

Chapter 4 Surveys and investigations

4.1 Topographical surveys

The topographical surveys and other investigations of the entire link canal (including for the initial 16.90 km and Barmul project) has been completed and extract of GSI, CSMRS, NECTAR, NIH and NTH reports were presented in Vol-IV of the report.

4.1.1 Head works (Barmul Project)

The topographical surveys for submergence area of proposed Barmul dam and connecting canal about 16.90 km from proposed Barmul dam to join Mahanadi-Godavari link (M-G link) using Remotely Piloted Application System (RPAS) had been awarded to "North East Center For Technology Application & Reach (NECTAR)". The NECTAR has completed the field survey works and submitted the report to NWDA during August, 2018.

4.1.2 Canal and canal structures

The Mahanadi (Barmul)-Godavari(Dowlaiswaram) link canal off takes from the right side of the proposed Barmul dam on Mahanadi River at about 17 km upstream of Manibhadra in Nayagarh district of Odisha State. The total length of the link canal is 844.595 km from the off take point to the outfall into Godavari at about 15 km upstream of Dowlaiswaram barrage.

The centre line of the link canal marked on the 1:50000 scale toposheets of Survey of India, is transferred to the ground by first measuring the bearings of the alignment on the toposheets and then setting them on ground with the help of compass/theodolite.

Along the centre line of the link canal, levels are taken at 50 m interval (mostly hilly terrain) upto RD 471.722 km (Vamsadhara crossing) and at 100 m interval for the remaining portion (mostly plains) upto the tail end, by double levelling. The double levelling carried out was checked for its accuracy by connecting to many GTS benchmarks located along the alignment. The plan and condensed L-section along the link canal alignment are given in **Plates 8 (1/34) to 8 (34/34)**.

Cross sections are taken by single levelling at 400 m interval along the alignment in the entire reach with levels at 50 m interval extending upto 200 m on either side of the alignment upto RD 371 km and beyond this point cross sections are extended to 500 m on either side of the alignment upto

Vamsadhara crossing (RD 471.722 km). In the remaining portion the cross sectional lines are extended up to 200 m on either side of the alignment with levels at 100 m interval. Wherever appreciable change in topography is noticed along the center line of the alignment and cross sectional lines, levels are taken at closer intervals.

Block levelling has been carried out at places where cross drainage works are proposed by forming 50 m or less interval grid lines to cover an area upto 300 m on either side of the centre line of the link canal along the stream and laterally upto the firm bank plus 100 m on either bank of the stream. Similarly, block leveling by forming 50 m interval grids was done at road/railway crossings along the alignment, covering an area upto 300 m on either side of the centre line of the link canal and 100 m either side from the centre line of the road/railway.

Centre line stones have been fixed all along the alignment at 1 km interval. In addition, centre line stones are also fixed along the alignment at road crossings and at important CD works and at all the turns/bends indicated by change in the bearings of the link canal alignment.

4.1.3 Tunnels

Two tunnels have been proposed along the alignment of Mahanadi – Godavari link canal. Topographical survey of these tunnel portions have been done by taking levels at closer intervals and shown in L section of the link canal alignment. A tunnel of length 0.75 km has been proposed across Pecha Mundia ridge between RD 24.475 km and 25.225 km, near Gania village in Odisha and another tunnel of length 5.40 km from RD 634.050 km to 639.450 km has been proposed near Kottavalsa village across the ridge of Gosthani and Borrama gedda rivers.

4.1.4 Command area

The command area proposed en route the link canal lies in the States of Odisha and Andhra Pradesh. The total culturable command area (CCA) under the canal is 363959 ha out of which 256770 ha (70%) lies in Odisha and 107189 ha (30%) in Andhra Pradesh. The proposed command area under the link canal has been identified by utilising the toposheets of scale 1: 50000. Topographical survey for a sample command of 1250 ha in Odisha portion and 1000 ha in Andhra Pradesh portion have been done. The State- wise / District-wise break up of CCA is given at **Annexure 4.1**.

4.2 Soil conservation, archaeological and mineral surveys

No mineral deposits, important religious and archaeological sites are coming under the submergence of proposed Barmul reservoir. Soil conservation measures are contemplated in the catchment of Barmul dam site.

