Chapter - 6
Design Aspects

6.1 General

The main objective of the Godavari (Inchampalli) - Cauvery (Grand Anicut) link project is to divert the unused waters of river Indravati in Chhattisgarh along with part of surplus water assessed at proposed Inchampalli barrage across river Godavari to stabilize existing irrigation systems and provide irrigation to available new areas in the states of Telangana, Andhra Pradesh and Tamil Nadu to meet the irrigation, domestic and industrial demands.

The link canal off-takes from the foreshore of the Inchampalli pond through an approach channel of length 10 km. The designed discharging capacity of the link canal has been considered as 1090 cumec (Refer Section 6.2.9).

6.2 Geology, seismicity and foundation

6.2.1 Geology

Geological Investigations are carried out by Geological Survey of India along the link canal. The details of the investigation are covered in Chapter 4: Surveys and Investigations.

6.2.2 Seismicity

The link canal takes off from the proposed Inchampalli barrage and falls into existing Grand Anicut utilizing existing Nagarjunasagar and Somasila as balancing reservoirs. Thus, there is only one proposed barrage with full pond level limited to river portion and hence no site specific seismic studies are proposed. Seismic studies, if required shall be carried out at pre-construction stage.

6.2.3 Foundation Treatment

As per the report on the geological features and sub strata of the major structures and the soil profiles along the canal alignment received from the GSI & CSMRS, it is seen that the hard rock formation is visible at many places and is available in shallow depth. The foundation treatment as would be required shall be assessed during the pre-construction stage.

6.3 Barrage at Inchampalli

The barrage is proposed at latitude 18^{o} 37' N and longitude 80^{o} 20' E with catchment area of 269000 km^2 at the site. The total length of the barrage is 688.50 m. The FPL of the barrage is proposed at 87.0 m. The gross and live storage capacity of the pond are 450 Mm^3 (15.88 TMC) and 388 Mm^3 respectively.

6.3.1 Hydraulic design of barrage

The barrage at Inchampalli is designed for a flood of 71030 cumec for which the Lacey's waterway is obtained as 1287 m. The number of bays proposed in under sluice portion are 5 and the number of bays proposed in river sluice portion are 34. After due provision of 3.0m wide piers for under sluices and 2.50 m wide piers for river sluices and 2nos of 3.0 m thick divide walls, the overall waterway obtained is about 688.50m. The barrage will pass safely the designed discharge considering an afflux of 1.0m. The details are furnished in **Table 6.1.**

Table 6.1 Salient features of headworks

Sl.No	Details	Barrage at Inchampalli
1	FPL (m)	87.0
2	Crest level (m) (i) Under sluice (ii) River sluice	 75.0 76.0
3	Afflux (m)	1.0 m
4	No. of bays	

	Under sluice	5
	River sluice	34
5	Gate size	
	Under sluice	15 x 11 m
	River sluice	15 x 11m
6	Overall length of barrage (m)	688.5
7	Designed Discharge (cumec**)**	71030

The computation of rugosity coefficient of 0.04 for the barrage is given in **Annexure 6.1** while the hydraulic design of the barrage is furnished in **Annexures 6.1.1 to 6.1.4.** The layout of the Inchampalli barrage is shown in **Plate-6.1**. The plan of the barrage and its cross section through under sluice and river sluice are presented in **Plates-6.2 and 6.3** respectively. The installation of radial gates at the barrage is illustrated in **Plate-6.4**

6.4 Design of conveyance system

The design of conveyance system comprises design of open canal, tunnels, lifting arrangements and CD/CM works.

The proposed link canal project consists of three main reaches. They are:

i) Canal taking off from Godavari (Inchampalli) and terminating at Krishna (Nagarjunasagar) (0 – 299.256 km)
ii) Canal taking off from Krishna (Nagarjunasagar) and terminating at Pennar (Somasila) (299.256 – 692.276 km)
iii) Canal taking off from Pennar (Somasila) and terminating at Cauvery (Grand Anicut) (692.276 – 1210.841 km)

The bed slope of the canal is considered as 1 in 20,000 where as the same for the major tunnel (12.5 km) is considered as 1 in 6000. The link canal crosses the ridges between various basins and sub-basins enroute, where deep cuts are involved as well as many rivers / streams requiring construction of cross drainage works. Two tunnels are considered one for crossing Godavari - Krishna ridge and the other at the deep cut near offtake point of the canal from Nagarjunasagar.

The NSL at 50 m interval and at structures with corresponding Full Supply Level (FSL) of the canal in the three reaches are furnished as head loss statement in **Annexures 6.5.1 to 6.5.3**. The alignment has been generated as strip contour plan plotting about 25km in a sheet with the corresponding longitudinal profile.

The proposed link canal off-takes from the foreshore of the Inchampalli pond and utilises the existing Gandhamchekla vagu to form an approach channel of about 10 km long. An initial 55.00 m static lift (Stage - I) is proposed to maintain a full supply level of 141.00 m from where the actual link canal commences at RD 0.00 km to divert 7000 Mm^3 of water.

The link canal runs for most of its length in southwest direction from Inchampalli barrage pond to Nagarjunasagar reservoir. In the initial head-reach of about 65.00 km, the canal runs in dense forests and the remaining in patta lands. The total length of the canal from the Inchampalli to its outfall at the Nagarjunasagar reservoir is about 299.26 km. The FSL of the canal at the off-take and out-fall points are 86.0 m and 180.25 m respectively. The link canal runs in moderate lifts and by gravity in its initial stages upto RD 60.50 km. The total lift involved is about 127 m in four stages. The lifts involved in four stages at RDs 0.00, 18.00, 26.50 and 60.50 km are 55, 38, 23 and 11 m respectively. It crosses the ridge between the Godavari and the Krishna basins through a tunnel of about 9.15 km length from RD 86.350 to 95.500 km The link canal runs in deep cut reaches covering a total length of 161.71 km and the remaining 128.40 km in normal cut / partial cut / full embankments. Maximum depth of the cutting of the canal is 40 m and maximum height of filling is 14 m.

A uniform bed slope of 1 in 20000 has been adopted for the entire link canal whereas in case of tunnel, it is 1 in 5000. The canal is designed as a trapezoidal section with rounded bottom corners and is proposed to be lined for its entire length. Eight typical sections of the canal in four reaches have been designed based on depth of cutting / embankment etc. The velocities at the head and tail ends of the link canal are 1.31 and 1.30 m / sec respectively. The full supply depth is 7.40m in deep cut reaches and is 6.75 m in normal cut reaches. Sections of the canal at head and tail are 109.60 m x 6.75 m and 104.40 m x 6.75 m respectively. A free board of

1.0 m is provided throughout the length of the link canal. The canal designed discharges are 1090, 1074, 1061 and 1041 cumec for the four reaches RD 0.00 to 97.50 km, RD 97.50 km to RD 162.70 km, RD 162.70 km to RD 192.70 km and RD 192.70 km to RD 299.26 km respectively. Typical sections of link canal in deep cutting & full cutting and embankment are shown in **Plates-6.18 (1/3) and 6.18 (2/3)** respectively. Plan and sectional elevation of tunnel from RD 86.35 to 95.50 km are shown in **Plate 6.18 (3/3)**.

