgana is passing through the Submergence area of Jheri dam and approximately 1 km length is under the submergence. No road communication of any significance is existing in the submergence areas of the proposed Paikhed and Chasmandva reservoirs. National Highway (NH-360) connecting Waghai to Saputara is passing through the Submergence area of Chikkar dam and approximately 8 km length is under the submergence. Major road connecting Waghai to Ahwa is passing through the Submergence area of Dabdar dam and approximately 8 km length is under the submergence. Major road connecting Vyra to Ahwa is passing through the Submergence area of Kelwan dam and approximately 7 km length is under the submergence. Right of Way Surveys have been conducted for these Major

Roads and National Highways. Necessary provisions for all these works have been kept in the project estimate.

#### **4.2.4 Communication Surveys**

The Par-Tapi-Narmada link project is located in the Gujarat State except Jheri dam which falls in Maharashtra State while remaining dams viz. Paikhed, Chasmandva, Chikkar, Dabdar and Kelwan dams are located in Valsad and Dang districts of Gujarat State. Par-Tapi reach of link canal passes through Valsad, Navsari, Dang and Surat districts whereas Tapi-Narmada reach of link canal passes through Surat, Bharuch and Vadodara districts of Gujarat State.

The Jheri dam across Par river is located near village Jheri in Peint taluka of Nasik district of Maharashtra State. The Jheri dam site is approachable from Peint as well as from Dharampur, the taluka head quarters in Nasik and Valsad districts respectively via Valsad - Nasik National Highway. The nearest railway station is Nasik on Central Railway and nearest town is Peint, a taluka head quarter in Nasik district. The distance of Jheri dam site from Nasik via Peint is about 75 km.

The Paikhed dam across Nar river, a tributary of river Par is located near village Paikhed in Dharampur taluka of Valsad district. The nearest town is Dharampur and the nearest railway station is Valsad on Western Railway. The Paikhed dam site is approachable from Dharampur on Valsad – Nasik National Highway. The distance of Paikhed dam site from Dharampur is about 38 km.

The Chasmandva dam across Tan river a tributary of river Auranga is located near Chasmandva village in Dharampur taluka of Valsad district. The nearest town is Dharampur and the nearest railway station is Valsad from. The dam site is approachable from Dharampur on Dharampur – Vansda road and the distance of Chasmandva dam site from Dharampur is about 25 km.

The Chikkar dam across Ambica river is located near village Chikkar in Ahwa taluka of Dang district in Gujarat State. The Chikkar dam site is approachable from Waghai/Vansda on Gandevi – Saputara National Highway

No. 360. The nearest town and railway station is Waghai on narrow gauge (Bilimora – Waghai section) and Bilimora on Broad gauge of Western Railway. The dam site is approachable from Waghai. The distance of Chikkar dam site from Waghai is about 12 km.

The Dabdar dam across Khapri river, a tributary of river Ambica is located near village Dabdar in Ahwa taluka of Dang district in Gujarat State. The Dabdar dam site is approachable from Waghai on Gandevi – Saputara National Highway No. 360. The nearest town is Waghai and the nearest railway station is Waghai on narrow gauge (Bilimora – Waghai section) and Bilimora on Broad gauge of Western Railway. The distance of Dabdar dam site from Waghai is about 8 km.

The Kelwan dam across Purna river is located near village Kelwan and Kakarda in Ahwa taluka of Dang district in Gujarat State. The Kelwan dam site is approachable from Waghai on Gandevi – Saputara National Highway No. 360. The nearest town is Waghai and the nearest railway station is Unai on narrow gauge (Bilimora – Waghai section) and Vyara on Broad gauge (Surat – Bhusaval section). The distance of Kelwan dam site from Vyara and Waghai is about 30 km. The map showing the communication net work in the Par – Tapi – Narmada link project area is appended at Plate - 4.44 in Volume -VII.

#### **4.2.5 Drainage Survey**

The command area enroute the link canal is drained by a network of rivers namely Par, Auranga, Ambica and Purna in addition to number of small streams and nallas. The commands have quite good draining facilities. However, with the introduction of irrigation, as the command area develops, drainage problem may crop up in the course of time. Suitable provision is, therefore, made in the project estimate towards chalk and collecting drains in the command area.

#### **4.2.6 Soil Surveys**

The Par-Tapi-Narmada link project is mainly an Irrigation project to transfer the surplus waters of West flowing Par, Auranga, Ambica and Purna

river basins of South Gujarat and neighboring Maharashtra to north Gujarat for utilisation in drought affected Saurashtra region by substitution apart from providing Irrigation in its en route command. The taluka wise reports of the soil survey carried out by Gujarat Government in respect of the districts falling in the en-route command area have been collected from the Agriculture Department, Government of Gujarat. Reports on land irrigability and soil classification of Banni area of Kutch region and SSNNL phase I (Upto Mahi river), Soil classification report and soil maps for the talukas lying in reservoir submergence areas and link alignment have also been collected. Using this information the soil map of the enroute command area has been prepared and appended at Plate -4.45 in Volume -VII.

### **4.3 Geology, Geophysical and Seismic Investigations**

#### **4.3.1 Regional Geology**

The area of Par-Tapi-Narmada Link Project is mostly covered by basaltic rock formed by eruption and solidification of lava flows (Misra, 2005). The Indian sub-continent has experienced at least five continental flood basalt eruptions ranging in age from Middle Proterozoic to Late Cretaceous and Early Tertiary. The youngest of these is the Deccan Flood Basalt of Cretaceous to Eocene age. The series of eruptions proceeded from fissures and cracks in the surface of the earth, from where lava welled out intermittently till a thick sheet of basalt was formed. This obliterated the previously existing topography of the country, and converted it into an immense volcanic plateau. This epochal volcanic formation is known in Indian geology as the Deccan Trap formation. Most of the land around the project site is covered by Deccan Traps, which almost entirely constitute the exposed rock unit of this terrain.

The basement of the peninsula is mainly composed of folded and faulted rocks of Archaean and Proterozoic age, which in some areas are covered by Precambrian sedimentary sequences and large masses of plateau basalt. Based on structural trends, degree of metamorphism and age factor, the peninsular region can be divided into several crustal blocks. Towards north of the project site, Sone – Narmada -Tapti (SONATA) lineament zone is bound by the Great Vindhyan Range and the Malwa Plateau in the north and the Satpura

Range in the South. This area comprises a wide variety of rock types ranging from Archaean to recent sediments. Quaternary alluvial fills are deposited in E-W trending intracratonic linear Narmada and Tapti-Purna basins.

The western portion towards north of the region comprises of the Saurashtra plateau, which mainly consists of Deccan trap of Upper Cretaceous to Eocene age and the Kutch rift basin that shows development of both Mesozoic and Tertiary sequences comprising the rocks of the Deccan trap. The northern part of the region comprises of Indo - Gangetic plain and the Aravalli-Delhi belt, whereas the south east and north east corners are represented by basement elements comprising gneisses and migmatites of Peninsular Gneissic Complex.

#### **4.3.2 Local Geology**

The Par-Tapti-Narmada Link project area is occupied by Deccan Lava flows intruded by dolerite dykes and sill. Very commonly due to differentiation the middle portion of a flow exhibits a dolerite texture. They are of Cretaceous-Eocene age. The flows comprise vesicular and amygdaloidal basalts with vesicles filled by zeolite, calcite and green-earth. In general the basalts are without olivine, consisting of basic glass. Where coarsely crystalline they show appreciable quantity of olivine. Porphyrs are formed by phenocrysts of feldspar. The flows commonly contain ash beds. These ash beds resemble the flows in their macroscopic appearance. Another feature of the Traps is the alteration of its basal portion into green earth. Frequently it is found not only in between the flows but also in vesicles. Another common occurring rock type is the red-bole, characterized by its conspicuous colour. The red-bole is clay formed by decomposition of the crust of lower flow, something a kin to present day laterisation of the traps. The area has been subjected to faulting and shearing. Several instances of block faulting with small throws area common. These are related to the Sone – Narmada - Rift system and the Sabarmati – west coast faulting.