4.3 Geology and geo-technical features

4.3.1 Head works

Reconnaissance Survey (Field visit) of Barmul dam site and about 16.90 km long canal from Barmul to earlier M-G link off take point of Mahanadi-Godavari link project has been conducted by Geological Survey of India (GSI), Bhubaneswar team. The drilling work has been conducted at the following locations. Details are given in **Table 4.1**

Table 4.1
Details of bore holes

Sl. No.	Description of bore hole /location	No. of bore holes
1	Left bank, Right bank and Centre of Mahanadi river at Barmul dam axis	3 Nos.
2	Downstream and Upstream of Barmul dam axis at a distance of 40 m in the bed of Mahanadi river	2 Nos.
3	Left Bank, Right bank and Centre of Khalakala nadi (RD 1.000 km)	3 Nos.
4	Left Bank, Right bank and Centre of Brutang nadi (RD 15.800 km)	3 Nos.
5	Centre of deep cut reach (RD 12.600 km)	1 No.
	Total	12 Nos.

The report is appended in Vol – IV of the Report.

4.3.2 Canal, tunnels and cross drainage structures

The preliminary geological investigations, Geological mapping of the proposed canal alignment including tunnels and major cross drainage works of the proposed link canal alignment have already completed by the Geological Survey of India (GSI) and report submitted to NWDA.

The geological evaluation of the link canal alignment by the GSI has been done by observing the nature of rock type available at road crossings, nala crossings and railway crossings. The dug wells located in the area have also been observed which includes enquiries from local people regarding nature of excavated strata from dug wells. Taking all the above mentioned points into consideration and based on the available geological literature of the area, it has been estimated that the depth of fresh rock generally ranges from 12 to 18 m.

The geological evaluation of the project area as presented by the GSI in their report is detailed in the following paras.

a) Canal

As assessed by GSI, the geological formation along the canal alignment are mainly Charnockites and khondalites with minor migmatitic gneiss, quartzo – feldspathic gneiss and anorthosities in Odisha portion. In Andhra Pradesh portion the canal media most of its length except in the tail end reaches comprise of the Eastern Ghat Super Group of rocks i.e. garnetiferous silliminite gneiss, garnetiferous biotite gneiss, quartzo feldspathic gneiss, quartzite, calc, granulite intruded by charnockite. The deccan traps and Rajahmundry sand stones are expected in the tail end reaches.

b) Tunnel

Massive quartzites are exposed as small patchy outcrops and also as blocks/boulders mixed with reddish brown soil over most of the area along the proposed alignment of the tunnel near Gania village of Nayagarh district in Odisha across Pecha Mundia hills. The quartzites are pale brown and buff coloured, and are medium to fine grained. They are horizontally bedded except for minor undulations. Two prominent sets of vertical joints trending in N 75° W – S 75° E and NE – SW directions are present in the quartzites besides bedding joints.

Another tunnel is proposed in the reach where the deep cut is more than 30 m. As per the sub-surface geological observations, link canal is crossing different geological formations like granite, Khondalite, Charnockite and quartzite. At the bed level of the canal mostly hard rock, hard rock with minor fractures and fractured rock are likely to be encountered.

The proposed tunnels are considered feasible in the context of improved techniques in the support system, which are available today. However, in view of non-uniform thickness and distribution of various sub-units present within the quartzites, a detailed sub-surface exploration by means of bore holes would be necessary in order to prepare a dependable geological section based on which the tunnel level itself can be decided and tunnelling conditions can be prognosticated. Such a programme of drilling can be mounted and taken up during the pre-construction stage.

Geological map of the area along the proposed tunnels along the link canal alignment are given in **Plate 9(1/2) and 9(2/2)**.

c) Cross drainage structures

Primarily to ascertain the nature of the media and secondarily to have an assessment of bed rock profile, the GSI suggested a set of minimum number of bore holes with NX bits with triple tube core barrel at the proposed major

cross drainage locations. This work from Mahanadi to Vamsadhara has been entrusted to Department of Geology, Government of Odisha and from Nagavali to Godavari it has been entrusted to Andhra University, Visakhapatnam.

