Chapter 6
Designs and layout

6.1 Structure, layout and design features of the head works

6.1.1 Location of the head works

The Mahanadi (Barmul)-Godavari (Dowlaiswaram) link canal off takes from the right bank of the proposed Barmul dam at about 17 km. upstream of Manibhadra on River Mahanadi 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 in East Godavari District of Andhra Pradesh near Rajahmundry.

6.1.1.1 Barmul project and the link canal off-take

The Barmul project is a proposed multi-purpose project on river Mahanadi. The project comprises of a dam to be constructed across Mahanadi about 17 km upstream of Manibhadra on River Mahanadi in Nayagarh district of Odisha State. The Mahanadi(Barmul)- Godavari(Dowlaiswaram) link canal off takes from the right bank of Barmul dam near Barmul village. The link canal project provides irrigation to about 3.70 lakh ha land in Puri, Cuttack, Khurda, Nayagarh, Ganjam and Gajapati districts of Odisha and Srikakulam, Vizianagaram and Visakhapatnam districts of Andhra Pradesh besides meeting domestic and industrial water requirements, pisciculture, recreation and mitigation of flood hazards.

The proposed Barmul dam is located at latitude 20° 30’ 44”N and longitude 84° 52’ 34” (Toposheet No. 73D/14). The total length of the dam is about 850 m, comprising of concrete dam with overflow and non-overflow sections.

The maximum height of the concrete dam is about 25 m above ground level. The tentative FRL of the reservoir is 80.00 m. The corresponding gross storage capacity of the reservoir at FRL is 1216 MCM and live storage is 965 MCM. The Index map of head works of proposed Barmul project is at **Plate 15.**

The submergence area under Barmul reservoir is shown in Plate **16**. The cross sections of concrete dam (overflow and non-overflow sections) are presented in **Plate 17(1/2 & 2/2)**.

6.2 Salia dam

Salia reservoir is an existing medium irrigation project on river Salia in Khurda district of Odisha State. The existing FRL of the Salia dam is 58.52 m with a gross storage capacity of 59.868 MCM and live storage capacity of

51.968 MCM. The proposed link canal out falls into Salia reservoir on left bank and again takes off from the right flank of the Salia dam. The FRL of the Salia project is proposed to be raised to 62.32 m for the purpose of the link canal. The corresponding increase in gross storage of the project will be utilized for diversion of link canal. The Index map of Salia project head works is at **Plate 18.**

6.3 Dowlaiswaram barrage (Cotton barrage)

Dowlaiswaram barrage is an existing major project located on river Godavari near Rajahmundry town in East Godavari District of Andhra Pradesh. The pond level of the barrage is 13.64 m and length of the barrage in 5837m. The Mahanadi – Godavari link canal out falls in to the river Godavari at Torrigedda village about 15 km upstream of the barrage. The plan of Dowlaiswaram barrage is at **Plate 19.**

6.4 Other Projects

Six projects namely i) Ong Project, ii) Tel Integrated Project, iii) Upper Udanti irrigation Project, iv) Uttei Roul Project, v) Khadaga Hydropower Project and vi) Salki Hydropower Project proposed by State Government are integrated with Barmul project. The details of all these projects are explained in Chapter 7.

6.5 Design features of Mahanadi (Barmul)- Godavari (Dowlaiswaram) link canal

6.5.1 Description of the canal system

As already mentioned, the proposed link canal off -takes from the right flank of the proposed Barmul dam through a canal head regulator. The general topography of the area through which the Mahanadi(Barmul)-Godavari(Dowlaiswaram) link canal traverses is mostly hilly in Odisha State and mostly plain with a few local high mountains and sporadic hills in Andhra Pradesh State. In the initial reach of 80 km, the canal runs in south-east direction and then takes a right turn and runs in south-westerly direction parallel to sea coast up to its out fall in to river Godavari. The total length of the link canal is 844.595 km with a longitudinal slope of 1:20,000 in the entire reach except in the tunnel portions.

6.5.2 Description of the canal alignment

A statement showing locations of the various structures along the link canal, head losses provided at these structures, fall due to the bed slope and full supply levels at the start and end of the reach is at **Annexure 6.1**. **Plates**

8(1/34) to 8(34/34) present the longitudinal sections with strip contour plan of the link canal indicating important structures enroute. Reach-wise brief description of the special features of the link alignment from the off-take point to the out fall into the Godavari river is presented in the following paragraphs.

6.6 Reach wise Description

The alignment of the link canal was initially studied on Survey of India topo-sheets of scale 1:50,000. Topographical survey has been carried out along the alignment finalized on the topo-sheets. The total length of the link canal is 844.595 km. A brief reach wise description of the special features of the link alignment from the right bank of the proposed Barmul Reservoir off take point to the outfall into Godavari at about 15 km upstream of Dowlaiswaram barrage in East Godavari District of Andhra Pradesh near Rajahmundry is presented below.

(i) Reach RD 0.0 to 0.950 km

This reach is shown in **Plate-8(1/34)**. The waters from the proposed Barmul Reservoir on Mahanadi river will be picked up into the canal with FSL 75.060m. The FSL at the end of this reach is 74.862 m. A regulator is proposed here to let the excess releases into the main river. One super passage is proposed at RD 0.950 Km on Khalakhala nala near Bahali village.

(ii) Reach RD 0.950 km to 20.900 km

The FSL of the link canal at the beginning of the reach is 74.862 m. and at the end of reach is 73.594 m. The link canal passes to the west of village Tangisahi and runs in the south-east direction crossing small streams which will be syphoned under it. The canal passes near the boundary of villages Malatipura, Nuagan, Mainsibindha, Kondhamiriks, Kiajhora, Khalisahi and Guriabari protected forest. One super passage is proposed at RD 15.800 km on Brutanga Nala near Raigarha village. Four single lane bridges are proposed at RD 1.050, 11.400, 15.000 and 16.400 km on roads Khalkhala nadi towards Dipasahi, Haripur to Kaniphukhuri, Gupteswar mandir to Mohanpada, Dankarisahi- Gupteswar road near Dankarisahi village respectively. And it runs in south-east direction along the right bank of the Mahanadi river upto 19.500 km. One under tunnel is proposed in this reach.