#### **4.3.3 Geological Investigations**

The basic purpose of the geological investigations was to find out type of rock, major joints, shear zones, faults and fractured zones if any, in the area. The geological investigations were carried out for Jheri, Chasmandva, Chikkar, Dabdar and Kelwan dam sites during the preparation of Feasibility Report (FR) of Par-Tapi-Narmada Link Project by Engineering Geology Division, GSI, Western Region, Jaipur. Due to public hindrance the geological investigations at Mohankavchali and Paikhed dam sites, tunnels alignment and at all the three barrage sites could not be carried out. The DPR stage geological investigation work of Par – Tapi – Narmada link project was assigned to GSI, Jaipur. But, due to opposition from local peoples in carrying out the field survey and investigation work the geological investigations could not be taken-up by GSI. As such, the data of geological investigation carried out at FR stage have been used for designing the various components of Par–Tapi–Narmada link project at DPR stage. The details of these investigations are as under:

#### **i Jheri Dam Site**

The detailed geological mapping in the scale of 1:1000 was carried out in the area of proposed Jheri dam site by GSI, Jaipur covering an area of about 0.56 km<sup>2</sup>. Two dam alignment have been proposed; one on the downstream and another about 170 m on its upstream. All investigations are with reference to downstream alignment. At the dam site, the river is divided into two channels. The left bank is steep and forms on escarpment, while the right bank is steeped up. Outcrops are seen either on the left bank of left channel or right bank of right channel. Massive and amygdular basalts intruded by dolerite dykes are exposed. The geological map of Jheri dam axis (final dam axis) area on the scale 1:1,000 H is appended as Plate 4.46 in Volume -VII. During preparation of DPR no further work could be carried out due to opposition by local people.

#### **ii Paikhed Dam Site**

The detailed geological mapping in the area of proposed Paikhed dam site could not be carried out due to public hindrance either during FR stage or DPR stage. However, at FR stage GSI, Jaipur carried out Photogeological and Remote sensing Investigation for all the 7 dam site areas and field checks were

carried out on these investigations except for the Paikhed and Mohankavchali dam sites.

Aerial photo-interpretation of area around Paikhed dam site shows presence of numerous major lineaments trending in NE-SW, NNW - SSE, ENS - WSW directions. Three prominent dykes have also been picked; two of which are on the right bank, trending NNE-SSW and NW-SW. Dyke on the left bank trends in ENE - WSW. A major ENE - WSW trending lineament passes along the left bank of the river at the dam site. Another NW - SE trending lineament passes about 250 m upstream of dam site. Two major lineaments about 750 m and 3.5 km east of Paikhed, trending NW-SE appear to be faults as seen in the IRS-IA image of the area.

### **iii Chasmandva Dam Site**

The detailed geological mapping in the scale of 1:1000 was carried out in the area of proposed Chasmandva dam site by GSI, Jaipur covering an area of about 1.98 km<sup>2</sup>. The area on the left flank of the dam is covered by thick clayey soil. Rock outcrops are scanty, seen in nala beds. The trap is medium grained, massive with occasional vesicles at the top of flow. Joints are sparse and do not persist over long distance. In the river bed, the left bank forms a steep escarpment 5 m – 16 m high, while the right bank is gently sloping. Except for the rock outcrops in the escarpment face on the left bank and 100 m – 200 m upstream in the river bed on the right bank, the area is covered with clayey soil or river-borne silt sand, pebbles. At the dam site, on the left bank, amygdaloidal and massive basalts are exposed in the vertical escarpment. They are weathered, sheared and fractured; traversed by close-spaced joints. The basalts are horizontal in disposition. The contact of amygdaloidal and massive basalt is sheared. Its thickness varies from 30 cm to 50 cm and is occupied by sheared rock fragments. Spheroidal weathering is seen in the outcrops on the upstream of the right bank of river. The right flank of the dam is formed by gently sloping ground. Except for a few scattered outcrops of massive and amygdular basalts, the area is covered by clayey soil. About 400 m downstream of the proposed dam site, a 5 m high water-fall is observed. This fall has developed due to erosion of sheared material from along vertical joints

trending N 65°E – S 65°W. This has resulted in formation of a 12 m long gully. The formation of gully/water fall has been aided by a set of two joints striking N 55°W – S 55°E dips vertical and strike N 65°W – S 65°E, dips vertical. These joints are spaced 75 cm to 180 cm and 30 cm to 80 cm, respectively. The geological map of Chasmandva dam axis area on the scale 1:1,000 H is appended as Plate 4.47 (3 sheets) in Volume - VII. During preparation of DPR no further work could be carried out due to opposition by local people.

#### **iv Chikkar Dam Site**

The detailed geological mapping in the scale of 1:1000 was carried out in the area of proposed Chikkar dam site by GSI, Jaipur covering an area of about 2.43 km<sup>2</sup>. The mapping was done to delineate the distribution of the bed rock and alluvial / overburden and to study the structural feature. Although in general the area is covered with alluvial at place isolated outcrops have been observed. These comprise a sub-horizontal sequence of lava flows of Deccan traps. The thickness of an individual flow is about 5 to 20 m. The contacts zone between the successive lava flows are moderately to highly weathered and marked by presence of flow breccia, predominance of amygdules at top of the lower flow; pipe amygdules at the bottom of the upper flow and or red bole bed. A total of six number of dykes intrude these flows. These trending N 25°W - S 25°E / vertical to E – W/vertical. A total of four numbers of lava flow has been delineated during the course of investigation. The geological map of Chikkar dam axis area on the scale 1:1,000 H is appended as Plate 4.48(2 sheets) in Volume - VII. During preparation of DPR no further work could be carried out due to opposition by local people.

#### **v Dabdar Dam Site**

The detailed geological mapping in the scale of 1:1000 was carried out in the area of proposed Dabdar dam site by GSI, Jaipur covering an area of about 1.5 km<sup>2</sup>. The area is predominantly covered by Deccan traps with thin to thick cover of overburden. The bed rock constituting the foundation is a sequence of lava flows, which comprises amygdaloidal, dense, porphyritic

basalt and flow breccia. These are horizontally to sub-horizontally disposed, having of maximum dip of 8°. These flows are separated on the basis of lithological characteristic. The average thickness of these flows are ranging between 3 and 18 m, and the contacts between these successive flows are moderately to deeply weathered and are marked by the presence of flow breccia and zeolite filled amygdules pipes. The geological map of Dabdar dam axis area on the scale 1:1,000 H is appended as Plate 4.49 (2sheets) in Volume - VII. During preparation of DPR no further work could be carried out due to opposition by local people.

#### **vi Kelwan Dam Site**

The detailed geological mapping in the scale of 1:1000 was carried out in the area of proposed Kelwan dam site by GSI, Jaipur covering an area of about 1.63 km<sup>2</sup>. Based on the surface geological studies the bed rock/overburden has been demarcated. The exposed outcrops are mainly consisting of horizontal to sub-horizontal sequence of lava flows, which include amygdaloidal, dense, porphyritic basalt and flow breccia. The average thickness of these flows is worked out 3 to 15 m. The contact of individual flow are marked by the presence of red bole, flow breccia, predominant rich amygdules at top of lower flow and pipe amygdules at the bottom of the upper flow unit. A red bole horizon having thickness 40 cm is exposed at R.D. 870 m u/s 250 m. It consists of fine grained, hard, compact, fresh rock reddish, in colour. The rocks exposed in the river beds are mainly made up of amygdaloidal basaltic flow of Deccan trap. The rock is moderately weathered to fresh, compact and moderately jointed. It is fine grained, and grayish to greenish gray in colour. The bulk of rock mass contains sparsely distributed vesicles and filled with the secondary material of zeolite and green earth.