6.4.1 The lead canal

A lead canal is proposed to divert 514 Mm^3 of water from the link canal to the ongoing Kakatiya canal Sage - II (SRSP Stage - II) in order to provide irrigation to the part command area under the Kakatiya canal by lift. The length of the lead canal from its off-take to the outfall point into Kakatiya canal is 21.85 km. It takes off from RD 97.50 km where the FSL of the link canal is 204.90 m. The FSL of lead canal when outfalls into the Kakatiya canal is 256.53 m. This difference in levels is proposed to be negotiated through a lift of 55 m at RD 0.00 km. A uniform bed slope of 1 in 20000 has been adopted for the entire length of the lead canal. The lead canal is designed as a trapezoidal section with rounded bottom corners and is proposed to be lined. The reach between 9.50 km and 12.50 km involves deep cutting and the remaining length is of normal cutting. The maximum depth of cutting in the lead canal is 17 m and the maximum height of embankment is 13 m. Velocities in the deep cut and normal cut portions are 0.79 and 0.74 m / sec respectively. Full supply depth in the deep cut reach is 3.50 m and it is 3.25 m in other reaches. Cross section of the canal both at the head and tail end is 20 m x 3.25 m. The designed discharge is 31 cumec.

6.4.2 Description of the canal alignment

The plan and longitudinal sections of the link canal plotted in 12 sheets, with a horizontal scale of 1:100000 and vertical scale of 1:1000 are shown in **Plates-4.2.1(1/12) to 4.2.1(12/12).** The plans show the link canal alignment along with the topographical features such as contours, rivers, towns, villages and roads whereas the longitudinal sections indicate the sub-surface profiles along with the locations of important cross drainage and cross masonry works proposed enroute. Out of its total length of 299.26 km, the canal runs 54% in deep cutting and 43% in normal cutting / partial cutting / full embankment reaches. In addition, a 9.15 km long tunnel is proposed to negotiate the ridge between Godavari and Krishna basins. The reach-wise

brief description of the link alignment from the off-take point to the tail end is given in the following paragraphs.

i) Reach RD 0.00 to 25.00 km

This reach is shown in **Plate-4.2.1 (1/12).** An approach channel of 10 km off-takes from the foreshore of the Inchampalli pond. The existing Gandhamchekla vagu will be utilized to form an approach channel.

A pump-house (Stage-I) with a static head of about 55 m is proposed at RD 0.00 km at the end of the approach channel in the Gandhamchakla vagu valley. Twenty pumps of 28.9 MW each are proposed to lift the water to a FSL of 141.00 m. The alignment upto 5.10 km runs in partial cutting & filling and normal cutting. The canal bed width in the head reach is 109.60 m and the full supply depth is 6.75 m in normal cutting/partial cutting and filling/full embankment reaches. From RD 5.10 to 8.30 km, the alignment runs in deep cutting in hard rock, the maximum depth of cutting being 22 m. The canal bed width in this reach is 98.10 m and the full supply depth is 7.40 m. Between RD 8.30 km to 13.50 km, the canal generally runs in full cutting. The significant feature of the canal in this reach is utilising the Peddavagu at RD 13.50 km as an intermediate balancing reservoir. The canal will out-fall into the proposed Peddavagu reservoir with FSL 140.33 m through a regulator. The canal off-takes from Peddavagu reservoir with FSL 139.50 m. Again from RD 13.50 to 14.75 km, the canal runs in full cutting. The canal runs in deep cutting from RD 14.75 km to 18.00 km, the maximum depth of cutting being 24 m. A pump-house (Stage-II) at RD 18.00 km with a static head of about 38.00 m is proposed near Nandigama village to lift the water to RL + 177.25 m. Twenty pumps of 21.6 MW each are proposed to lift the water. The canal runs in 9 m high embankment for 1 km from RD 18.00 to 19.00 km, in partial cutting & filling for another 1 km from RD 19.00 to 20.00 km, in full cutting of 9 m depth from RD 20.00 to 23.75 km, in full embankment from RD 23.75 to 24.75 km and the remaining 0.25 km reach ends with normal cutting. The design of turbine pumps, sumps and other appurtenant works pertaining to Stage–I and II are given in **Annexures 6.12 (a) and (b)** respectively.

The link canal crosses Peddavagu at RD 16.65 km where a super passage is proposed. The minor streams enroute will be siphoned under the canal. FSL of the canal at the end of the reach is 176.90 m.

ii) Reach RD 25.00 to 50.00 km

This reach is shown in **Plate-4.2.1 (2/12)**. The canal runs in normal cutting and partial cutting & filling from RD 25.00 km to RD 26.50 km. A pump-house (Stage–III) at RD 26.50 km with a static head of about 23.00 m is proposed to lift the water to the proposed Tummalagutta reservoir with FRL 200 m on the river Tummalavagu. Twenty pumps of 14.4 MW each are proposed to lift the water into the Tummalagutta reservoir with FSL 200.02 m. The canal off-takes with FSL 199.50 m from the reservoir. The canal runs in deep cutting in hard rock for a continuous stretch of 6.15 km from RD 26.50 to RD 32.65 km, the maximum depth of cutting being 26 m. From RD 32.65 to RD 34.25 km, the canal runs in full cutting, from RD 34.50 to RD 39.20 km in 11 m high embankment, again from RD 39.40 to RD 43.50 km in full cutting. The canal runs in partial cutting & filling from RD 43.50 to RD 47.75 km and it is in full embankment from RD 48.50 to RD 49.75 km, the maximum height of filling being 12 m. The design of the turbine pumps, sump etc. is given in **Annexure 6.12 (c)**.

Five double lane road bridges at RDs 34.50, 37.00, 38.25, 41.70 and 47.75 km are proposed in this reach. The minor streams enroute will be syphoned under the canal. FSL of the link canal at the end of the reach is 198.28 m.

iii) Reach RD 50.00 to RD 78.35 km

This reach is shown in **Plate 4.2.1 (3/12).** In this reach the link canal mostly runs in deep cutting except the portion between RD 50.00 km and RD 54.15 km where the canal runs in partial cutting & filling. The depth of cutting in this reach ranges from 5 to 25 m. A pump-house (Stage–IV) with a static head of about 11.00 m is proposed at RD 60.50 km near Tirumalagiri to lift the water to 208.75 m and lead into a gravity canal. Twenty pumps of 8 MW each are proposed to lift the water. The gravity canal off-takes at RD 60.50 km with FSL 208.75 m. The design of turbine pumps, sump and its appurtenant works are given in **Annexure 6.12(d)**.