(iii) Reach RD 20.900 to 58.900 km

The canal passes near the boundary of villages Malatipura, Nuagan, Mainisibindha, Kondhamiriks, Kiajhora, Khalisahi and Guribari protected forest. Two cross regulators are proposed at RD 23.250 km for Kantilo

branch canal and at RD 48.900 Km for Khalisahi branch canal. And it passes to the Malatipura village and to north of Nuagan village. A tunnel of 0.75 Km is proposed at RD 24.475 km and it takes a serpentine course from RD 25.600 km to cross Pechamundia hills and proceeds in south-east direction in the remaining reach. The link canal crosses the Kuaria nadi at RD 37.600 km. and Kusumi nadi at RD 51.915 km. where aqueducts have been proposed. The link canal crosses the Gania – Dasapalla , Adakata – Singhaparha, Khalisahi – Khandapara and Khandapara – Fatehgarh roads at RD 27.775 km , 39.758 km, 49.875 km. and 56.141 km. respectively, where suitable road bridges have been proposed. It crosses numerous small streams which will be syphoned under the canal. The FSL of link canal is 73.594 m at the start of the reach and 70.056 m at the end of the reach.

(iv) Reach RD 58.900 to 107.200 km

The link canal runs towards east near the Nagapalli reserved forest up to RD 93.900 km. The canal then passes west of the villages Patabhandha, Kantilo, Rajsunakhala, Sanapadara, Kulasara, Manapur and east of Raja Ranpur. Road bridges have been proposed near village Rajsunakhala on the Nayagarh-Khurdha road at RD 74.325 km, on the Rajsunakhala – Rajranpur road at RD 76.628 km, on the road connecting Arakhapalli to Rajsunakhala – Rajranpur at RD 85.625 km, on the road connecting Nuagar - Garhbanikila at RD 90.940 km, on Rajranapur – Belaparha road at RD 95.531 km. and Raja Ranpur – Khanadanayagarh road at RD 96.385 km and on Gundabari – Gopalpur road crossing at RD 103.644 km. The link canal crosses river Mandakini at RD 95.231 km where an aqueduct has been proposed. A canal escape is provided at RD 101.050 km to facilitate diversion of link canal waters into Mandakini river in case of breach of bunds or repairs. Two nos. of under tunnels are proposed at RD 102.600 km on Kankar Jhora and at RD 106 .950 km across tributary of Mandakini river respectively. It crosses numerous small streams which will be syphoned under it. The FSL of link canal is 70.056 m at the start of the reach and 66.830 m at the end of the reach.

(v) Reach RD 107.200 to 137.550 km

Initially, the canal runs towards east near the boundary of Dhanai reserved forest up to RD 116.900 km. and south-west up to the end of the reach. It crosses the Gopalpur - Khandanayagarh road at RD 115.395 km, road from Gorisahi to Patia to (NH – 16) at RD 125.350 km and Nachuni on NH - 16 to Gachipatra at RD 135.000 km. The canal passes west of Raipara and east of Patia villages. The canal crosses various small streams which will be syphoned under the canal. The FSL of link canal at the start and end of this reach is 66.830 m and 64.903 m respectively.

(vi) Reach RD 137.550 to 166.400 km

The canal passes in the initial reach inside and along the boundary of the Chakara Pathar and Jharan protected forests and the Sandhamul, Arang and Bankar reserved forests and enters the Salia reservoir at RD 160.900 km. From RD 143.400 km to RD 154.900 km i.e., for a length of 11.50 km, where the alignment runs in heavy embankment of about 30 m, an aqueduct has been proposed. The link canal passes west of the Pankal, Ayatpur, and Sanasiralpur. The link canal takes off from the right dyke of Salia reservoir with FSL 61.820 m near Kumaripari village and runs south - west direction. The link canal crosses various small streams which will be syphoned under it. The FSL of the link canal at start of the reach is 64.903 m and at the end of the reach is 61.545 m.

(vii) Reach RD 166.400 to 170.600 km

In this reach, the canal runs east of the Bhabinpur, Haripur, Paikpoda and Nuapalli villages and west of the Suanri village. The canal then passes east of the Kumari-Pari and Bore Band reserved forests. It crosses numerous small streams which will be syphoned under it. The FSL of the link canal at the start of the reach is 61.545 m and at the end of the reach is 61.270 m.

(viii) Reach RD 170.600 to 203.375 km

The link canal runs south-west up to RD 182.280 km and towards west up to RD 191.900 km and north-west in its remaining length of the reach. It crosses the Dhanei nadi at RD 195.285 km and Bhagua nadi at RD 199.000 km where syphon aqueduct and aqueduct respectively have been proposed. Road bridges have been proposed on the Kodala - Kasiparha road at RD 182.280 km, on the Mathura - Polasara road at RD 193.893 km and on Polasara - Rukakana road at RD 197.252 km. The canal runs north of the Tentulipalli, Gorhaparha, Kalimeghi, Mathura and Rumagarh villages and south of the Marirhipalli, Dhaumal, Polasara and Barittini villages. En route, the link canal crosses various small streams which will be syphoned under it. The FSL of link canal at start of the reach is 61.270m and at the end of the reach is 58.875 m.