Report on Preliminary Geotechnical, Investigation for Par-Tapi-Narmada Link Project of National Water Development Agency in The Dangs and Valsad Districts of Gujarat and Nasik District of Maharashtra (F. S. 1993 - 94) is at Appendix 4.2 in Volume – III.

#### **4.3.4 Seismicity**

Par-Tapi-Narmada project area lies in the seismic zone-III as per seismic zoning map of India (IS:1893–2002, Part-1). The historical and instrumentally recorded earthquake data provided by Indian Meteorological Department (IMD) indicates that the significant event closest to the project site is the 26<sup>th</sup> May, 1618 earthquake of magnitude 6.9 which occurred near Mumbai. However, since there was a hurricane on the same day the intensity of the earthquake could not reliably be known. There were 4 more events of magnitude above 6.0 within a distance of 300 km from the project area. The details are given at Table: 4.1:

**Table: 4.1**  
**Events of Magnitude Above 6.0 within a Distance of**  
**300 km from the Project Area**

Place	Date	Magnitude	Distance (km) from:		
			Jheri	Chasmandva	Kelwan
Near Mumbai	26.05.1618	6.9	171.5	196.1	233.5
Near Ahmedabad	09.10.1842	6.3	214.4	186.3	155.1
Khandwa area	27.05.1847	6.5	199.5	190.5	161.5
Hebatpur-Bhavnagar area	21.04.1919	6.0	275.2	255.7	256.8
Bhusaval - Sawda area	14.03.1938	6.2	272.4	266.4	239.3

The data for 1449 earthquake events with magnitude of 2.4 and above have been compiled from different sources for the period from 1594 – 2009. There are 9 earthquake events with a magnitude of 5.5 and above within a distance of 300 km from project site.

The studies for site specific design ground motion parameters for the various components of Par-Tapi-Narmada Link Project has been carried out by Central Water and Power Research Station (CWandPRS), Pune during the year, 2011. As per these studies the deterministic estimate is found to be governed by a maximum credible earthquake magnitude of 6.3 at a closest distance of 20.1 km to the fault rupture plane. The area of seven dams and three barrage sites proposed in Par-Tapi-Narmada link project has been divided into three clusters. Both deterministic and probabilistic approaches have been applied to arrive at the Maximum Credible Earthquake (MCE) and the Design Basis Earthquake (DBE) levels of ground motion. For both the MCE and DBE levels of design ground motion, it is found that the deterministic target spectra are higher than the probabilistic spectra for all the three clusters. To be on the conservative side, the same has been recommended as a basis for the design ground motion. The values of the peak ground acceleration for horizontal and vertical components are found to be 0.172 g and 0.145 g for MCE condition, and 0.089 g and 0.076 g for DBE condition, respectively for Cluster-1. For Cluster-2 and Cluster-3, the corresponding values are found to be 0.171 g and 0.139 g for MCE condition, and 0.079 g and 0.067 g for DBE condition respectively.

The site specific design ground motion study of Par-Tapi-Narmada Link Project prepared by Central Water and Power Research Station, Pune is at Appendix-4.3 in Volume – III.

This report has been approved by the National Committee on Seismic Design Parameters in its 23<sup>rd</sup> meeting held on 20<sup>th</sup> November 2012. The dam wise summarised seismic design parameters have been communicated by FEandSA Directorate of CWC vide their letter No. 2/2/2012 (vol-I)/FEandSA/16 dated 4<sup>th</sup> January, 2013 (Annexure -4.4 in Volume -II)

#### **4.4 Sub-surface Geology and Foundation Investigations**

**Dams:** During the year 1993-94, at FR stage, the foundation investigations for the proposed dams of Par – Tapi – Narmada link project were carried out through GSI, Jaipur. The geo-technical assessment of surface and

sub-surface data along the axes of Jheri, Chasmandva, Chikkar and Dabdar dams collected through geological mapping at 1:1000 scale and core logging of exploratory drill holes was carried out to ascertain the sub-surface rock condition. The laboratory testing of rock core samples has been carried out by GSI, Jaipur. The findings and the test results of the GSI are used in the designs of various components of these dams by Design Directorate of CWC for suitable foundation grade level. Interim Report on Geophysical Surveys for Par-Tapi-Narmada Link Project of National Water Development Agency in Dang and Valsad Districts of Gujarat and Nasik District of Maharashtra (Field Season 1993-94) is at Appendix 4.4 in Volume – III.

During preparation of DPR the geological and geo-technical investigations at Paikhed and Chasmandva dam sites were carried out through GSI, Jaipur. Logging of rock cores recovered from the bore holes was done by GSI, Jaipur. The laboratory testing of rock core samples has been carried out by CSMRS, New Delhi. The findings and the test results of the GSI and CSMRS are used in the designs of various components of Paikhed and Chasmandva dams by Design Directorate of CWC for suitable foundation grade level. However, due to public hindrances in the project area, no drilling could be carried out at Jheri, Chikkar, Dabdar and Kelwan dam axes. As such, the data from drilling/trial pits carried out at FR stage in respect of foundation investigations of Jheri, Chikkar, Dabdar and Kelwan dam axes have been used in the DPR. At Mohankavchali no geological/ geotechnical investigations could be carried out, as such at DPR stage the Par–Tapi–Narmada link has been planned without Mohankavchali dam. Along the tunnel alignment also no survey and investigation works could be carried out. The details of dam-wise foundation investigations carried out at FR / DPR stage are discussed below:

**Jheri Dam:** Jheri dam site has been explored by four numbers bore holes, in order to evaluate the sub-surface rock/over burden conditions. The bore hole cores have been logged by GSI, Jaipur and their data was analysed to find out foundation grade levels and water tightness of bed rock as well as to ascertain the soil structure and its permeability characteristics. The details of these bore holes suggested by GSI, Jaipur are tabulated below in the Table 4.2:

**Table-4.2**  
**Details of Bore Holes for Jheri Dam Site Suggested by GSI**

Sl. No.	Drill Hole No.	RD (m)	Depth of Bore Hole Proposed/Drilled (m)
1.	BH-1	411.468 (Right Non Overflow section)	27.73
2.	BH-2	70 m downstream of RD 351.628 m in the stilling basin	31.04
3.	BH-3	604.206 (Right Non Overflow section)	29.62
4.	BH-4	231.500 (Left Non Overflow section)	25.86

The Details of drill hole logs are appended in Annexure 4.5 in Volume - II. The geological section along the proposed Jheri dam axis in the scale of 1: 1000 is at Plate – 4.52 in Volume - VII.

**Paikhed Dam:** The basalts of the Deccan trap are exposed at the Paikhed dam site. The left bank forms cliff and river Nar passes through the gorge portion in the proposed dam alignment. The right bank is flat topped with slight undulations and has cultivated fields. The river channel exposes bed rock-basalt at a few places; at other places river channel is strewn with boulders and gravels. Geological mapping of the dam site could not be carried out due to hostile working condition prevailing at the dam site.