4.4 Foundation investigations along the canal alignment (except for the initial 16.90 km)

CSMRS was entrusted with the work of carrying out geo-technical investigation along the canal alignment. Soil samples have been collected by excavating open trial pits/auger holes along the canal alignment. Sixty-five disturbed soil samples and thirty-five undisturbed soil samples have been collected along the link canal alignment from Vamsadhara to Godavari and tested at CSMRS.

The foundation and soil characteristics at river crossings / proposed CD works along the length of the canal from Vamsadhara to Godavari have been studied by drilling bore holes and collecting soil samples at 11 locations. These samples are tested at Andhra University, Visakhapatnam.

In deep cut reaches of Andhra Pradesh portion where the depth of cutting is more than 10 m and at the proposed location of the tunnel, geophysical investigations have been conducted to determine the sub-surface lithology from the ground surface upto the bed level of the canal. This work was entrusted to Andhra University, Visakhapatnam. Vertical Electrical Soundings were conducted by the University at 262 locations covering a total length of 105 km in 18 different reaches at 500 m interval and at 200 to 300 m interval at the tunnel portion.

4.5 Construction material investigation

4.5.1 Soils (Borrow area Survey)

Forty-three borrow areas have been identified along the entire length of the alignment from which soil samples have been collected and tested in the laboratory of the CSMRS. The test results indicate that soils from most of the identified borrow areas are generally suitable for embankment. It is estimated that sufficient quantity of earth for net filling of the link canal is available from these borrow areas. The average lead is around 10 km.

4.5.2 Fine aggregate

A total number of 22 sand samples were collected from 20 different prospective river bed quarries for assessing their suitability for use as fine aggregate in concrete. These sand quarries have been identified in the rivers Bahuda, Madala, Mandakini, Dhanei, Rushikulya, Goraharah, Vamsadhara,

Nagavali, Champavati, Gosthani, Sarada, Varaha, Tandava and Godavari. The average lead from the above quarries varies from 10 to 25 km. It is estimated that sufficient quantity of fine aggregate is available from these quarries for use in the link canal.

4.5.3 Coarse aggregate

A total number of 38 rock samples were collected from prospective quarries for assessing their suitability for use as coarse aggregate in concrete. These samples were tested by the CSMRS. The average lead from different quarries varies from 10 to 50 km to the respective reaches. It is estimated that sufficient quantity of coarse aggregate is available from these quarries for use in the link canal.

The quarry area surveys have been carried out by the CSMRS for construction materials viz. coarse aggregate and fine aggregate. The locations of quarries are shown in Plate **10(1/2) to 10(2/2)**.

4.5.4 Bricks

Soils of suitable quality for manufacture of bricks and tiles for use in building construction are available along the entire length of canal alignment. Brick kilns are located near Khurda, Nayagarh, Banpur, Aska, Palasa, Srikakulam, Vizianagaram, Kottavalasa, Tuni, etc., along the alignment of link canal.

4.5.5 Cement and steel

The quantity of cement required for completion of the project is estimated to be approximately 2.5 million metric tonnes. This requirement is proposed to be met from several cement factories (with varying installed capacities) located in the vicinity of project area viz., Hira Cement Works, Baragarh (0.504 million metric tonnes) and Kalinga Cement Company, Bhubaneswar (0.04 million metric tons) in Odisha State and Andhra Cement Co., Porlupalem, Visakhapatnam (0.5 million metric tonnes) and Sagar Cements, Anakapalli (0.132 million metric tonnes) in Andhra Pradesh State. Visakhapatnam Steel Plant is located in the vicinity of link alignment i.e. at Visakhapatnam, Andhra Pradesh from where required quantity of steel can be obtained. The link alignment almost runs parallel to the Howrah-Chennai railway line and National Highway NH 16. Cement and steel can be received easily at all railway stations located near the canal alignment i.e. Khurda, Balugan, Berhampur, Palasa, Vizianagaram, Kottavalsa, Duvvada, Anakapalli, Tuni, Annavaram, Samalkot and Rajahmundry and transported to the site of construction.