(ix) Reach RD 203.375 to 245.400 km

In the initial reach, the link canal runs west up to RD 210.350 km and south-west up to RD 227.400 km. It crosses Mahanadi (Badanadi) and Rushikulya rivers at RD 213.047 km and RD 226.845 km respectively, where aqueducts have been proposed. The link canal crosses Rushikulya RBC at RD

227.350 km and runs parallel to the west of Rushikulya canal up to the end of the reach. The canal passes north of the Shandhasolia reserved forest and east of the Machhakhai reserved forest, Suliyagurhiya Ambada and Bansa protected forests. The Garhagarha and Pakirhi reserved forests are located east of the link canal. The villages Balipadara, Aska and Takararha lie on left of the alignment. The villages Arkhapur, Dharakota and Sheragarh lie on right of the alignment. Road bridges have been proposed on the Bugurha-Balipadar road at RD 209.270 km, on the Aska - Bhanjanagarh road at RD 219.669 km, on the Surada-Aska road at RD 227.322 km Bariguraha-Kushuraha at RD 234.300 km, Aska-Digapahandi forest road at RD 234.900 km, Padmapur-Borhgarha at RD 239.550 km and on the Aska-Digapahindi road at RD 242.463 km. The canal crosses various small streams which will be syphoned under it. The FSL of the link canal at start of the reach is 58.875 m and at the end of the reach is 56.136 m.

(x) Reach RD 245.400 to 280.500 km

The link canal runs parallel to Rushikulya canal up to RD 259.800 km. It passes west of the Banimar reserve forest and east of the Gaida reserve forest. It crosses the Nandini Nadi and the Ghorhaharh river at RD 245.435 km and RD 250.475 km respectively where syphon aqueducts have been proposed. A canal escape has also been proposed in this reach at RD 272.850 km. Road bridges have been proposed on the Jagannathpur-Arhaparah road at RD 248.562 km, on the Churhannapur - Gautumi road at RD 257.300 km, on the Taptapani-Brahmapur road at RD 263.205 km and the Digapahandi – Purushottampur road at RD 272.818 km. The canal passes west of the Brahampur, Arhaparha, Hansarali, Gautumi, Gokaranpur, Sandumla and Banthamadali villages and east of the Dharmaraypur, Sahaspur, Digapahandi, Chaitanyapur, Guhalpur and Pitamparapur villages. It crosses numerous small streams which will be syphoned under it. The FSL of link canal at the start of the reach is 56.136 m and at the end of the reach is 53.930 m.

(xi) Reach RD 280.500 to 288.750 km

The canal runs south-west upto RD 285.900 km and crosses the Bahuda river at RD 286.325 km where a syphon aqueduct has been proposed. Then the link canal turns to east and runs in north-east direction up to end of the reach. Road bridges have been proposed near the village Dauni at RD 284.750 km. and on road Chandrapur - Samasingi at RD 285.979 km. The canal passes to the west of the Barha Kelajhur and Dauni villages and to the east of the Balrampur village in this reach. The canal crosses various small streams which will be syphoned under the canal. The FSL of link canal at the start of the reach is 53.930 m and at the end of the reach is 53.323 m.

(xii) Reach RD 288.750 to 325.800 km

The canal runs south-east up to RD 294.900 km, south up to RD 297.200 km, east upto RD 303.500 km and south-west upto the village Suvranapur. From here it runs south east for some distance up to RD 318.150 km. and then south up to the end of the reach. Road bridges have been proposed on the Rajpur, Seshpur - Mahalapur road at RD 293.050 km, on the Surangi-Kelua road at RD 297.428 km, on Samantapalli – Jarada road crossing at RD 312.014 km and on Ghati Mukundapuram -Kanchili road at RD 319.375 km and on Kanchili road crossing near Gundam village at RD 324.497 km. In this reach the link canal crosses Odisha - Andhra Pradesh boarder at RD 318.600 km. The canal passes to the east of the Nakoi block of protected forest and the Rusimal Shandhabhunja and Jalantrakota reserved forests. It passes west of the Bira Singhpur, Sahaspur, Phul Rajpur, Kelua, Bhejipader, Badpur, Narinbati, Gundan and Sariapalli villages and to the east of Surangi, Suvaranapur, Mundala, Bhairipuram and Jillunda villages. The canal crosses numerous small streams which have to be syphoned under the canal. The FSL of the link canal at the start of reach is 53.323 m and at the end of the reach is 51.122 m.

(xiii) Reach RD 325.800 to 336.550 km

In this reach, the canal runs in the south-west direction. It passes to the east of the Jalantrakota reserve forest. The link canal passes east of the Daleswaram village and west of the Jalantra village. The link canal crosses small streams which will be syphoned under it. A road bridge is proposed at RD 330.483 km on Jalantra – Nuvagada road. The FSL of link canal at the beginning of the reach is 51.122 m and the end of the reach is 50.555 m.

(xiv) Reach RD 336.550 to 391.850 km

The canal runs west upto RD 338.900 km. south-west up to RD 351.150 km. east up to RD 353.900 km. and south upto RD 366.900 km. It then taken a turn towards west and continues upto RD 377.400 km and then south for the remaining reach. The link canal passes along the boundary of the Kausalya Metta, Buderosingi, Hunnali, Rukki, Badambo, Narasingpur, Ramarayikonda, Tarlakota, Mendu, Lavanyakota and Sanapuram reserved forests and crosses the Madala river at RD 338.385 km where an aqueduct has been proposed. Road bridges have been proposed near the village Kuranjabhadra at RD 337.529 km. on the Chinabarampur – Budamba colony road at RD 354.875 km and Mandasa - Goppili road at two times at RD 356.425 km and RD 379.912 km. Road bridges have also been proposed on Palasa-Tarlakota road crossing at RD 372.000 km and on Goppili- Bhimapuram road at RD 381.675 km. The link canal passes west of the Chagapuram, Kristapuram, Padmapuram, Hunnali, Mandasa, Lakshmipuram and Karajeda Muktapur

villages east of the Budarosingi and Lavanyakota villages, north of the Kaijola, Rentikuta and Goppali villages and south of the Tarlakota village. The link canal crosses various small streams which will be syphoned under it. The FSL of link canal at the beginning of the reach is 50.555 m and the end of the reach is 46.659 m.