In order to evaluate the sub-surface rock/over burden conditions the Paikhed dam site has been explored by 12 numbers of NX size bore holes. The bore hole cores have been logged and their data was analysed to find out foundation grade levels and water tightness of bed rock as well as to ascertain the soil structure and its permeability characteristics. The summarized log details of these drill holes are in Table – 4.3:

**Table – 4.3**  
**Details of Drill Holes for Paikhed Dam Site Suggested by GSI**

<b>Sl. No.</b>	<b>Bore Hole No.</b>	<b>RD from Left Flank (m)</b>	<b>Depth of Bore Hole Proposed/Drilled (m)</b>
1	BH-1	50 m U/S and 50 m away from Left Bank	10
2	BH-2	50 m away from Left Bank	10
3	BH-3	0.0	10
4	BH-4	90.00	38
5	BH-5	180.00 Left NoF	82.80
6	BH-6	260.00 Left end Spillway	88.5
7	BH-7	330.00 Right end Spillway	70.85
8	BH-8	390.00 Right end NoF	36.70
9	BH-9	550.00 Earth dam	30.50
10	BH-10	700.00 Earth dam	15
11	BH-11	870.00 Earth dam	23.50
12	BH-12	1030.00 Earth dam	32
13	BH-13	1200.00 Earth dam	31
14	BH-14	1360.00 Earth dam	19
15	BH-15	1525.00 Earth dam	10
16	BH-16	1680.00 End of Earth dam	10
17	BH-17	50 m away from Right end of earthen dam	10
18	BH-18	50 m upstream of Right end of earthen dam	10
19	BH-19	At Power house site	20
20	BH-20	Left side downstream of Spillway	85
21	BH-21	Right side downstream of Spillway	85.5
22	BH-22	Left side upstream of Spillway	42.5
23	BH-23	Right side upstream of Spillway	42.5

Out of the 23 proposed drill holes, 11 (BH-1 to BH-4 and BH-12 to BH-18) drill holes could not be carried out due to public resistance. The remaining 12 bore holes were drilled with an aggregate core length of 622.95 m and logged. Basalts of the Deccan trap forms the foundation rock at the project area. The rocks have horizontal to sub horizontal dips. The

water percolation test carried out in these bore holes indicate that the rock strata in general have low permeability. The details of drill hole logs are appended in Annexure 4.6-- in Volume - II. The Report of GSI on geotechnical investigations at Paikhed and Chasmandva dam sites carried out at DPR stage is at Appendix 4.5 in Volume – III.

The core samples collected from exploratory drill holes at Paikhed dam site were got tested at CSMRS, New Delhi. The report on laboratory investigations of Rock core samples submitted by CSMRS, New Delhi (CSMRS Report No. 2/RM-I/CSMRS/E/4/2011of April, 2011) is appended as Appendix – 4.6 in Volume – III.

**Chasmandva Dam:** At the Chasmandva dam site both the banks are covered with thick clayey soil with occasional outcrops in nala beds. The rock outcrops are scanty. The basalt is medium grained, massive with occasional vesicles. Joints are sparse and do not persist over long distances. The rock outcrops can be observed in the escarpment face on the left bank and upstream in the river course. The basalts are horizontal in disposition. The right flank is formed by gently sloping ground. Except for a few scattered outcrops of massive and amygdaloidal basalt, it is covered by soil.

In order to evaluate the sub-surface rock/over burden conditions the Chasmandva dam site has been explored by 19 numbers of NX size bore holes. The bore hole cores have been logged and their data was analysed to find out foundation grade levels and water tightness of bed rock as well as to ascertain the soil structure and its permeability characteristics. The summarized log details of these drill holes are in Table – 4.4:

**Table – 4.4**

**Details of Drill Holes for Chasmandva Dam Site Suggested by GSI**

<b>Sl. No.</b>	<b>Bore Hole No.</b>	<b>RD from Left Flank (m)</b>	<b>Depth of Bore Hole Proposed/Drilled (m)</b>
1	BH-1	50 m U/S and 50 m away from Left Bank	10

<b>Sl. No.</b>	<b>Bore Hole No.</b>	<b>RD from Left Flank (m)</b>	<b>Depth of Bore Hole Proposed/Drilled (m)</b>
2	BH-2	50 m away from Left Bank	10
3	BH-3	Left bank end (0.0)	10
4	BH-3A	155.00	10
5	BH-4	310.00	10
6	BH-5	465.00	10
7	BH-5A	620.00	11
8	BH-5B	775.00	18
9	BH-6	970.00	17
10	BH-6A	1120.00	14
11	BH-7	1280.00	15.50
12	BH-8	1450.00	45
13	BH-9	1480.00	45.20
14	BH-10	1650.00	35
15	BH-11	1780.00	28.50
16	BH-12	1960.00	10
17	BH-13	2180.00	10
18	BH-14	2360.00	19
19	BH-15	2390.00	19
20	BH-15A	2540.00	10
21	BH-16	2680.00 (TP)	18
22	BH-17	2750.00	10
23	BH-18	50 m away from Right Bank	10
24	BH-19	50 m upstream and 50 m away from Right Bank	10
25	BH-20	D/S of Spillway	20
26	BH-21	U/S of Spillway	13.55
27	BH-22	At Power House	21
28	BH-23	Left side, Downstream (Gorge portion)	46
29	BH-24	Right side, Downstream (Gorge portion)	45

Out of the 29 proposed drill holes, 10 (BH-1 to BH-5A; BH-17 and BH-18; and BH-23) drill holes could not be carried out due to public resistance. The remaining 19 bore holes were drilled with an aggregate core length of

413.75 m and logged. The basaltic flows of Deccan Trap form the foundation rock at the dam site. The rock has horizontal to sub horizontal disposition. The water percolation test results of these bore holes indicate that permeability of the rock strata is low. The Details of drill hole logs are appended in Annexure 4.7 in Volume - II. The geological section along the proposed Chasmandva dam axis in the scale of 1: 1000 is at Plate –2.53(3 sheets) in Volume - VII. The Report of GSI on geotechnical investigations at Paikhed and Chasmandva dam sites carried out at DPR stage is at Appendix 4.5 in Volume – III.

The core samples collected from exploratory drill holes at Chasmandva dam site were got tested at CSMRS, New Delhi. The report on laboratory investigations of Rock core samples submitted by CSMRS, New Delhi (CSMRS Report No. 1/RM-I/CSMRS/E/4/2011of April, 2011) is appended as Appendix – 4.7 in Volume – III.

**Chikkar Dam:** Chikkar dam site has been explored by four numbers of NX size bore holes and eight numbers of trail pits, in order to evaluate the sub-surface rock/over burden conditions. The bore hole cores and trail pits have been logged and their data was analysed to find out foundation grade levels and water tightness of bed rock as well as to ascertain the soil structure and its permeability characteristics. The details of these drill holes and pits/trenches are in Table – 4.5 and 4.6 respectively.

**Table – 4.5**

**Details of Drill Holes for Chikkar Dam Site Suggested by GSI**

<b>Sl. No.</b>	<b>Bore Hole No.</b>	<b>RD (m)</b>	<b>Depth of Bore Hole Drilled (m)</b>
1	CKR-1	1386.00	54.86
2	CKR -2	1394.31	29.39
3	CKR -3	1477.33	54.86
4	CKR -4	1223.58	51.81

**Table – 4.6**

**Details of Exploratory Pits/Trenches for Chikkar Dam Site Suggested by GSI**

Sl. No.	Pit/ Trench No.	RD (m)	Depth of Pit/ Trench Drilled (m)
1	PT-11	45.0	1.40
2	PT-13	352.5	1.50
3	PT-14	612.0	1.15
4	PT-15	705.0	1.23
5	PT-16	965.0	0.64
6	PT-7	1065.0	0.53
7	PT-6	1261.65	River side – 0.75, Hill side – 1.4
8	PT-10	1950.0	0.80

The bed rock encountered is basaltic flows and flow breccia. Rock core samples have been collected for determining the specific gravity, water absorption and UCS in GSI geotechnical laboratory, Jaipur. Eight exploratory pits along the earth section of varying depths from 0.53 to 1.5 m have been carried out. These trial pits have been excavated through hill wash material, fluvial sediments and weathered basaltic flows. These pits have established that the thickness of the hill wash material on the left flank varies from 0.15 to 0.8 m. The sub- surface geology indicates that the bed rock is available at 6.70 m, weathered rock/limit of weathering depth extends to a depth of 10.30 m, water percolation test indicates the permeability between 10 and 16 lugeons. Summarised details are given in Annexure 4.8 in Volume - II. The geological section along the proposed Chikkar dam axis in the scale of 1: 1000 is at Plate – 4.54(2 sheets) in Volume - VII. A Report on Sub-Surface Exploration at the Chikkar Dam Site of Par-Tapi-Narmada Link Project, of National Water Development Agency, in District The Dangs, Gujarat (Field Season 1994-95) is at Appendix 4.8 in Volume – III.