The canal crosses Salivagu at two points at RD 72.90 km and RD 77.00 km where super passages are proposed. Two single lane road bridges and two double lane road bridges are proposed at RDs 61.50, 67.00 and 63.00, 78.35 km respectively. Under tunnels are proposed to negotiate the minor streams across the link canal. FSL of the canal at the end of this reach is 207.76 m.

The details of pump-houses are given briefly in **Table 6.2**.

Table 6.2
Details of pump-houses

Stage	Location (RD in km)	No. of units x capacity (MW)	Energy required (MU)
1	0.00	20 x 28.9	1296
2	18.00	20 x 21.6	969
3	26.50	20 x 14.4	648
4	60.50	20 x 8.0	360

iv) Reach RD 78.35 to 103.35 km

This reach is shown in **Plate-4.2.1 (4/12).** The entire length of the link canal in this reach runs in deep cutting in hard rock, the depth of cutting being 20 to 30 m except in the portion from RD 86.35 to RD 95.50 (9.15 km long) where two tunnels of 16 m dia. each have been proposed. The FSL of the canal at RD 86.35 km i.e. at the entry of the tunnel is 207.27 m and at the exit of the tunnel at RD 95.50 km is 205.27 m. A lead canal of length 21.85 km has been proposed to take-off at RD 97.50 km in order to facilitate the link canal to serve the command area under the Kakatiya canal stage–II of Sri Ram Sagar Project stage–II being developed by the Irrigation Department, Government of Telangana.

Six super passages are proposed at RDs 81.60, 85.10, 95.75, 97.05, 99.58 and 102.36 km in this reach. A cross regulator at RD 97.50 km is provided downstream of the lead canal's off-take. Four single lane road bridges at RDs 82.45, 84.30, 85.70 and 97.10 km are proposed. Two double lane road bridges at RD 100.05 km and RD 100.80 km are proposed for the roads connecting Narsampet–Warangal and Narsampet–Nekkonda respectively. FSL of the canal at the end of the reach is 204.53 m.

v) Reach RD 103.35 to 128.35 km

This reach is shown in **Plate-4.2.1 (5/12)**. The entire length of the link canal in this reach almost runs in deep cutting, the depth of cutting being 10 to 28 m except in the last 1 km stretch where it is in normal / partial cutting & filling. The canal bed width and full supply depth of the canal in this reach are 107.90 m and 6.75 m respectively in normal / partial cutting & filling / full embankment whereas these are 96.70 m and 7.40 m respectively in deep cut portions.

Eleven super passages are proposed at RDs 103.85, 105.55, 106.15, 107.35, 108.75, 110.15, 113.35, 116.75, 124.46, 125.10 and 126.15 km. Nineteen single lane road bridges are also proposed at RDs 104.55, 108.55, 109.10, 110.90, 111.80, 113.65, 114.25, 114.85, 115.35, 115.95, 116.45, 118.25, 120.15, 120.60, 121.35, 122.37, 123.00, 125.75 and 128.05 km. The minor streams crossing the link canal will be syphoned under the canal. The FSL of the link canal at the end of the reach is 202.76 m.

vi) Reach RD 128.35 to 153.35 km.

This reach is shown in **Plate-4.2.1 (6/12)**. The alignment for the initial 3.4 km i.e. from RD 128.35 to 131.75 km runs in normal cutting / partial cutting & filling and for the middle 13.15 km stretch i.e. from RD 131.75 to 144.90 km in deep cutting in hard rock, the maximum depth of cutting being 40 m. In the last 8.45 km of the stretch, it runs generally in partial cutting & filling.

The link canal crosses the Kakatiya canal of SRSP at RD 136.96 km where a super passage is proposed. It crosses three more branch canals of Kakatiya canal at RDs 147.33, 150.56 and 151.94 km where three syphon aqueducts are proposed. The canal crosses South Central Railway main line joining Warangal–Vijayawada (Kazipet–Dornakal) at RD 132.97 km. Twelve single lane road bridges are proposed at RDs 131.60, 133.85, 134.35, 134.79, 138.55, 139.95, 141.25, 146.10, 146.45, 148.40, 149.45 and 150.05 km. An escape regulator along with a cross regulator is proposed at RD 151.80 km to escape the water to the tributary of Akeru river in case of any eventuality. The minor streams crossed by the link canal will be

syphoned under the canal. The FSL of the link canal at the end of the reach is 201.15 m.

vii) Reach RD 153.35 to 178.35 km

This reach is shown in **Plate-4.2.1(7/12).** The canal runs in full embankment from RD 153.35 to 155.35 km and thereafter it runs in partial cutting & filling and normal cutting upto RD 158.70 km. It runs in deep cutting in hard rock from RD 158.70 to 162.35 km, the maximum cutting being 16 m. The canal runs in partial cutting & filling / full embankment involving a maximum height of filling of 16 m between RD 162.35 and 171.95 km & from RD 171.95 to RD 178.35 km, the canal runs in deep cutting, the maximum depth of cutting being 18 m. The canal section changes from RD 162.70 to RD 192.70 km with the bed width of canal 106.60 m and the full supply depth 6.75 m in normal sections whereas the size of the canal section is 95.50 m x 7.40m in deep cutting in this reach. Two aqueducts are proposed at the crossings of Akeru and Palleru rivers at RDs 153.59 and 167.07 km respectively. A super passage is also proposed at RD 160.55 km. The canal crosses Thallampadu, Chinna Nemulla branch canals of the Kakatiya canal stage–II of SRSP Stage–II at RD 162.70 km and 177.70 km where two cross regulators are planned. A double lane road bridge is proposed at RD 161.15 km. Fourteen single lane road bridges are also proposed in this reach at RDs 154.15, 155.75, 157.48, 159.15, 163.25, 164.75, 165.23, 165.57, 166.83, 169.20, 172.69, 173.77, 175.85 and 177.70 km. The minor streams crossing the link canal will be syphoned out. The FSL of the link canal at the end of the reach is 199.05 m.