(xv) Reach RD 391.850 to 418.550 km

The link canal runs south-west upto RD 394.350 km. south up RD 402.350 km. west up to RD 408.900 km. and south west for the remaining length of the reach. A road bridge has been proposed on the Tekkalipatnam - Parlakamidi road at RD 395.603 km. A canal escape has been proposed at RD 393.900 km. The canal passes west of the Regulapadu, Kasi-Rajukasi Puram, Naugam, Malapeta and Pedda Tamarpalli villages east of the Badagam village, south of the Madanapuram village and north of the Temburu village. The canal crosses various small streams which will be syphoned under the canal. The FSL of link canal at the beginning of the reach is 46.659 m. and the end of the reach is 45.294 m.

(xvi) Reach RD 418.550 to 466.550 km

In the beginning of the reach, the canal runs south west and then west up to RD 430.150 km. It turns again south-west near village Balrampur and continues up to RD 441.900 km. It then runs west up to RD 449.900 km. north east up to RD 454.900 km. and west for the remaining reach. The link canal crosses various small streams which will be syphoned under it. A canal escape has been proposed at RD 456.350 km. Road bridges have been proposed on Tekkali- Narsingapalli road at RD 420.775 km and Tekkali-Parlakimidi road at RD 430.779 km and on the Narsannapeta – Parlakimidi road at RD 447.716 km. One Railway bridge has been proposed on the Naupada-Gunupur Branch of the East Coast Railway at RD 430.571 km. The link canal passes to the south of the Pedda Kedari, Temburu Konda, Bejji, Saravakota and Ashokam reserve forests and the Saipatta, Balarampuram, Lingalapadu and Janakia villages, to the north of the Tekkali, Raghunathapuram, Rama Krishna Puram, Darivada, Rupu Sagaram and Gopalapuram villages, east of the Kotapalli, Donta villages and to the west of the Kurudu village. The FSL of link canal at the beginning of the reach is 45.294 m and at the end of the reach is 42.250 m.

(xvii) Reach RD 466.550 to 492.890 km

In the beginning of the reach, the link canal runs north - west up RD 472.250 km (up to which the link canal is considered as Odisha portion), and in south-west direction up to the end of the reach. The canal crosses the Vamsadhara river at RD 471.722 km, where an aqueduct has been

proposed. Road bridges have been proposed on Srimukhalingam - Hiramandalam road at RD 470.596 km, on Turakapeta – Hiramandalam to Amudalavalsa road at RD 474.903 km, on the Hiramandalam - Amudalavalasa road at RD 480.875 km and on the Srikakulam - Palakonda road at RD 491.226 km. It passes east of the Kadagandi reserved forest, west of the villages Sitarampuram, Baratam, Gonepadu, Sarubujjili, Marripadu and north of the villages Srimukhalingam, Kollivalasa, Miriyapalli, Totavada and Manidivalasa. The link canal crosses various small streams which have to be syphoned under the link canal. The FSL of link canal at the beginning of the reach is 42.250 m and at the end of the reach is 40.619 m.

(xviii) Reach RD 492.890 to 506.500 km

The link canal runs south and crosses the Nagavali river at RD 494.645 km, where an aqueduct has been proposed. The canal flows to the west of the Santakaviti and Mandarada villages and to the east of the Mudugulapeta and Narana Rajpuram, villages. A road bridge has been proposed on Santakavati - Rajam road at RD 498.880 km and Mandavakurti to Palakandyam road at RD 506.250 km. The FSL of link canal at the beginning of the reach is 40.619 m and at the end of the reach is 39.382 m.

(xix) Reach RD 506.500 to 509.720 km

The link canal initially runs south west and takes a turn towards south east and runs in this direction up to the end of the reach. The canal passes east of the Santavuriti village. It crosses various small streams which will be syphoned under the canal. The FSL of link canal at the beginning of the reach is 39.382 m and at the end of the reach is 39.111 m. One syphon aqueduct has been proposed at RD 507.050 km across the tributary of Relligedda.

(xx) Reach RD 509.720 to 539.190 km

The link canal reenters the 65 N/15 sheet and runs south-east up to RD 525.650 km and then west up to the end of the reach. Bridges have been proposed on the Ponduru - Rajam road at RD 510.476 km, Ponduru - Siripuram road at RD 514.761 km, Darmapuram - Buridikancharam road at RD 520.500 km, on NH-16 near Etcherla village at RD 525.659 km, on NH-16 Koyyam road crossing at RD 531.133 km and again on NH-16 near Chilakapalem at RD 533.808 km. The link canal also crosses East Coast railway main line at RD 511.907 km. The link canal crosses Relligedda at RD 510.970 km where an aqueduct has been proposed. The canal passes to the east of the Buridikancharam and Mullugu Konda villages and to the west of the Dharampuram and Shermohammadpur villages. It crosses small

streams, which will be syphoned under it. The FSL of link canal at the beginning of the reach is 39.111 m and the end of the reach is 36.712 m.

(xxi) Reach RD 539.190 to 543.690 km

This reach is shown in Toposheet No. 65N/11. The link canal reenters this sheet and initially runs west and then flows south-west up to the end of the reach. Two road bridges have been proposed at RDs 540.391 km across Adapaka to Gorlapalem and across Ijjapalem to Adapaka at RD 541.745 km. The link canal crosses Pedda gedda at RD 540.720 km where an aqueduct has been proposed. A canal escape has been proposed at RD 543.450 km. The canal passes south of the Gurralapalam village. It crosses various small streams which will be syphoned under the canal. The FSL of link canal at the beginning of the reach is 36.712 m and at the end of the reach is 36.318 m.