**Dabdar Dam:** Dabdar dam site has been explored by four numbers of NX size bore holes and seven numbers of trail pits, in order to evaluate the sub-surface rock/over burden conditions. The bore hole cores and trail pits have been logged by GSI, Jaipur and their data was analysed to find out foundation grade levels and water tightness of bed rock as well as to ascertain the soil structure and its permeability characteristics. The details of these drill holes and

pits/trenches suggested by GSI, Jaipur are tabulated below in Table 4.7 and 4.8 respectively.

**Table: 4.7**  
**Details of Drill Holes for Dabdar Dam Site Suggested by GSI**

Sl. No.	Drill Hole No.	RD (m)	Depth of Drill Hole Proposed/Drilled (m)
1.	DH-1	821.593 (River channel/Overflow section)	27.42
2.	DH-2	976.401 (Right flank)	44.19
3.	DH-3	790 (River channel) 61 m downstream	35.05
4.	DH-4	689.393 (Left flank)	30.48

**Table: 4.8**  
**Details of Exploratory Pits/Trenches for Dabdar Dam Site Suggested by GSI**

Sl. No.	Exploratory Pit/Trench No.	RD (m)	Depth of Pit/ Trench Drilled (m)
1.	PT-1	109.19	Varying from 0.72 to 6
2.	PT-2	306.08, 30 m upstream	-- do --
3.	PT-3	473.85, 60 m upstream	-- do --
4.	PT-4	562.78	-- do --
5.	PT-5	866.03	-- do --
6.	PT-6	1042.28 6 m upstream	-- do --
7.	PT-7	1119.17 m	-- do --

The Details of drill hole logs are appended in Annexure 4.9 in Volume - II. The geological section along the proposed Dabdar dam axis in the scale of 1: 1000 is at Plate –4.55 in Volume - VII.

**Kelwan Dam:** To evaluate the details sub-surface conditions at Kelwan dam site four numbers of bore holes were recommended by GSI; two in the river section and one each on the either bank. Due to public hindrance in the project area no bore hole could be drilled. However, the Kelwan dam site could be explored by 8 trial pits/ trenches. The details of these pits/trenches are tabulated below in Table 4.9:

**Table: 4.9**  
**Details of Exploratory Pits/Trenches for**

### **Kelwan Dam Site Suggested by GSI**

<b>Sl. No.</b>	<b>Exploratory Pit/Trench No.</b>	<b>RD (m)</b>	<b>Depth of Pit/ Trench Drilled (m)</b>
1	PT-3	995	1.21
2	PT-5	790	1.60
3	PT-6	715	1.50
4	PT-7	660	0.50
5	PT-8	527	1.60
6	PT-10	255	1.40
7	PT-11	215	0.93
8	PT-12	115	1.06

At Kelwan dam site Deccan trap and its differentiates forming the bed rock in the foundation of the proposed structures. Based on the surface geological studies the bed rock/overburden have been demarcated. The exposed outcrops are mainly consisting of horizontal to sub-horizontal sequence of lava flows, which include amygdaloidal, dense, porphyritic basalt and flow breccia. The intrusive body is prominently exposed in the river Purna about 500 m d/s from the proposed dam axis. At this location the bed rock shows a sudden drop of 7 to 9 m, and marked by a narrow gorge with a water fall. The geological section along the proposed Kelwan dam axis and Kelwan Saddle dam axis in the scale of 1: 1000 are at Plate –4.56 and 4.57 respectively in Volume - VII.

#### **4.4.1 Geophysical Investigations**

Geophysical Surveys were conducted for the proposed dams of Par-Tapi-Narmada link project during the year 1993-94, at FR stage by GSI, Jaipur for delineating the bedrock topography and structural features. Electrical resistivity, refraction seismic and magnetic (Vertical field) methods were employed for the purpose. The bedrock topography has been delineated successfully at all the five sites and is presented in the form of depth sections of competent bedrock (Trap). The depth to bedrock varies from 2.5 m to 37 m. The compact bedrock has a characteristic electrical resistivity in the range of 60 to 350 ohm.m and P.wave velocity varying from 4500 m/s to 5500 m/s. Some structural features like lineaments/dykes have also been inferred from magnetic survey. The investigation has also brought out some buried channels

and weak zones cutting across the dam axis at some sites which should be taken care of. GSI Report is at Appendix: 4.4 in Volume-III.

**i. Jheri Dam Site**

A total of 22 V E S, 22 H.S, 4 S.P. and 84 magnetic observations were recorded along dam axis and E.D. line. The depth to the bedrock (trap) varies between 2.9 m and 20.0 m along dam axis whereas it ranges from 3.0 m to 21.5 m along E.D. line (70 m downstream). In general the resistivity of the trap varies between 200 ohm-m to 350 ohm m with associated P-wave velocity of the order of 5000 m/s to 5170 m/s indicating the compact nature of trap. It may be noted that the exposed trap overlying the geophysically inferred bedrock (compact trap) is likely to be fractured, particularly in the river bed, where the bed rock is at a depth of 14.7 m at R.D. 423 m (V E S.5).

The magnetic profile reflects the variation of bedrock topography. Between R.D. 640 m to 665 m on dam axis and between R.D. 585 to 645 m on E.D. line two high magnetic anomalies have been recorded. These anomalies may be because of Dyke/lineaments passing through the above mentioned RD's. This shallow and thin linear feature appears to have nearly E-W trend and is becoming deeper towards E-D line and possibly has a northward dip.

**ii. Paikhed Dam Site**

The detailed geophysical investigation in the area of proposed Paikhed dam site could not be carried out due to public hindrance either during FR stage or DPR stage.

**iii. Chasmandva Dam Site**

A total of 51 VES, 16 SP, 62 HS and 321 magnetic observations were recorded on the dam axis and E.D. line (55 m downstream). The depth to bedrock (trap) varies from 3.0 m to 18.5 m along the dam axis and from 2.5 m to 15.5 m along E.D. line The resistivity of the trap, in general, ranges between 100 ohm-m and 350 ohm-m. The P-wave velocity associated with trap has

been observed in the range of 4800 m/s to 5200 m/s along dam and E.D. line. Both these parameter ranges indicate the compactness of the trap. The magnetic profiles along dam and E.D. line reflect in general, variations of bedrock topography. Two magnetic highs have been recorded between R.D.2655 m and 2895 m on dam axis and between R.D.2630 m and R.D.2826 m on E.D. line. These magnetic anomalies could be representing linear features.

#### **iv. Chikkar Dam Site**

A total of 42 VES, 46 H.S., 8 S.P. and 225 magnetic observations were recorded along dam axis and energy dissipation line. Depth to bedrock (trap) varies between 2.0 m and 10.2 m along dam axis. It varies between 2.0 m to 26.5 m along E.D line (60 m downstream). The resistivity of the bedrock generally ranges from 60 ohm.m to 350 ohm-m with associated P-wave velocity ranging between 4800 m/s to 5000 m/s. These parameter ranges suggest compactness of the trap. The depth to the bedrock in river section is inferred to be 7.2 m at R.D 1311 m (42 m west of TBM-A) on dam axis, which is in agreement with the results obtained from Bore hole-1 drilled subsequently.

The magnetic profiles reflect the variations in bedrock topography in general. Two magnetic high anomalies have been recorded between R.D. 165 m and R.D. 195 m and between R.D. 420 m and R.D. 450 m on the dam axis. The corresponding magnetic anomalies on E.D line lie between R.D. 120 m and R.D. 160 m and R.D. 390 m and R.D. 435 m. These four magnetic anomalies perhaps represent two linear features.