Testing results of all the above material and investigation works are given in **Annexures 4.2 to 4.7.2.**

4.6 Soil Surveys - mapping of existing land use/land cover and Irrigability

Red sandy loams, red sandy soils and black cotton soils are the predominant soils available in the command. Soil map of the command area is appended as **Plate 11(1/2) to 11(2/2).**

The thematic maps of the land use/land cover and land irrigability prepared by the NBSS & LUP, Nagpur were utilised for planning of the command area. Irrigable tracts of land were delineated and demarcated on 1:50000 land irrigability maps which facilitated reliable identification of the irrigable area under each of the branch canals.

4.6.1 Land use classification details

The land use classification details of the command area of the link canal are given in **Table 4.2.**

Table 4.2
Land use statistics of the command area of Mahanadi (Barmul) –
Rushikulya- Godavari (Dowlaiswaram) Link canal

Sl. No.	Land use/Land cover category	Area in ha.	Percentage
1	Forest	85975	14.79
2	Barren land	50434	8.68
3	Land put to non-agricultural use	66843	11.50
4	Permanent pastures and other grazing land	14108	2.43
	Sub-Total:	217360	37.40
5	Land under miscellaneous Crops and trees	27343	4.70
6	Culturable waste	14793	2.54
7	Other fallows	21753	3.74
8	Current fallows	36902	6.35
9	Net area sown	263168	45.27
	Sub-Total:	363959	62.60
	Grand-Total	581319	100.00

4.6.2 Soil classification

The available soils of the command area are grouped according to the physiographic units having similar soil characteristics such as soil depth,

texture, permeability, moisture holding capacity, sub-surface cover, salinity, sub-soil drainage, erosion status etc. **Plate 11(1/2) to 11(2/2)** shows various soils available in the command area. The broad description of these soils is furnished below.

Clay soil: These soils are very deep, imperfectly drained, on very gently sloping coastal plains with loamy surface and slight erosion; associated with very deep, poorly drained, fine loamy soils with loamy to fine loamy surface, moderate erosion and slight salinity (limited extent).

Clay loamy soils: These soils are very deep, imperfectly drained, fine cracking soils on very gently sloping inland plain with clayey surface and slight erosion; associated with deep, imperfectly drained, fine soils with clayey surface and slight erosion.

Gravelly clay soils: These soils are deep, imperfectly drained, fine swell shrink soils on gently sloping valley with clayey surface and slight erosion; associated with very deep, poorly drained, fine cracking, soils with fine, clayey surface and slight erosion.

Gravelly loamy soils: These soils are very deep, poorly drained, fine cracking soils on nearly level swamps with clayey surface, slight erosion and moderate flooding; associated with very deep, imperfectly drained, fine soils with loamy Surface and slight erosion.

Fine loamy soil: These soils are moderately deep, somewhat excessively drowned, fine loamy soils on moderately slopping hills with loamy surface, severe erosion and strong stoniness, associated with moderately shallow, well drained loamy skeletal soils with loamy surface and moderate erosion.

Sandy soils: These soils are very deep, somewhat excessively drained, sandy soils with very low AWC, on very gently sloping sandy plains, slightly eroded; associated with deep, imperfectly drained, loamy soils with high AWC.

4.6.3 Land Irrigability classification

Land Irrigability classification is further grouping of the irrigable soils into land irrigability classes considering the slope, subsurface grading, drainage, depth of water table below ground level etc. Land suitable for irrigation are grouped under classes 1 to 4 according to their limitations. Lands not suitable for irrigation are grouped under classes 5 and 6.

4.7 Drainage survey

The proposed en route command area is well drained by rivers/streams like Kuaria, Kusimi, Mahanadi, Salia, Dhanei, Baghua, Mahanadi, Rushikulya, Nandini, Ghoraharah, Bahuda, Madala, Vamsadhara, Nagavali, Kandivalsa, Champavati, Gosthani, Borammagedda and Naravagedda and also by a number of major/minor drains. As such, the proposed command area is not likely to encounter any serious drainage problem. However, certain provision is made in the estimate for providing drainage facilities in the command, though no detailed surveys were undertaken for the purpose. The available natural drainage system in the command area in the form of rivers, streams, nallas etc., is shown in **Plate 12**.