(xxii) Reach RD 543.690 to 593.280 km

This reach is shown in Toposheet No. 65N/12. The link canal runs south-east up to RD 551.900 km, south - west up to RD 566.900 km, west for a short distance and then south upto RD 577.300 km. From this point it runs north-west up to the end of the reach. The link canal crosses Chittigedda at RD 543.740 km where a syphon aqueduct has been proposed. The link canal crosses a tributary to Kandivalasa river at RD 568.530 km and Kandivalasa river at RD 569.865 km where aqueducts have been proposed. It also crosses various small streams which will be syphoned under it. Road bridges have been proposed on NH-16 at RD 545.774 km on Teppalavalasa – Ranasthalam road at RD 554.341 km and on road Patarlapalli to NH-16 at RD 558.094 km and again on NH-16 at RD 566.708 km, RD 574.106 km, RD 577.352 km, RD 585.015 km and RD 588.607 km. The canal passes east of the Kumuli reserve forest, west of the Kottapali and Kandivalasa villages, east of the Tallavalasa and Ravada villages, north of Patarlapalli, Rellivalasa, Kumuli and Pusapatiraga villages. It crosses various small streams which will be syphoned under the canal. The FSL of link canal at the beginning of the reach is 36.318 m and at the end of the reach is 32.881 m.

(xxiii) Reach RD 593.280 km to 627.085 km

In this reach, the link canal runs south-west. It crosses the Champavati river at RD 594.445 km, Gosthani river at RD 619.350 km where aqueducts have been proposed. The canal crosses various small streams, which will be syphoned under the link canal. It passes east of the Phulbagh protected forest. Road bridges have been proposed on Kumuli - Vizianagaram road at RD 597.090 km, Vizianagaram to NH-16 road at RD 600.092 km, Vizianagaram to Akkivaram road at RD 605.400 km, on NH-26 at RD

608.470 km, on Reddipalli to Vizianagaram road at RD 614.797 km and on Vizianagaram to Kothavalasa road at RD 621.057 km. A railway bridge has also been proposed on Chennai – Howrah main line at RD 620.124 km. The link canal passes to the west of Gunupur, Denkada and Godipalem villages. The FSL of link canal at the beginning of the reach is 32.881 m and at the end of the reach is 30.334 m.

(xxiv) Reach RD 627.085 km to 628.085 km

The link canal runs in south-west direction in this reach. The FSL of link canal at the beginning of the reach is 30.334 m and at the end of the reach is 30.281 m.

(xxv) Reach RD 628.085 to 659.450 km

In the beginning of the reach, the canal runs south-west up to RD 637.450 km and in southern direction in the remaining reach upto RD 639.450 km. In this reach, the link canal passes in deep cut where depth of cutting exceeds 30 m and a tunnel of 5.4 km is proposed from RD 634.050 km to RD 639.450 km. The canal passes east of the Nidigattu, Tummikapalli, Gollalapalem and Sabbavaram villages and west of Alamanda, Kottavalsa and Pendurti villages. In this reach, a canal escape has been proposed at RD 652.250 km. It crosses the Boramma Gedda and Narava Gedda at RD 652.420 km and 654.950 km respectively, where under tunnels have been proposed. The canal crosses various small streams, which will be syphoned under it. Road bridges have been proposed on Tummikapalli – Devarapalli road at RD 640.303 km, on Kottavalasa – Sabbavaram road at RD 643.500 km, on Anakapalli - Pendurti road at RD 652.018 km and on Jerripotulapalem to Narava road crossing at RD 659.143 km. The FSL of link canal at the beginning of the reach is 30.281 m and at the end of the reach is 27.050 m.

(xxvi) Reach RD 659.450 to 687.240 km

In the beginning of the reach the link canal runs south up to RD 663.900 km, takes a turn around Narava reserve forest and runs in south - west direction up to the end of the reach. The canal crosses various small streams which will be syphoned under the canal. Road bridges have been proposed on a colony road at RD 665.058 km near Fakirtikya, on a road to Kuraanpalem at RD 665.508 km, on NH-16 at RD 667.325 km near Gajuwaka, on Visakhapatnam Steel Plant to NH -16 road at RD 669.543 km, on Steel Plant Colony – Desapatrunipalem road at RD 671.500 km, on Paravada – Gajuwaka road at RD 677.150 km and on Anakapalli to Gajuwaka – Elamanchili road at RD 682.728 km. A railway bridge has been proposed on Howrah-Channai main line at RD 663.950 km. The link canal

passes to the west of the Narava, Kottanarava, Desapatruripelam and Maduturi villages and to the east of the Aganampudi, Paravada and Chimalepalli villages. The FSL of link canal at the beginning of the reach is 27.050 m and the end of the reach is 25.042 m.

(xxvii) Reach RD 687.240 to 714.000 km

The link canal runs in south - west direction up to RD 698.900 km and runs in western direction up to the end of the reach. It crosses Sarada river at RD 699.350 km where an aqueduct has been proposed. En route, the link canal crosses various small streams which will be syphoned under it. Bridges have been proposed on Visakhapatnam - Elamanchili road at RD 689.136 km, on Velcheru to Gajuwaka – Elamanchili road at RD 694.044 km and on NH-16 at RD 706.374 km. A railway bridge has been proposed on South Central Railway line at RD 706.630 km. The canal passes to the north of the Kotturu, Mamidivada and Kottali villages and to the south of Elamanchili, Veduruvada, Venkatapuram and Erravaram villages and the Panchadarla, Gokivada and Peddapalli reserve forests. The FSL of link canal at the beginning of the reach is 25.042 m and at the end of the reach is 23.237 m.