#### **v. Dabdar Dam Site**

A total of 28 VES, 8S.P. 44 H.S. and 149 magnetic observations were recorded along dam and energy dissipation (E.D.) axis. The depth to bedrock (Trap) varies from 3.0 m to 32.0 m along the dam axis and from 4.0 m to 30.0 m along E.D. line (62 m downstream of dam axis). In general its resistivity varies from about 80 ohm m to 300 ohm m is also observed elsewhere in Deccan trap country, with associated P-wave velocity varying from 4500 m/s

to 5500 m/s which is suggestive of compact nature of the trap. The few VES in which higher resistivity was observed for trap, have not been considered.

On the left bank a buried channel has been indicated on dam axis between R.D. 180.0 m (VES-5) and R.D. 324 m (VES-8) having the maximum depth of 26.4 m at R.D. 252 m (at Geophone No. 11 of SP-1D). This buried channel has also been indicated on the left bank on E.D. line between R.D. 171 m (VES-28) and R.D.321 m (VES-20) having maximum depth of 29.0 m at R.D.231 m (VES-27).

Similarly, on the right bank buried channel (hanging nala ) has been indicated on dam axis between R.D. 69 m (VES-13) and R.D. 213 m (36 m right of borehole BH-2) having its maximum depth at R.D. 153 m (VES-14) where the bedrock is 22.2 m below ground surface. This buried channel has not been clearly indicated on E.D. line and it appears to meet the river near R.D. 50.8 m (DR – 0) on ED line. However, there is a depression in bedrock topography between R.D. 50.8 m (D.R.-O) and R.D. 159.1 m (D.R.3) which might have been filled with saturated river borne material as indicated by low order of resistivity values recorded in VES-24 nearby.

The magnetic profiles over dam and energy dissipation axis generally reflect the variations in bedrock topography. The overlying river borne material has feeble magnetism. The magnetic high recorded on the left bank at R.D. 400.1 m (L-5) on dam axis and R.D. 369 m (DL-5) on E.D. line is perhaps the magnetic indication of a linear features. Similarly on right bank the magnetic highs recorded at R.D. 30.6 m on dam axis and at R.D.120 m (near D.R.-2) on E.D. line also indicate a linear feature. There may be additional linear features as well.

Four subsequent bore holes have indicated excellent agreement with geophysically inferred depth to bedrock.

## **vi. Kelwan Dam Site**

A total of 30 VES, 26 HS, 8 S.P. and 136 magnetic observations were recorded along dam and energy dissipation axes. The depth to bed-rock (Trap) varies between 2.5 m and 20.0 m along dam axes, where as it ranges between 3.0 m to 37.0 m along E.D. line (54 m downstream of dam axis) showing resistivity variation, in general from about 60 ohm-m to 350 ohm-m with associated P-wave velocity ranging between 4700 m/s to 4900 m/s both of which may be attributed to the compactness of the trap. The few VES indicating higher resistivity have not been taken into account for depth section. The material overlying the trap is generally clayey soil. The maximum thickness of the overburden is indicated between RD. 231 m (SP-3D) and RD.351 m (VES-6) on the dam alignment. On the right bank along E.D. line the maximum overburden thickness is inferred to be 37 m at R.D. 987 m (VES-29) while on the corresponding point on dam axis it is only 7 m. The unusual greater depth to bedrock indicated by VES-29 on E.D. line is perhaps due to its location in Nala which is filled with transported material.

Two high magnetic anomalies of the order of 2000 gammas have been recorded on the dam axis between R.D. 180 m and R.D. 270 m and on energy dissipation line between R.D.137 m (KDR-2) and R.D. 206.7 m (KDR-3) which may be attributed to the presence of lineament/dyke cutting the two axis in N-S direction which appears to be trending towards waterfall downstream.

#### **4.5 Construction Material Investigations**

##### **4.5.1 Soils**

At FR stage, the borrow area soil investigations for construction of Kelwan, Chikkar, Chasmandva and Paikhed dams were carried out through Gujarat Engineering Research Institute (GERI), Surat during the year 1994-95. The similar investigations in respect of Jheri and Dabdar dam sites were carried out during preparation of DPR. Representative bulk soil samples from potential borrow areas in the vicinity of the dam sites were collected and laboratory tests were got carried out for ascertaining their suitability for use as construction materials based on soil classification and also to determine the strength, consolidation and compressibility characteristics of the same for arriving at various design parameters.

For Jheri dam a total 8 no. of soil samples collected from trail pits of dam axis and got tested from Gujarat Engineering Research Institute, Vadodara at FR stage. The test results are at Annexure 4.10.1 in Volume-II. At DPR stage a total no. of 5 soil samples from prospective borrow areas up-stream of the dam axis were collected and got tested from the private consultant M/s NKPC, Valsad. The test results are at Annexure 4.10.2 in Volume-II. The location plan of borrow area pits is given at Plate – 4.58 in Volume - VII.

For Paikhed dam, a total no. of 8 soil samples from prospective borrow areas up-stream of the dam axis were collected and got tested from Gujarat Engineering Research Institute, Vadodara at FR stage. The test results are at Annexure 4.11 in Volume-II. Due to public hindrance, no soil samples from perspective borrow area up-stream of the dam axis could be collected. The location plan of borrow area pits is given at Plate – 4.59 in Volume - VII.

For Chasmandva dam, a total 9 no. of soil samples were collected from trail pits of dam axis and a total no. of 19 soil samples from prospective borrow areas up-stream of the dam axis were collected at FR stage. These samples got tested from Gujarat Engineering Research Institute, Vadodara. The test results are at Annexure 4.12.1 and 4.12.2 respectively in Volume-II. The location plan of borrow area pits is given at Plate 4.60 in Volume - VII.

For Chikkar dam, a total 6 no. of soil samples were collected from trail pits of Chikkar dam axis and a total no. of 12 soil samples from prospective borrow areas up-stream of the dam axis were collected. These samples got tested from Gujarat Engineering Research Institute, Vadodara. The test results are at Annexure 4.13.1 and 4.13.2 respectively in Volume-II. The location plan of borrow area pits is given at Plate 4.61 in Volume - VII.

For Dabdar dam a total 4 no. of soil samples collected from trail pits of dam axis and got tested from Gujarat Engineering Research Institute, Vadodara at FR stage. The test results are at Annexure 4.14.1 in Volume-II. At DPR stage a total no. of 10 soil samples from prospective borrow areas up-stream of the dam axis were collected and got tested from the private consultant M/s NKPC,

Valsad. The test results are at Annexure 4.14.2 in Volume-II. The location plan of borrow area pits is given at Plate – 4.62 in Volume - VII.

For Kelwan dam, a total 11 no. of soil samples were collected from trail pits of Kelwan dam axis and a total no. of 6 soil samples from prospective borrow areas up-stream of dam axis were collected. These samples got tested from Gujarat Engineering Research Institute, Vadodara. The test results are at Annexure 4.15.1 and 4.15.2 respectively in Volume-II. The location plan of borrow area pits is given at Plate 4.63 in Volume - VII.

Laboratory tests such as Mechanical analysis and Atterberg Limits, Specific Gravity, Standard Proctor Compaction, Triaxial Shear Test with Pore water pressure measurement, One Dimensional Consolidation, Laboratory Permeability etc, were carried out on the collected Borrow area samples. The Mechanical analysis result indicates that the tested soil samples are in general dominated by finer fractions with particular reference to silt sizes followed by fine and medium sand size. Soil samples tested are impermeable and in general possess medium to high plasticity characteristics, medium to high compressibility characteristics and fairly good shear strength.