viii) Reach RD 178.35 to RD 199.15 km

This reach is shown in **Plate-4.2.1 (8/12).** In the initial 1.25 km stretch, the canal runs in deep cutting, the maximum depth of cutting being 15 m. From RD 179.60 to 188.85 km, the canal runs in partial cutting & filling / full embankment to a maximum height of 10 m and in normal cutting. The canal runs in deep cutting in hard rock from RD 188.85 to 197.85 km, the maximum depth of cutting being 36 m. From RD 197.85 to 199.15 km it is in normal cutting / partial cutting & filling. Canal section changes from RD 192.70 to RD 299.26 km i.e. upto the tail end of the canal. X-section of the canal is 104.40 m x 6.75 m in normal cutting and is 93.70 m x 7.40 m in deep cutting. A cross regulator at RD 192.70 km is proposed where the link

canal crosses the Viblapuram branch canal of the Kakatiya canal stage–II of SRSP Stage–II. A double lane road bridge at RD 193.50 km is proposed connecting Suryapet and Jangaon. Nine single lane road bridges are proposed at RDs 182.40, 185.45, 187.47, 187.90, 189.95, 192.70, 195.67, 196.74 and 198.07 km. An in-fall regulator is also proposed at the end of the canal at RD 199.15 km. Finally, the canal outfalls into the existing Musi reservoir at RD 199.15 km with FSL 197.52 m. The FRL of Musi reservoir is 197.00 m.

ix) Reach RD 199.15 to RD 224.15 km

This reach is shown in **Plate-4.2.1 (9/12).** The link canal takes off from the Musi reservoir with FSL 187.30 m. An off-take regulator is provided at the start of this reach which enables regulated flows into the canal from the Musi reservoir. The canal runs in deep cutting ranging from 12 to 20 m for a total length of 9.15 km in this reach from RDs 199.15 to 202.40, 208.65 to 211.40, 213.85 to 214.85 and 219.00 to 221.15 km. In the remaining portions for a length of 15.85 km, it runs in partial cutting / filling and normal cutting. A canal powerhouse has been proposed in the downstream of the Musi reservoir for generation of power by utilising a gross head of about 10.00 m available between the FRL of the reservoir and the canal FSL. The design of canal power house at Musi reservoir is given in **Annexure 6.13**. Plan and its sectional elevation are shown in **Plates-9.1 and 9.2** respectively. The canal crosses Palleru river at RD 223.43 km by means of a syphon aqueduct. Three super passages are proposed at RDs 208.90, 219.58 and 222.74 km. The link canal crosses Hyderabad–Vijayawada National Highway (NH-9) at RD 208.45 km where a four lane road bridge is proposed. Nine single lane road bridges are provided at RDs 200.20, 202.80, 204.15, 206.80, 213.66, 216.50, 217.91, 220.68 and 223.26 km. The minor streams enroute will be syphoned under this canal. The FSL of the canal at the end of this reach is 185.72 m.

x) Reach RD 224.15 to RD 249.15 km

This reach is shown in **Plate-4.2.1 (10/12).** The canal runs in normal cutting for the initial 2 km reach and thereafter for a continuous stretch of 9 km i.e. from RD 226.15 to 235.15 km, it runs in deep cutting in hard rock, the maximum depth of cutting being 24 m. From RD 235.15 to RD 236.30 km,

RD 238.45 km to RD 240.15 km, RD 242.15 km to RD 243.15 km and RD 248.65 km to RD 249.15 km i.e. for a length of 4.35 km the canal generally runs in normal cutting and partial cutting & filling. In the remaining portions of this reach from RDs 236.30 to 238.45, 240.15 to 242.15 and 243.15 to 248.65 km i.e. for a length of 9.65 km, it further runs in hard rock in deep cutting ranging from 12 to 24 m. The canal crosses Peddavagu river at RD 239.03 km by means of a syphon aqueduct. Three super passages are proposed at RDs 232.10, 235.98 and 238.25 km. It crosses a railway line and a road connecting Nalgonda– Mirialaguda at RD 240.56 and RD 239.39 km respectively where a railway bridge and a double lane road bridge are provided. Ten single lane road bridges are also proposed in this reach at RDs 226.18, 227.61, 231.15, 234.36, 235.47, 236.18, 237.10, 242.10, 243.10 and 243.69 km. The FSL of the canal at the end of this reach is 184.16 m.

xi) Reach RD 249.15 to RD 274.15 km

This reach is shown in **Plate-4.2.1 (11/12).** The canal runs in partial cutting & filling from RD 249.15 to 251.35 km and thereafter in full cutting upto RD 256.75 km. It follows in deep cutting in the portions from RDs 256.75 to 257.80, 261.35 to 262.80, 265.15 to 268.40 and 273.65 to 274.15 km for a total stretch of 6.25 km. The depth of cutting varies from 12 to 18 m. In the remaining portions for a total stretch of 11.15 km, it runs in partial cutting & filling and normal cutting. The maximum height of filling involved is around 8 m. The canal crosses Hallia river at RD 260.70 km where a syphon aqueduct is proposed. An escape regulator along with a cross regulator is also proposed at RD 260.40 km to pass waters to Hallia river in case of any eventuality. Four super passages are provided at RDs 258.85, 261.36, 269.16 and 273.50 km. The canal crosses a road at RD 257.13 km, which connects Nalgonda and Nagarjunasagar where a double lane road bridge is provided. Sixteen single lane road bridges are also provided wherever necessary in this reach. The minor streams crossed in between by the link canal will be syphoned under the canal. The FSL of the canal at the end of this reach is 182.26 m.

xii) Reach RD 274.15 to RD 299.26 km

This reach is shown in **Plate-4.2.1 (12/12).** The canal runs in deep cutting in hard rock from RD 274.15 to 288.15 km continuously for a length of 14 km. The depth of cutting varies from 12 to 24 m. From RD 288.15 to

295.15 km, the canal traverses in full embankment/full cutting. The maximum height of embankment is about 12 m. The canal runs in hard rock in deep cutting in the end portion of the reach from RD 295.15 to 299.26 km. The link canal crosses Gudipalli river at RD 289.00 km by means of an aqueduct. It crosses the ongoing Srisailam left bank canal (Alimineti Madhava Reddy Lift Irrigation Scheme) at RD 292.04 km and again at RD 294.53 km where two syphon aqueducts are proposed. Four super passages are provided at RDs 276.46, 278.40, 281.04 and 283.20 km. Two double lane road bridges are proposed at RDs 290.25 and 295.75 km where the canal crosses Hallia–Peddavur road and Hyderabad–Nagarjunasagar road respectively. Ten single lane road bridges are also provided in this reach wherever necessary. The minor streams will be syphoned under the canal. Finally, at RD 299.26 km, the link canal outfalls into the existing Nagarjunasagar reservoir (FRL 179.83 m). FSL of the link canal at the out-fall into the Nagarjunasagar reservoir is 180.25 m. An out-fall regulator is proposed at RD 299.00 km.

6.4.3. Description of the lead canal alignment

The lead canal takes-off from the Inchampalli barrage–Nagarjunasagar link canal at RD 97.50 km with FSL 244.90 m to transfer 241 Mm^3 of water to the Kakatiya canal stage–II in order to provide irrigation facility to an extent of 56860 ha. The length of Lead canal is 21.85 km.