(xxviii) Reach RD 714.000 to 715.650 km

In this reach, the link canal runs in south-west direction. En route, the canal crosses small streams, which will be syphoned under it. The FSL of link canal at the beginning of the reach is 23.237 m. and at the end of the reach is 23.155 m.

(xxix) Reach RD 715.650 to 751.310 km

In this reach, the link canal runs in south - west direction. It crosses Varaha and Tandava rivers at RD 717.965 km and 744.954 km where a syphon aqueduct and an aqueduct respectively have been proposed. In this reach the canal crosses various small streams which will be syphoned under it. Road bridges have been proposed on Narsipatnam to NH-16 road at RD 720.892 km, on Uddandapuram – Gullipadi road at RD 734.678 km, on NH-16 at Payakaraopeta at RD 742.021 km, on Payakaraopeta - Mangavaram road at RD 744.419 km, on Tuni – Ramabhadrapuram road at RD 745.530 km and on Hamsavaram – NH-16 road crossing at RD 749.168 km. Railway bridges have been proposed at RD 723.500 km. and 749.711 km. A canal escape is proposed at RD 737.750 km. The link canal passes south - west of the Payakaraopeta and Jagannathpuram reserve forests, south of Paykaraopeta and Tuni towns and north of Etikoppaka and Nakkapalli

villages and the Vempudu reserve forest. The FSL of link canal at the beginning of the reach is 23.155 m and at the end of the reach is 20.741 m.

(xxx) Reach RD 751.310 to 766.450 km

In this reach, the link canal runs in south - west direction. The link canal runs south of Jagannathapuram and Tetagunta reserve forests. Road bridges have been proposed on Hamsavaram RS – NH-16 road crossing at RD 754.185 km and on Annavaram - Kottapalli road at RD 762.642 km. The link canal crosses Pampa river at RD 761.400 km where a syphon aqueduct has been proposed. The link canal passes west of Hamsavaram and Kottapalli villages and east of Annavaram town. En-route, the link canal crosses various small streams which will be syphoned under it. The FSL of link canal at the beginning of the reach is 20.741 m and at the end of the reach is 19.737 m.

(xxxi) Reach RD 766.450 to 781.850 km

The link canal runs in south-west direction up to RD 773.900 km and west up to the end of the reach. Road Bridges have been proposed on Ravikampadu – NH-16 road crossing at RD 769.628 km, on Durgada to Kakinada – Kattipudi road at RD 772.850 km, on Kattipudi - Kakinada road at RD 775.007 km and on Chandurti to Kakinada – Kattipudi road crossing at RD 777.557 km. In this reach, the link canal crosses Konda Kalva at RD 780.250 km, where a syphon aqueduct has been proposed. The link canal passes north of the Durgada and Chebrolu villages and south of Kattipudi village. En-route, it crosses various small streams, which will be syphoned under it. The FSL of link canal at the beginning of the reach is 19.737 m and at the end of the reach is 18.728 m.

(xxxii) Reach RD 781.850 to 814.800km

In this reach, the link canal runs in south - west direction up to RD 791.900 km. and in west direction upto the end of the reach. Road bridges have been proposed on Timmapuram – Veldurti road at RD 786.880 km, on Pithapuram – Divili road crossing at RD 792.236 km, on Divili - Samalkota road at RD 796.480 km, on Peddapuram - Jaggampeta road at RD 805.266 km and Patanayakampalli – Rangamapeta road crossing at RD 809.253 km. The link canal crosses Gorrekhandi (Eleru) river at RD 790.080 km, where a Level crossing is proposed. The link canal crosses two branches of Eleru river at RD's 792.102 km and 803.378 km, where syphon aqueducts have been proposed. The link canal passes south of the Kilrampudi, Jaggampeta villages and north of the Peddapuram and Samalkot towns. The FSL of the link canal at the beginning of the reach is 18.728 m and at the end of the reach 16.195 m.

(xxxiii) Reach RD 814.800 to 844.595 km

In this reach, the canal runs in western direction and crosses Rangampeta – Gandepalli road at RD 817.052 km, NH-16 at RD 822.801 km near Murari and Rajahmundry - Korukonda road at RD 832.756 km where road bridges have been proposed. The link canal passes to the north of Rajanagaram, Rajahmundry towns and Balabhadrapuram village. The link canal outfalls into Torrigedda near Torredu village at RD 844.595 km with an FSL of 14.505 m. An outfall regulator has been proposed at this point. The Torrigedda stream in turn out falls into Godavari at about 15 km upstream of Dowlaiswaram barrage.

6.7 Utilisation of water potential from the streams crossed by the canal

Various streams and rivulets crossed by the Mahanadi-Godavari link canal are not perennial. The yields are non-dependable and the streams are prone to flash floods. The possibility of providing additional storage on these streams is remote because of the nature of the topography and likely submersion of large tracts of cultivable lands. In view of the above, utilisation of water from these en-route streams is not feasible.

6.8 Description of soil profile along the canal alignment

The details of sub-surface strata along the link alignment from Mahanadi to Godavari are derived by excavating trial pits, augur boring, geo-physical investigations and drilling. The soils mostly are ordinary gravel and loamy soil for the top 1.2 m to 1.5 m depth below ground level, soft rock from 1.5 m to 3.0 m and medium rock from 3.0 to 7.0 m. Hard rock is generally met with at depths of more than 7.0 m.

6.9 Evaluation of the design parameters in embankment reaches

The canal alignment generally runs in cutting and partial cutting and filling and deep to very deep cut at some stretches of the alignment. The soils as available from cutting and adjoining identified borrow areas are considered to be generally suitable for embankment purposes.