#### **4.5.2 Sand**

At DPR stage total 12 nos. of sand samples, six are natural sand samples and six were crushed stone sand samples of the rock quarries have been tested for assessing their suitability for use as fine aggregate in concrete. The samples are collected in the project area and the laboratory investigations of the samples for use as crushed sand in the concrete has been carried out through CSMRS, New Delhi. The report of CSMRS bearing No. C-I/ CSMRS/ E/ 04/ 2014 is at Appendix – 4.9 in Volume – III. The physical and chemical tests viz. fineness modulus, specific gravity, silt and clay content, organic impurities, soundness loss, aggregate reactivity tests and petrographic analysis are conducted on the above samples for assessing their suitability for use as fine aggregate in concrete. This report indicates that, based on physical tests it is found that the fineness modulus is 3.11 to 4.19 for the 9 sand samples which shows that sand is coarser in nature and 3 samples do not conform to any

grading zones I to IV of BIS:383-1970. Natural sand which is coarser in nature may be used in construction works after blending with fine sand to make the FM 2.5 to 3.0. The crushed sand samples, fineness modulus varying between 2.73 to 3.77 and conform to the grading zone I and II as per IS:383-1970 may also be used in construction after more crushing the sand to make FM between 2.5 to 3.00 so that it conforms the grading zone II/III of IS:383-1970 and the dust finer than 150 micron should not be more than 15 %. Petrography analysis was conducted in Geological Survey of India, Faridabad, Report shows that the natural sand samples consists of quartz, feldspar, mica and lithic fragments. Altered feldspar and mica may have deleterious effect but the alkali aggregate reactivity test shows that there is no undue expansion.

#### **4.5.3 Rock and Aggregates**

At DPR stage, 12 nos. coarse aggregate samples collected from different locations of rock and river boulder quarries of the project area. The CSMRS, New Delhi had carried out the Construction Material Survey and Laboratory Testing of rock samples for assessing their suitability for use as coarse aggregate in concrete. The report of CSMRS bearing No. C-I/CSMRS/ E/04/ 2014 is at Appendix – 4.9 in Volume – III. The physical and chemical tests viz. fineness modulus, specific gravity, silt and clay content, organic impurities, soundness loss, aggregate reactivity tests and petrographic analysis are conducted on the above samples as per IS 2386 – 1963 for assessing their suitability for use as coarse aggregate in concrete. Based on these tests, it is found that 10 nos. of coarse aggregates samples are conforming to the code requirements for use as coarse aggregates in concrete for both wearing as well as non wearing surfaces as per IS: 383-1970. The 2 nos. river boulder samples are suitable only for non wearing surfaces. Petrography analysis was conducted in Geological Survey of India, Faridabad. Report shows that the rock is Amygdaloidal Basals type and it is hard and compact but it is having altered olivine and mineral present around vesicles may have deleterious effect but the alkali aggregate reactivity test shows that there is no undue expansion.

#### **4.5.4 Bricks and Tiles**

Bricks and tiles are available locally in the project area

#### **4.5.5 Pozzolona**

The pozzolonic materials are not considered to be used in the construction of the project

#### **4.5.6 Cement**

The nearest cement factory for the dam sites is Narmada Cement Factory, Magdalla in Surat district. The cement manufactured from this factory can be transported to Vyara and Valsad through rail head. Later the cement bags collected at Vyara can be transported to Chikkar, Dabdar and Kelwan sites by road, whereas cement bags collected at Valsad can be transported to remaining other sites. Since requirement of cement for all the six dam sites and other structures will be considerably high, the cement can also be procured from other factories located at Ahmedabad and Mumbai etc.

#### **4.5.7 Steel**

Friends Ispat plant is located at Ahmadabad. The steel required for project construction can be procured from these plants and transported to Valsad, Billimora, and Vyara rail heads by rail and further upto project sites by road.

#### **4.5.8 Scarce Material**

No scarce materials are anticipated to be used in the project which may cause hindrance to the construction of the project.

#### **4.5.9 Steel pipe of 2.5 To 2.9 m dia.**

Friends Ispat plant is located at Ahmadabad. The steel required for project construction can be procured from these plants or other sources and transported to Valsad, Billimora, and Vyara rail heads by rail and further upto project sites by road.

#### 4.5.10 Any Other Material

Apart from above, there will be many other items such as asbestos, CGI sheet, coal tar, wood, paint etc. which will be required for construction of temporary sheds, approach roads etc. All such items are available locally.

### 4.6 Hydrological and Meteorological Investigations

#### 4.6.1 Rainfall

There are 10 rain gauge stations located in and around Par basin, 10 rain gauge stations located in and around Auranga basin, 25 rain gauge stations located in and around Ambica basin, and 24 rain gauge stations located in and around Purna basin. The average annual rainfall of Par basin is 2180 mm, Auranga basin is 2055 mm, Ambica basin is 1830 mm and that of Purna basin is 1472 mm. The period of availability of data and average annual rainfall (mm) of each rain gauge station is given in Table – 4.10:

**Table – 4.10**  
**Period of Availability of Rainfall data**

S. No.	RG Station	Period of Availability of Data	Average Annual Rainfall (mm)
<b>A</b>	<b>Par Basin</b>		
1	Peint	1901 to 2008	2273
2	Pardi	1901 to 2003	1926
3	Mandavi	1964 to 2007	2669
4	Panchalai	1969 to 2007	1920
5	Nanivahiyal	1968 to 2006	2215
6	Dhamni	1969 to 2000	2019
7	Pindval	1977 to 2006	2406
8	Dharampur	1901 to 2003	2368
9	Surgana	1955 to 2006	1997

<b>S. No.</b>	<b>RG Station</b>	<b>Period of Availability of Data</b>	<b>Average Annual Rainfall (mm)</b>
10	Bildha	1965 to 2006	2010
		<b>Average</b>	<b>2180</b>
<b>B</b>	<b>Auranga basin</b>		
1	Valsad	1901 to 2003	1890
2	Hanmatmal	1962 to 1998	2124
3	Bopi	1962 to 2006	2187
4	Pindval	1977 to 2006	2406
5	Surgana	1955 to 2006	1997
6	Bildha	1965 to 2006	2010
7	Dharampur	1901 to 2003	2368
8	Pardi	1901 to 2003	1926
9	Rundhapura	1970 to 1998	1644
10	Chorvani	1963 to 2006	2001
		<b>Average</b>	<b>2055</b>
<b>C</b>	<b>Ambica basin</b>		
1	Galkund	1964 to 2006	1669
2	Borkhal	1970 to 2006	1697
3	Kalibel	1962 to 2006	1559
4	Ahwa	1903 to 2003	1962
5	Surgana	1955 to 2006	1997
6	Jhuj	1969 to 2003	1973
7	Dharampur	1901 to 2003	2368
8	Saputara	1971 to 2006	2520
9	Rundhapura	1970 to 1997	1644
10	Chorvani	1963 to 2006	2001
11	Satem	1973 to 2001	1460
12	Waghai	1931 to 1997	1946
13	Vansda	1901 to 2003	1935
14	Garkhadi	1967 to 2006	1787
15	Antapur	1965 to 2006	1733
16	Mahuva	1962 to 2003	1419
17	Dholikuva	1969 to 2003	1953
18	Kalwada	1973 to 2006	1982
19	Chikhali	1901 to 2003	1800
20	Gandeva	1979 to 2006	1754
21	Dungari	1983 to 2006	1786
22	Amalsad	1973 to 2006	1599