As the FSL of the Inchampalli barrage– Nagarjunasagar link canal at the off-take point of the lead canal is 204.90 m and the FSL of the Kakatiya canal where the lead canal has to join is 256.15 m, the water needs to be lifted to a height of 55 m at the off-take of the lead canal with two pumps of 27.7 MW each. The lead canal will have FSL of 259.90 m at its head (RD 0.00 km) after the initial lift. From RDs 0.00 to 1.65 and 2.97 to 5.50 km, the lead canal runs in full embankment, the maximum height of embankment being 13 m. From RD 1.65 to 2.97 km it runs in partial cutting & filling. Then, the lead canal generally runs in cutting from RD 5.50 to 21.00 km except for a 3 km stretch i.e. from RD 9.50 to 12.50 km where it runs in deep cutting, the maximum depth of cutting being 16 m. Beyond 21 km till it joins the Kakatiya canal, the lead canal runs in partial cutting & filling. The FSL at its tail end is 256.53 m where the FSL of the Kakatiya canal is 256.15 m. An outfall regulator is provided at RD 21.85 km to regulate the flows into the

Kakatiya canal. The design of turbine pumps and sumps etc. pertaining to the pumping station is given in **Annexure 6.12 (e).**

The bed width of the lead canal is 20 m and the full supply depth is 3.25 m in normal cutting / partial cutting & filling / full embankment portions, whereas, the bed width and depth are 18 m and 3.50 m respectively in case of deep cutting portions. A bed slope of 1 in 20000 has been provided for this canal.

Five super passages are proposed at RDs 9.71, 10.56, 10.89, 14.11 and 20.95 km in which the first three are for crossing the branch canals of the existing Kakatiya canal stage–I and the last two are for crossing natural streams. One double lane road bridge is proposed at RD 2.20 km, for crossing Warangal–Narsampet road. The lead canal crosses South Central Railway main line connecting Warangal and Nekkonda at RD 18.61 km where a railway bridge is proposed. Nine single lane road bridges are also proposed across the lead canal wherever necessary.

6.4.4. Gottimukkala feeder canal

The Gottimukkala feeder takes-off from the Musi reservoir at RD 199.15 km to carry 400 Mm3 of water to provide irrigation facility to an extent of 80000 ha in the water short areas of Nalgonda district. The length of feeder canal is about 116 km.

As the FRL of Musi reservoir is 197 m and the maximum RL of the command area where the feeder canal has provide irrigation is about 392 m, the water needs to be lifted to a height of 196.5 m , which is planned in three stages of 64.5 m, 58 m and 74 m at RD 0 km, 75 km and 95 km respectively. The feeder canal will have FSL of 262 m at its head (RD 0.00 km) after the initial lift. The designs of turbine pumps and sumps etc. pertaining to the pumping stations at the three stages are given in **Annexures 6.12 (f) to (h).** The bed width of the feeder canal is 16 m and the full supply depth is 3.00 m in normal cutting / partial cutting & filling / full embankment portions, whereas, the bed width and depth are 14 m and 3.25 m respectively in case of deep cutting portions. A bed slope of 1 in 20000 has been provided for this canal.

6.4.5. Srisailam LBC feeder branch

The Srisailam LBC feeder branch (Alimineti Madhava Reddy Lift Irrigation Scheme) takes-off from the Nagarjunasagar reservoir to carry 411 Mm^3 of water to provide irrigation facility to an extent of 57946 ha. As the FRL of Nagarjunasagar reservoir is about 180 m and the maximum RL of the command area where the feeder canal has provide irrigation is about 247 m, the water needs to be lifted to a height of 67 m. The design of turbine pumps and sumps etc. pertaining to the pumping station for the lift are given in **Annexure 6.12 (i).** The bed width of the feeder canal is 12 m and the full supply depth is 2.75 m in normal cutting / partial cutting & filling / full embankment portions, whereas, the bed width and depth are 10 m and 3.10 m respectively in case of deep cutting portions. A bed slope of 1 in 20000 has been provided for this canal.

6.4.6 Utilisation of water potential from the streams crossed by the link canal

Various streams and rivulets crossed by the Godavari (Inchamapalli) – Krishna (Nagarjunasagar) link canal are not perennial. Their yields are undependable and these streams are flowing in drought-prone areas. Moreover, all the streams flowing in this area are inter connected by a series of tanks, which play vital role for drinking and irrigation purposes. In view of the above, utilization of water from these enroute streams may not be feasible.

6.4.7 Description of soil profile along the canal alignment

Geo-physical investigations along the Inchampalli – Nagarjunasagar link canal from RD 78.35 km to RD 299.26 km has been entrusted to the National Geo-physical Research Institute (NGRI), Govt. of India, Hyderabad for assessing the soil profile. The details of the sub-surface strata/profile as investigated and analysed by the NGRI are shown in **Plates-4.2.1 (4/12) to 4.2.1(12/12).** A report on Geological investigations submitted by Geological Survey of India (GSI), Hyderabad contains particulars of soil profile along the link canal alignment from RD 59.75 to RD 78.35 km. Based on this data,

NWDA has extrapolated the soil profile data from RD 0.00 to RD 59.75 km. These details are also shown in **Plates-4.2.1 (1/12) to 4.2.1 (3/12).**

6.4.8 Evaluation of the design parameters based on samples collected enroute

54% of the canal alignment generally runs in deep cutting and 43% runs in normal cutting/partial cutting & filling/full embankments. The soils as available from cutting and adjoining identified borrow areas are considered to be generally suitable for embankment purposes.

6.4.9 Lining

The IS 3873–1978, recommends minimum thickness of CC lining related with the canal capacity and full supply depth. For a canal capacity of 300 to 700 cumec and FSD 6.5 to 9.0 m, a minimum thickness of 12 to 15 cm is recommended. However, considering other R&D works done on this aspect and the thickness of lining provided on other major projects, a 100 mm thick CC 1:2:4 lining is proposed for both bed and sides throughout the length of the canal.

6.4.10 Transmission losses

The transmission losses are considered at about 7.6% of the combined utilization for irrigation and M&I based on the previous feasibility reports in which it was assumed 0.60 cumec per million m^2 of wetted area as per the Bureau of Indian Standard Code IS: 10430–1982.