6.10 Lining

100 mm thick CC (1:3:6) lining is proposed for both bed and sides throughout the length of the canal.

6.11 Transmission losses

The transmission losses are assumed as 0.60 cumec per million sq.m of wetted area as per Bureau of Indian Standard Code IS: 10430 – 1982.

6.12 Design of canal section

a) Formulae used

The canal sections for various reaches are designed using Manning's formula for velocity,

$V = (1/n) R^{2/3} S^{1/2}$ where

V = Velocity

n = Rugosity co – efficient

S = Bed slope

R = Hydraulic mean depth (A/P)

A = Area of cross section = $bd + d^2 (\varnothing + \cot \varnothing)$

P = Wetted perimeter = $b + 2d (\varnothing + \cot \varnothing)$

b = bed width, d = depth of water

$\varnothing$ = Angle of the side slope

The formula adopted for critical velocity is $V_o = 0.55\ d^{0.64}$

The Rugosity co-efficient for the lined canal is taken as 0.018. Side slope of 1.5H: 1V is adopted except for deep cutting in hard rock where the slope adopted is 0.25H: 1V. A longitudinal slope of 1: 20000 is considered for the entire length of the link canal.

b) Design of canal sections in various reaches

The Mahanadi(Barmul)- Rushikulya-Godavari(Dowlaiswaram) link canal is proposed for diversion of 10105 Mm^3 from surplus waters of Mahanadi river from the proposed Barmul dam site. The link canal will command an area of 363959 ha out of which 256770 ha lie in Odisha and 107189 ha in Andhra Pradesh utilising a total quantity of 3790 Mm^3 of water. The link canal meets the en route domestic and industrial requirements of the command area to an extent of 700 Mm^3. Transmission losses in the link canal are estimated to be 569 Mm^3 and thus finally releasing a quantity of 5046 Mm^3 into the Godavari upstream of Dowlaiswaram barrage.

The maximum diversion proposed is 1859 Mm^3 during the month of July based on monthly crop water requirements. The canal sections are designed for 10% of the above the peak discharge with additional provision to take care of any future eventualities. The canal is designed for this discharge as a trapezoidal section with rounded corners and to be lined for its entire length. The hydraulic design is done as per Manning's formula with values of co-efficient of rugosity as 0.018 and 0.014 for the open channel and the tunnel portions respectively. The typical section of the canal as given in IS: 10430-2000 "Criteria for design of lined canals and guidelines for selection of type

of lining" is adopted. The salient features of the canal are given at **Table 6.1.** The typical design computations of the canal are given in **Annexure 6.2**

As the canal advances from the reservoir, the discharge in the canal gets reduced at every off-take point due to drawal of water into the branch canals to meet the requirement of en route command, resulting in scope for reduction in the canal section. Hence the canal is broadly divided into three hydraulic reaches depending on the reduction in the discharge and the sections have been designed accordingly.

6.13 Design of tunnel section

Two tunnels of 0.75 km and 5.4 km lengths have been proposed in the link canal at RD 24.475 km and RD 634.050 km respectively. The tunnels are designed as modified horse shoe sections with 500 mm thick PCC. The following formulae are used.

Cross sectional area, A = $3.253572r^2$
Wetted perimeter, P = 6.426334r
Hydraulic mean depth, R = 0.506287r
Entrance loss coefficient, k_e = 0.60
Exit loss coefficient, k_{ex} = 1.0
Rugosity coefficient, n = 0.014

The salient features of tunnels area given at **Table 6.1**. The typical design computations for tunnel sections are given in **Annexure 6.3.1 & 6.3.2**

Table 6.1
Salient features of the link canal and tunnels

	Reach – I (RD 0.00 to 225.050 km)	**Reach – II** (RD 225.050 to 661.100 km)	**Reach – III** (RD 661.100 to 844.600 km)
Link canal	Lined, Trapezoidal	Lined, Trapezoidal	Lined, Trapezoidal
Type of canal	with rounded corners	with rounded corners	with rounded corners
Design discharge (cumec)	763.48	501.05	359.36
Bed width (m)	69.00	42.00	28.00
Full supply depth (m)	7.00	7.00	7.00
Velociy (m/sec)	1.292	1.234	1.181
Actual discharge (cumec)	756.00	489.00	353.00
B. Tunnel	**AT RD 24.475 km**		**AT RD 634.050 km**
Section	Modified horse shoe		Modified horse shoe
Length (km)	0.75		5.40
Design discharge (cumec)	763.48		501.05
Radius (m)	9.00		7.00
Velocity (m/sec)	3.01		2.46
Bed slope	1 in 4300		1 in 4600
Actual discharge (cumec)	766.90		528.90

Four typical cross sections of the link canal in deep cutting, full cutting, partial cutting and filling and full embankment and a typical section of the tunnel are shown in **Plates 20(1/2)** and **20(2/2)**. The values of head loss provided at different structures are given in **Table 6.2**.

Table 6.2
Head losses provided at different structures

S. No.	Name of structure	Head loss (m)
1.	Aqueduct	As per design
2.	Superpassage	As per design
3.	Bridges	0.03
4.	Regulator	0.20
5.	Syphon aqueduct	As per design
6.	Under tunnel	Nil
7.	Level crossing	0.30

The total head loss due to structures is worked out to be 15.979 m in the entire 844.595 km length of the canal and that due to bed fall is 44.576 m.

6.14 Canal structures

6.14.1 General

The link canal is aligned as a contour canal and it crosses a number of major and minor rivers / streams en route. It crosses several roads as it passes through fairly developed and densely populated areas. It also crosses Howrah-Chennai Railway line at six locations, Kottavalasa-Kirandol line at one location and Naupada-Gunupur railway line at one location. The type of cross drainage work is decided based upon the physical features of the stream with reference to the bed and full supply levels of the link canal at the crossing.