4.8 Communication Surveys

All the important structures of the project are approachable by pucca / kachcha roads. The National Highway No. 16 (NH 16), the South Eastern Railway and the South Central Railway line connecting Howrah and Chennai pass through proposed command area. All the important villages/towns situated along the canal alignment and in the command area are well connected by telephone lines, power lines and a wide network of roads. The major communications available in the area at present are shown in **Plate 12**. There can be further improvement in the communication system in the command area in the course of development in future. Inspection roads of link canal and major branch canals in the command area would lead to further improvement in the communication systems.

4.9 Hydrological and meteorological investigations

The data from hydrological and meteorological stations available in the command area were collected and used for computations and designs of the canal components. The details of these stations are given in the following paragraphs.

4.9.1 Hydrological data

There are six gauge and discharge sites in the area between Mahanadi and Godavari adjacent to link alignment. Salia site on Salia river maintained by Govt. of Odisha, Purushottampur site on Rushikulya river maintained by CWC, Kaliguda weir site on Bahuda river maintained by Govt. of Odisha, Kasinagar site on Vamsadhara river maintained by CWC, Narayanpuram Anicut site on Nagavali river are maintained by Government of Andhra Pradesh and Anapalli site on Sarada river maintained by CWC. The inflows at the Eleru reservoir also utilised in the basin streams between Nagavali and Godavari.

4.9.2 Climate

The summer season is from March to May, the monsoon is from June to November and the winter is from December to February in the vicinity of the command area. There are four IMD observatories viz. Puri, Gopalpur, Kalingapatnam and Visakhapatnam, in and around the command area. The data on rainfall, temperature, relative humidity, wind speed, cloud cover, etc. are available at the observatories.

4.9.3 Rainfall

There are about 65 rain-gauge stations in and around the command area. The rainfall data of these stations are available for varying periods.

4.9.4 Temperature

The monthly average maximum and minimum temperatures observed at Visakhapatnam and Gopalpur observatory are 37.1°C and 18.3°C and 36.7°C and 13.8°C respectively in the months of June and January.

4.9.5 Relative humidity

The maximum and minimum values of relative humidity observed 85 % in July and 61 % in December at Puri observatory, 80 % in September and 65 % in December at Visakhapatnam observatory.

4.9.6 Wind speed

The command area is influenced by winds from the south-west during the monsoon season. The maximum wind velocity is 16.1 km/hr in May and the minimum is 6.3 km/hr in November observed at Puri and the same are 13.7 km/hr in May and 6.7 km/hr in January observed at Visakhapatnam observatory.

4.9.7 Cloud cover

The sky is heavily clouded during the south-west monsoon. During remaining part of the year, clear or lightly clouded sky prevails. The maximum cloud amount is 6.6 oktas in the month of July and minimum is 0.4 oktas in the month of December observed at Gopalpur. The same are 6.7 oktas in the month of July and 0.5 oktas in the month of December observed at Visakhapatnam observatory.

4.10 EIA and Socio-economic surveys

Barmul project involves creation of reservoir with water spread area of 13768 ha. There will be dislocation of existing settlements 58000 persons in 93 villages. The area under submergence upstream located six dams 10098 ha. There is a crocodile project at Tikarpara gorge which will be affected by Barmul reservoir. Satkosia tiger reserve is located on right side of the Barmul reservoir. The total land area of 22587 ha is to be required for main canal, borrow areas, rehabilitation colonies and power houses. Out of which 1178 ha is Forest land, 1900 ha Govt. land. Due to link canal 76 villages partially affected, 648 people are to be rehabilitated. The total area of 5.46 lakh ha of irrigation will be benefited by the link canal. Employment generation of 33821 Nos. A total hydro power of 210 MW is benefit of the project.

4.11 Archeological surveys

No historical monuments or archeological structures are found in the project area.

4.12 Topographical survey of Six projects

Govt. of Odisha has prepared project reports for these projects and the status is given in **Table 4.3** below:

Table 4.3

Sl. No.	Name of Project	Type of project	Report status
1	Ong Dam	Major -Proposed	DPR completed (Aug -2015)
2	Utti Roul	Major - existong	FR completed (Mar -2008)
3	Upper Udanti	Major -Proposed	PFR completed (Nov -2013)
4	Tel Integrated project	Existing -Medium	DPR completed (Feb -2015)
5	Salki HE Project	Medium-Existing	PFR completed (2011)
6	Khadaga HE project	Major -Proposed	FR completed (June -2015)