6.5.1 Design calculations for adequacy of canal section

a) Formulae used

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

$$V = (1/N)*(R^{2/3})* (S^{½})$$

Where,

V = Velocity

N = Rugosity co-efficient

S = Bed slope

R = Hydraulic mean depth (A/P)

A = Area of cross section

= $bd + (d^2/2)^* (\phi/2 + \cot\phi + \in\text{osec } \phi)$

- for deep cut portions (considering r = d/2)

= $bd + d^2 (\phi + \cot \phi)$

- for normal cut portions (considering r=d)

P = Wetted perimeter

= $b + d (\phi + \cot \phi + \text{cosec } \phi)$ - deep cut portions

= $b + 2d (\phi + \cot \phi)$ - normal cut portions

b = bed width

d = depth of water

ϕ = Angle of side slope

The formula adopted for critical velocity is Vo = 0.55 d 0.64

The rugosity co-efficient for the lined canal is taken as 0.018. Side slope of 1.5 H: 1 V is adopted except for deep cutting in hard rock where the slope adopted is 0.5 H: 1V. A uniform bed slope of 1 in 20000 is adopted for the entire length of the canal.

b) Design of canal sections in various reaches

The Inchampalli–Nagarjunasagar link is planned to divert annually a total quantity of 7000 Mm^3. The maximum daily diversion proposed through the link canal is 62 Mm^3 (2.2 TMC) and the peak discharge works out to 721 cumec. However, keeping in view the likely augmentation of waters from Mahanadi basin as well as Himalayan component, the canal sections as designed earlier for this link project with a designed discharge of 1090 cumec at the head are retained as such. The cut-off statement is furnished at **Annexure 6.2.3**. The canal is designed as a trapezoidal section with rounded

corners and is 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 portion respectively. The typical sections of the canal as given in IS 10430–1982 "Criteria for design of lined canals and guidelines for selection of type of lining" are adopted. The typical design computations of the canal and the tunnel sections are given in **Annexure 6.2.1** & **Annexure 6.2.2**.

As the canal advances from the Inchampalli pond, the discharge in the canal gets reduced at every off-take point due to drawl of water into the branch canals to meet the requirement of enroute commands, resulting in scope for reduction in the canal section. Hence, the canal is broadly divided into suitable hydraulic reaches depending on the reduction in the discharge and the sections have been designed accordingly into 4 reaches.

Salient features of the link canal at its head and the tunnel are given in **Table 6.3.**

Table 6.3
Salient features of the link canal and tunnel

Particulars	**Full cutting /partial cutting & filling / full embankment portion**
A. Link canal at head	
Type of canal	Lined (Trapezoidal with bottom rounded corners)
Design discharge	1090 cumec
Bed width	109.60 m
Full supply depth	6.75 m
Velocity	1.306 m/s
Bed slope	1 in 20000
Side slope	1.5 H to 1 V
Manning's 'N'	0.018

B.	Tunnel	
	Shape	Modified Horse–shoe
	No. of tunnels	2
	Design discharge	545 cumec each
	Dia of the tunnel	16 m
	Velocity	2.80 m/s
	Bed slope	1 in 5000
	Manning's 'N'	0.014

The hydraulic particulars of the link canal for various reaches are given in **Annexure 6.3.1** to **Annexure 6.3.3**. Four typical sections of the link canal in deep cutting, full cutting, partial cutting & filling and full embankment and a typical section of the tunnel with 500 mm thick P.C.C. lining are shown in **Plates-6.18 (1/3 to 3/3)**. Similar cross sectional details in respect of lead canal are presented in **Plates-6.18 (1/2 & 2/2).** The hydraulic particulars in respect of lead canal, Gottimukkala feeder and Srisailam LBC (AMRLIS) are furnished in **Annexure 6.4.** The head loss calculations for various major structures along the link canal have been worked out and are taken into account as given in **Table 6.4**.

Table 6.4
Head loss calculations for major structures

S.No.	Name of the structure	RD (km)	Head loss (m)
A.	Aqueducts		
1.	Akeru river	153.59	0.156
2.	Palleru river	167.07	0.122
3.	Gudipalli vagu	289.00	0.111
B.	Syphon aqueducts		
1.	Palleru river	223.43	0.106
2.	Pedda vagu	239.03	0.106
3.	Hallia river	260.70	0.156

4.	AMRLIS canal	292.04	0.101
5.	AMRLIS canal	294.53	0.101

The head losses for the remaining structures are considered as given in **Table 6.5.**

Table 6.5
Head losses provided for the remaining structures

Sl.No.	Name of the structure	Head loss (m)
1.	Super passage	0.030
2.	Road / Railway bridge	0.010
3.	Regulator	0.200
4.	Under tunnel	Nil

The typical hydraulic designs of the above structures have also been carried out and it is found that the head losses obtained are within the above values only.

The total head loss due to structures worked out to be 5.48 m. in the entire 299.26 km length of the canal and that due to bed fall is 16.50m. The head loss statement is given at **Annexure 6.5.1** to **Annexure 6.5.3**.

6.5.2 Canal capacity

The 1210.841 km long link canal, takes off from the Inchampalli barrage with FSL of 87 m. The monthly demands of command area in various reaches are worked out and furnished in Chapter 8: Irrigation planning and command area development. The discharge in initial reach is worked out as 721cumec. As the canal moves southwards, it releases water into various branch canals identified along the alignment of the canal. In all, 35 outlets are proposed all along the link canal. The cutoff statement of the canal considering the water requirement of feeder canal and direct sluices and transmission losses enroute is prepared and is shown in **Annexure 6.2.3**. The canal carrying capacity at different reaches are given in **Table: 6.6**

Table 6.6
Canal carrying capacity at offtake of the three reaches

Sl. No	Reservoirs	RD (km)	Canal FSL (m)	Canal capacity (cumec)
1	Inchampalli	0.00	141.0	1090
2	Nagarjunasagar	299.256	151.665	488
3	Somsaila	692.276	97.30	603
4	Grand Anicut	1210.841	-	-

6.5.3 Design of canal

The canal releases water at various locations to feed enroute proposed/ existing reservoirs and accordingly the section of the canal needs to be reduced. However, it is not practical to change the section of the canal at each and every off-take point of branch canal. Therefore, the canal is divided into suitable reaches and canal sections are designed to carry the required discharges in the particular reaches. In general, a new canal section is designed wherever the discharge reduces by 10% from that of the previous reach.

The canal has been designed as a trapezoidal section with rounded corners as per provisions of IS Code: 10430 - 2000. Normally, the FSD has been kept constant in a particular reach with gradually reduced bed width. The fluming of canal is also considered by increasing the canal FSD by about 0.5 m wherever the deep cut reaches are encountered on hard /weathered rock strata. In order to prevent losses and reduce the required section of canal, plain cement concrete (M 15) lining is proposed throughout the length of link project.

The canal section is designed using Manning's formula. The side slope of 1.5:1 (H: V) in normal cutting and 0.5: 1 on hard rock portion (deep cut) have been assumed for design of canal section. Outer side slope in embankment is considered as 2: 1 (H: V). Berms of 2.0 m wide on each side wherever, the height of embankment exceeds 6.0 m is provided.