Based on field survey, the locations of the cross drainage works and cross masonry works have been identified. In general, aqueducts have been proposed across major rivers / streams and under tunnels across small drains. Super-passages have been provided where the drains are to be taken over the canal. Cross regulators have been proposed at the off-take points of the branch canals and the points of change in the section of the canal to facilitate negotiation of variation in the bed width and levels.

6.14.2 Cost curves for cross drainage and cross masonry works

Cost curves for cross drainage and cross masonry works are developed based on the estimates available with the State Govts. for the projects

located in the vicinity of the link alignment. Leads statement for structures were prepared based upon the locations of stone/sand quarries and nearby towns. Rate analysis for each item of work has been freshly carried out considering the standard schedule of rates of concerned districts for the year 1998 for Odisha State and 2001 for Andhra Pradesh State with a cost escalation of 7.5% per year to arrive at the 2018-19 price level. These cost curves are made use of for estimating the cost of the proposed structures on the link canal.

6.14.3 Head regulators

One head regulator is proposed on right flank of Barmul dam on Mahanadi at RD 0.00 km from where the link canal takes off. The design features of the head regulator at RD 0.00 km are given below. The typical hydraulic design of head regulator is given at **Annexure 6.4** and shown in **Plate 21.**

Design discharge	=	763.48 cumec
Effective water way	=	90 m (10 bays of 9 m width)
Overall water way	=	112 m
Sill level	=	68.65 m

6.14.4 Cross drainage works

In its entire run of 844.595 km, the link canal has been provided with 138 cross drainage works, of which 25 are aqueducts, 28 are syphon aqueducts, 14 are super passages, 20 are cross regulators, 44 are under tunnels, 7 canal escapes and one level crossing. The design flood value of each drain has been worked out using the empirical formulae given in **Table 6.3.**

Table 6.3
Formulae for computing design flood

S. No.	Catchment area (km^2)	Design flood value (cumec)
1.	<2.6	$19.50\ A^{3/4}$
2.	2.6 to 78	$16.70\ A^{3/4}$
3.	78 to 1300	$14.75\ A^{3/4}$
4.	>1300	$123.20\ A^{1/2}$

Where A is the catchment area of the drain in km^2.

6.14.4.1 Aqueducts / Syphon Aqueducts

Aqueducts have been proposed at the crossings of the major streams where the bed level of the canal is above the high flood level of the drain. Head

losses have been provided as per the actual design carried out. In all, 25 aqueducts have been proposed. Wherever the FSL of the link canal is above the bed level of the drainage trough but below the HFL of the drain, syphon aqueducts have been proposed. In all, there are 28 syphon aqueducts and head loss has been provided as per actual design. The locations of the proposed aqueducts and syphon aqueducts are shown in the longitudinal section of the link canal.

6.14.4.2 Super passages

Super passages have been proposed at the crossings, wherever the bed level of the intersecting drain is well above the FSL of the link canal. There are 14 such crossings where super passages are proposed. Head losses have been proposed as per the actual designs carried out at each super passage. The locations are shown in the longitudinal section of the link canal.

6.14.4.3 Under tunnels

Under tunnels have been proposed along the link canal at crossings of small drains. No head loss has been assumed at under tunnels. A total number of 44 under tunnels have been identified. Provision has also been made in the cost estimate for small hill side drains and diversion of nalas.

6.14.4.4 Typical hydraulic designs of cross drainage works

Typical hydraulic designs of (1) Aqueduct across Vamsadhara river at RD 471.722 km, (2) Superpassage across Meghadrigedda at RD 644.890 km, (3) Under tunnel across Buradagedda at RD 492.890 km, and (4) Cross regulator RD 80.900 km have been carried out and the same are furnished in **Annexure- 6.5 to 6.8**. The plan and section of these typical cross drainage works are shown in **Plates 22 to 25.**

6.14.5 Cross masonry works

6.14.5.1 Bridges

The link canal crosses National Highway 16 and 26, several state and district roads and a number of village roads. In order to facilitate free flow of traffic on these roads, four lane bridges have been provided across National Highways, double lane bridges and single lane bridges are proposed depending upon the type and importance of the road. Double lane road bridges are provided for state and district roads and single lane road bridges are provided for village roads coming across the alignment.

A total of 114 road bridges have been proposed across the link canal, of which 10 are four lanes, 21 are double lane and 83 are single lane bridges. The locations are shown in the longitudinal section of the link canal. Head loss of 0.03 m has been provided for each of these bridges. Plan and section of a typical double lane road bridge is shown in **Plate 26**.

The link canal crosses the Railway line (broad-gauge, double lane) at six places. At RD 430.571 km near Tekkali, it crosses railway line connecting Naupada and Gunupur. Suitable railway bridges are proposed at these crossings. Head loss of 0.03 m has been provided for each of these bridges.

6.14.5.2 Cross regulators

Out of 25 cross regulators proposed along the link canal, 20 are at off-take points of branch canals, 2 are at Salia reservoir, 2 are at the Level crossing across Gorrekhandi and 1 is at the tail end of the link canal. Typical hydraulic design of cross regulator at RD 80.900 km designed for Khurda branch canal is furnished in **Annexure 6.8**. **Plate 25** shows the plan and sections of the cross regulator.

6.14.5.3 Escape regulators/ Channels

Similarly, 7 escape regulators are also proposed along the canal at suitable places, where natural streams are available to accommodate the surplus discharges of the link canal. The discharging capacity of the escape regulator has been considered at half the discharge of the canal at that point.

6.14.5.4 Out fall Structures

Total three out-fall structures are proposed in the M-G link project:

(1) Out fall structure at Salia dam
(2) Out fall structure at Garrekhandi
(3) Out fall structure of Torrigedda/ Godavari.