<b>S. No.</b>	<b>RG Station</b>	<b>Period of Availability of Data</b>	<b>Average Annual Rainfall (mm)</b>
23	Gandevi	1962 to 2006	1884
24	Astagam	1970 to 1997	1558
25	Sara	1977 to 1997	1758
		<b>Average</b>	<b>1830</b>
<b>D</b>	<b>Purna basin</b>		
1	Laochali	1971 to 2006	1603
2	Dhanmodi	1971 to 2006	1295
3	Kalibel	1962 to 2006	1559
4	Ahwa	1903 to 2003	1972
5	Navsari	1927 to 2003	1469
6	Nizar	1963 to 2003	782
7	Jamkhadi	1965 to 2006	1617
8	Chimar	1971 to 1997	1217
9	Zankhari	1962 to 2006	1550
10	Raniamba	1969 to 2006	1538
11	Satem	1973 to 2001	1460
12	Subir	1964 to 2006	1601
13	Valod	1901 to 2003	1451
14	Garkhadi	1967 to 2006	1787
15	Antapur	1965 to 2006	1733
16	Mahuva	1962 to 2003	1419
17	Sarbhon	1973 to 2006	1420
18	Wankaner	1973 to 2006	1448
19	Ugat	1974 to 2002	1392
20	Vesma	1973 to 2006	1462
21	Maroli	1969 to 1997	1246
22	Vyara	1962 to 2003	1477
23	Astagam	1970 to 1997	1558
24	Dosvada	1972 to 2003	1279
		<b>Average</b>	<b>1472</b>

#### 4.6.2 Discharge Data

The Water Resources Department, Government of Gujarat is observing Gauge and Discharge at Nanivahiyal GandD site in Par basin; Amba, Bhervi and Asura GandD sites in Auranga basin; at Kudkas and Unai GandD sites in

Ambica basin; and at Kalibel and Navsari GandD sites in Purna basin. In addition Central Water Commission is observing Gauge and Discharge at Gadat GandD site in Ambica basin and at Mahuva GandD site in Purna basin. The details of these GandD sites along with respective period of availability of data are given in Table – 4.11:

**Table – 4.11**  
**Details of GandD sites**

<b>S. No.</b>	<b>Name of Discharge/ Gauge Site</b>	<b>River / Tributary</b>	<b>Catchment Area (km<sup>2</sup>)</b>	<b>Period of Availability of Data</b>
1	Nanivahiyal	Par	1254	1966 to 2004
2	Amba	Auranga/Tan	241.00	1962 to 2004
3	Bhervi	Auranga	628.65	1974 to 2006
4	Asura	Auranga/Man	309.29	1993 to 2005
5	Gadat	Ambica	1510	1979 to 2004
6	Kudkas	Ambica/Khapri	476	1980 to 2006
7	Unai	Ambica	1031	1979 to 2006
8	Mahuva	Purna	1750	1979 to 2004
9	Kalibel	Purna	720.85	1962 to 1990, 1997,1998,2000
10	Navsari	Purna	2012	1980 to 1997

#### **4.6.3 Wind Speed**

The mean maximum and minimum wind speed observed at Surat IMD station is 6.4 km/hr in May and 1.7 km/hr in October and the same at Vadodara IMD station is 13.3 km/hr in May and 2.2 km/hr in November.

#### **4.6.4 Humidity**

The maximum relative humidity observed at Surat and Vadodara IMD stations is 90% and 94% in August respectively and the minimum relative humidity is 53 % in March and 44 % in April respectively.

#### **4.6.5 Temperature**

The mean maximum temperature recorded at Surat and Vadodara IMD station is 36.8 °C and 39.9 °C in April respectively and the mean minimum temperature is 14.7 °C and 13.2 °C in January respectively.

#### **4.6.6 Sedimentation**

The reservoir sedimentation studies of all the reservoirs in Par – Tapi - Narmada link project were carried out through Hydrology (South) Directorate of Central Water Commission. Sediment data measurements are being observed in three rivers only: Ambica, Purna and Auranga rivers. Data for Par and Nar basins are not available. The sedimentation rates observed at GandD data sites are relatively lower as compared to sediment rate based on hydrographic survey of five reservoirs in the region and much lower than the generalized siltation rate recommended for the region (west flowing rivers beyond Tapi) in the “Compendium of Silting of Reservoirs in India”. The hydrographic survey of existing reservoirs generally provide sound basis for the assessment of sedimentation rate in the region. The hydrographic survey of five reservoirs indicate sedimentation rate of 7.15 ham/ 100 sq km/yr as above. The hydrographic Survey of Madhuban reservoir in Damanganga basin, which lies towards south of PTN link projects, gave sedimentation rate of 8.94 Ham/ 100 sq km/ yr. Normal rainfall in Damanganga basin is higher than the normal rainfall in river basins of PTN links and therefore sedimentation rate of 7.15 ham/ 100 sq km/yr, as assessed based on hydrographic survey of reservoirs in the region, appears in order. However the land use changes are likely to impact the sediment generation from the catchment in the future with increasing human activities such as agriculture etc. Presently the catchment of these river basins particularly the upper catchment are not significantly affected by the human activities. Impact of climate change is likely to increase rainfall intensities and extreme meteorological events. In view of above factors, the observed sedimentation

rate of 7.15 ha-m/100 sq km/ year is enhanced by 25% and sedimentation rate of 8.94 say 9 ha-m/100 sq km/ year has been adopted in the analysis of all the seven reservoirs in the PTN link

Accordingly, the total silt deposit in all the reservoirs has been estimated using Empirical area Reduction method in 100 years and 50 years duration and given in Table – 4. 12:

**Table – 4.12**  
**Sediment Deposit in Various Reservoirs**

S. No.	Reservoir	Total Sediment Deposit (Mm <sup>3</sup> )	
		After 50 Years	After 100 Years
1	Jheri	18.01	35.94
2	Paikhed	13.57	27.14
3	Chasmandva	3.88	7.76
4	Chikkar	13.04	26.03
5	Dabdar	19.55	39.03
6	Kelwan	29.90	59.69

#### 4.6.7 Water Quality

M/s WAPCOS Ltd, as a part of EIA study of the P-T-N link, collected the water samples from different river bodies and analysed for both chemical and physio-chemical analysis for ascertaining the water quality status in the project area during summer, winter and monsoon seasons. It is observed that the pH level in the project study area ranged from 6.95 to 8.32 during summer, 7.3 to 8.2 during winter and 7.2 to 8.1 during monsoon seasons. The pH level indicates neutral nature of the water and the values are within the permissible limit of 6.5 to 8.5 specified for drinking water requirements. The TDS level in summer, winter and monsoon seasons ranged from 150 to 1010 mg/l, 56 to 340 mg/l and 72 to 220 mg/l respectively. The TDS levels in some of the collected

samples were above the permissible limit of 500 mg/l specified for drinking water. However, they were well within the cause for rejection limit of 1500 mg/l. Further, it is found that the hardness level ranged from 50 to 230 mg/l, 20 to 110 mg/l and 52 to 120 mg/l during summer, winter and monsoon seasons respectively. The hardness level generally was well below the permissible limit of 200 mg/l specified for drinking water.

#### 4.6.8 Evaporation

There is no pan evaporimeter installed near any of the reservoirs proposed in Par–Tapi–Narmada link project. Therefore, the monthly reservoir evaporation losses of Madhuban (Damanganga) reservoir have been considered for hydrological study of Par-Tapi-Narmada Link Project. The monthly pan evaporation depths considered for the study are given in Table – 4.13:

**Table – 4.13**

**Monthly Pan Evaporation Depths at Madhuban Reservoir**

Sl. No.	Month	Monthly Pan Evaporation (mm)
1	January	127.6
2	February	127.6
3	March	203.2
4	April	225.6
5	May	251.6
6	June	203.2
7	July	101.6
8	August	101.6
9	September	152.4
10	October	203.2
11	November	152.9
12	December	127.6

#### **4.6.9 Morphological Studies**

The Morphological studies of the rivers involved in Par – Tapi – Narmada link project have been carried out through Regional Remote Sensing Center (RRSC), Nagpur. The report of RRSC, Nagpur on Morphological studies is at Appendix – 4.10 in Volume – III.