The hydraulic particulars of link are given in the **Table 6.7.**

Hydraulic parameters:

Area of Cross section (A) $= bd+d^2 (\theta + \cot \theta)$

Manning's formula (V) = $(1 / n)\ R^{2/3}\ \ S^{1/2}$
Rugosity coefficient = 0.018
Bed slope = 1 : 20000
Side slope = 1.5:1 (Normal cut)
= 0.5 :1(Deep cut)
Wetted perimeter (P) = $b+ 2d (\theta + \cot \theta)$

Table 6.7 Hydraulic particulars of canal at various reaches

Reach (km)		Design discharge (cumec)	Bed width (m)	FSD (m)	Area (sq.m)	Wetted perimeter (m)	Velocity (m/sec)	Actual discharge (cumec)
From	To							
Inchampalli to Nagarjunasagar (Bed slope of canal 1 in 20000)								
0.00	97.50	1090	109.60	6.75	834.93	137.79	1.306	1090.17
97.50	162.70	1074	107.90	6.75	823.46	136.09	1.304	1074.16
162.70	199.15	1061	106.60	6.75	814.68	134.79	1.303	1061.93
199.50	299.30	1041	104.40	6.75	799.83	132.59	1.302	1041.22
Nagarjunasagar to Somasila (Bed slope of canal 1 in 6000)								
299.256	502.006	488	21.3	7	226.32	43.36	2.16	488
Merger of link canal with existing NSRBC (Bed slope of canal 1 in 20000)								
502.006	558.256	565	67.5	6	480.17	92.56	1.18	565
558.256	602.806	539	64.1	6	459.77	89.16	1.17	539
602.806	692.276	498	58.9	6	428.57	83.96	1.16	499
692.276	841.026	603	73	6	512.87	98.01	1.18	607
841.026	882.136	524	62.5	6	449.87	87.51	1.17	526
882.136	1039.426	408	47	6	357.17	72.06	1.14	408
1039.426	1210.376	379	43.5	6	335.87	68.51	1.13	381
1210.376	1210.841	351	70	4.5	357.28	88.79	0.99	355

The design of canal in various reaches and reach wise hydraulic particulars are presented in **Annexure 6.2.** Typical canal sections at different normal reaches of main canal and the same in in deep cutting and high embankment, tunnel are shown at **Plate 6.7.**

6.5.4 Tunnels

The tunnels are designed as modified horse shoe type, free flow in nature and concrete lined. The alignment of the link tunnels and construction adits have been finalized on the basis of strip contour maps and depth of cutting.

The hydraulic design of the tunnels has been carried out for conveying actual discharge available at that location. The slope of the link tunnel is considered as 1 in 6000 in case of first tunnel at Godavari - Krishna ridge and 1 in 486 in second tunnel. The value of Manning's coefficient adopted is 0.014 for the concrete lined tunnel.

The link tunnels are provided with plain cement concrete lining of M25 grade concrete for ensuring smooth surface for conveyance of envisaged discharge. The lining shall be of RCC at junctions with shafts, very poor rock strata and any other specified reaches as would be identified during construction. The lining has been designed to resist the external and internal water pressure. The entire rock load is assumed to be carried by the rock support system consisting of rock bolts, steel fibre reinforced shotcrete (SFRS) and steel ribs. The link tunnels are proposed to be excavated by conventional drill and blast method (DBM).

The rock support system may need appropriate modifications depending upon the actual rock mass encountered. Also, the design of rock support system is not meant for shear zones, weak zones, cavities and very low cover zones at junctions with adits /vertical shafts, etc. of the tunnel and the design in these zones requires special consideration. Further, the design of the tunnel is valid for full face excavation of tunneling with conventional drill and blast method (DBM).

A typical scheme of contact and consolidation grouting has been proposed. The contact grouting in the tunnels is proposed to fully pack up the space between the concrete lining and the rock surface caused by shrinkage of concrete lining. The consolidation grouting is proposed to fill up the joints and discontinuity in the rock upto a desired depth.

The following assumptions have been considered for the hydraulic designs of link tunnels:

a. The minor losses occurring in the tunnel e.g. entrance losses, trash rack loss, transition loss, exit loss; bend losses etc. are of negligible amount in comparison to the friction losses occurring in the tunnels and therefore are not taken into consideration.

b. The flow through the tunnel is free flow and is driven by the head difference between the upper and lower FSL.

c. The tunnels are designed for free flow conditions and waters are regulated at Head regulators. As such, gates are not considered.

d. The maximum velocity in circular tunnels occurs when the depth of flow is 0.94 times of diameter. In this tunnel designs also, the depth of flow for maximum velocity is considered at 0.94 times of the dia. of tunnel.

e. The tunnel lining (PCC M25) is considered as 6 cm per m dia. of tunnel subject to minimum of 30 cm for good rocks.

(i) Tunnel at RD 86.35 km to 95.50 km

The designed discharge of the canal is 657 cumec and twin tunnels of dia 14 m each are proposed to carry the required discharge. The length of tunnel is 12500 m excluding transitions. The slope of the tunnel is 1 in 6000. The link tunnel is provided with 300 mm thick PCC lining of M25 grade concrete for ensuring smooth surface for conveyance of envisaged discharge.

The hydraulic design of tunnel and support system are furnished at **Annexure: 6.2.1.** The contact grouting and consolidating grouting shall be carried out as per the provisions of BIS-5878(Part-VII).

(ii) Tunnel at RD 302.786 km to 304.101 km

The designed discharge of the canal is 488 cumec and a tunnel of dia 10m is proposed to carry the required discharge. The length of tunnel is 1.27 km excluding transitions. The slope of the tunnel is 1 in 486. The link tunnel is provided with 300 mm thick PCC lining of M25 grade concrete for ensuring smooth surface for conveyance of envisaged discharge. The hydraulic design of tunnel and support system are furnished at **Annexure: 6.2.2.** The contact grouting and consolidating grouting shall be carried out as per the provisions of BIS-5878(Part-VII).

(iii) Tunnel at offtake of link canal from Somasila dam (692.276 km)

Two tunnels with dia 10.30m each are proposed as part of headworks at Somasila reservoir to carry designed discharge of 601 cumec. The length of tunnel is 4.0 km excluding transitions. The slope of the tunnel is 1 in 5000. The tunnels are provided with 300 mm thick PCC lining of M25 grade concrete for ensuring smooth surface for conveyance of envisaged discharge. The contact grouting and consolidating grouting shall be carried out as per the provisions of BIS-5878(Part-VII).

(iv) Tunnel at RD 700.976 km to 701.976 km

The designed discharge is 601 cumec and two tunnels of dia 12.62 m are proposed to carry the required discharge. The length of tunnel is 1.0 km excluding transitions. The slope of the tunnel is 1 in 5000. The link tunnel is provided with 300 mm thick PCC lining of M25 grade concrete for ensuring smooth surface for conveyance of envisaged discharge. The hydraulic design of tunnel and support system are furnished at **Annexure: 6.2.2.** The contact grouting and consolidating grouting shall be carried out as per the provisions of BIS-5878(Part-VII).

(v) Tunnel at RD 826.776 km to 829.876 km

The designed discharge is 580 cumec and two tunnels of dia 12.46 m are proposed to carry the required discharge. The length of tunnel is 3.1 km excluding transitions. The slope of the tunnel is 1 in 5000. The link tunnel is provided with 300 mm thick PCC lining of M25 grade concrete for ensuring smooth surface for conveyance of envisaged discharge. The hydraulic design of tunnel and support system are furnished at **Annexure: 6.2.2.** The contact grouting and consolidating grouting shall be carried out as per the provisions of BIS-5878(Part-VII).

6.5.5 Lifting arrangements

The link canal takes off from Inchampalli barrage with an FSL of 87 m and falls into Nagarjunasagar in its first reach. Lifting arrangements through 4 stages of 57 m (RD 0.0 km), 38 m (RD 18.0 km), 23.2m (26.50) and 11.0m (RD 60.50 km) totaling to 129.20m of static lift on main canal; a lift of 52.63m at 97.50km for Kakatiya Stage II feeder branch (at RD 97.50km on main canal), lifting through 3 stages of 64.50m (0.00km), 58.0m (75.00 km) and 74m (95.00km) for the 116 km long Gottimukkala feeder branch canal (taking off at RD 199.15km on main canal) totaling to 196.50m; a lift of 67.14m for Srisailam LBC feeder branch (Alimineti Madhava Reddy LIS) from Nagarjunasagar reservoir.

Surface pumphouses have been proposed to house number of vertical turbine pumps. The structure comprises of RCC columns and beams designed to carry the loads coming from various electro-mechanical equipment. A steel roof truss has been provided at top of the pump house. The location of surface pump house has been selected by studying the ground profile from toposheets/field surveys. However, the location of pump house, type of pumps, electrical and mechanical equipments will be studied in detail during the pre-construction stage. The preliminary details of pumping components are given below:

Sump/ intake well:

The sump is provided with RCC retaining walls of suitable size to retain the earth pressure. The retaining walls are proposed with RCC cantilever type. The width of the sump is taken at 1 to 2.0 times of the dia. of the bellmouth. Plain cement concrete of mix M10 1:4:8 of about 0.2 m thick is proposed for the floor of the bed.

Pumps

(a) Concrete volute pumps:

It is proposed to install concrete volute pumps with a capacity of 40 cumec discharging capacity for the pump houses. The concrete volute pumps are considered for the following reasons:

(i) Casing and suction draft tube is cast in-situ concrete.
(ii) The rotating parts are metallic.
(iii) Simple mechanical design.
(iv) Pumps are expected to run continuously for prolonged times.
(v) Concrete volute pump guarantees strength and rigidity and virtually eliminates the problems of corrosion and erosion.
(vi) Higher & consistent pump efficiencies over a sustained period of operation.
(vii) As the size of the pump increases, the dimension and weights of the heaviest parts have a large influence on the choice of construction material used. Concrete is therefore, the natural choice for the pump body.
(viii) Mass casing in concrete provides excellent inertia anti seismic construction & simple preventive maintenance on yearly schedule.
(ix) Main pump parts can be checked in-situ and without pump dewatering.
(x) Few moving and metallic parts in contact with water.
(xi) Perfect hydraulic design of draft tube and volute eliminates vortices and risks of concrete deterioration and low submergence required.
(xii) Lower crane height & lifting capacity requirement.

(xiii) Easy internal inspection without dismantling. Impeller can be examined from suction elbow and rotor from manhole.
(xiv) Overall expenditure for the complete pumping system is substantially lower.
(xv) No pump casing, therefore total weight of removable components is a small fraction of that of conventional units.
(xvi) No anchoring necessary.
(xvii) Low maintenance equipment and less manpower required. Fewer spare parts to be kept handy
(xviii) Simple to construct volute and draft tube and can be carried out by civil construction company at site.

Electro mechanical equipments

The electro mechanical components consist of pump turbine, motor, cooling system, transformer connections, inlet valve, surge protection & neutral earthing system, supervisory control and data acquisition system, pipe valves, main step-up transformer, switchyard equipment, control & protection equipment, auxiliary mechanical services, EOT crane for pump house, electrical lifts and elevators, workshop equipment, test laboratory, telemetry, ventilation & air conditioning, fire protection, auxiliary electrical services etc.

Delivery main

The mild steel rising mains of suitable dia are provided. Hazen Williams equation $V = K\ C\ (D/4)^{0.63}\ S^{0.54}$ has been considered to work out the frictional loss of the pipe, where K is unit conversion factor (0.85), C is Hazen William co efficient (145). D is dia. of pipe and S is head loss/ length of pipe. The thickness of pipe to withstand the pressure is computed considering 50 % above the working pressure. Extra thickness of 1 to 3 mm for corrosion is also considered. As epoxy painting is considered inside and outside the pipe, the provision for corrosion is limited to 1 mm.

The velocity in the pipes are almost limited to less than 3.0 m/sec. The PCC for bedding and RCC of about 1 m thick surrounding the pipe is also provided for anchoring and supporting the pipeline. The provision for

expansion joint, pressure relief valves, air relief valves and water draining arrangement is also provided.

Delivery cistern

The rising main from the pump house is let into fall in the delivery cistern. The rising main is kept in such a way that it is at least one metre above the delivery cistern pond level so that the water from the cistern is not entered into the pipeline. The delivery cistern is of rectangular size with transition to connect with the canal. The delivery cistern is provided with RCC retaining walls of suitable size to retain the earth pressure. In case the cistern is in hard rock strata, the RCC wall of 0.3 m uniform thickness is anchored with the sides. Plain cement concrete of mix M10 1:4:8 of about 0.2 m thick is proposed.The design of lifting arrangements is **shown** in **Annexure 6.12.**

6.5.6 Powerhouse at the offtake of link canal from Nagarjunasagar

The link canal takes off from the Nagarjunasagar at the same off-take level as that of the existing NSRBC and hence, it is proposed to construct a power house on the link canal similar to the existing one on NSRBC. The water to be drawn into link canal would be guided through the powerhouse. It is proposed to install 4 units of 30 MW each including one standby unit. The effective installed capacity of the powerhouse would be 90 MW. The head regulator of the link canal is proposed to be similar to that of the existing one on the NSRBC but with 8 vents of same size of 3.05 m x 4.575 m with a sill level of 149.05 m. A power block of length 70 m with 4 Nos. of penstocks and dam toe power house of size 67m x 39 m is proposed on the right side of the existing similar structures of NSRBC. The water after power generation using the available head would be guided to the link canal through 130 m long tailrace channel. Suitable modifications to the right embankment of Nagarjunasagar dam are proposed to be carried out for accommodating the proposed head regulator, power block with penstocks etc., leading to the proposed power house on the link canal.

The following civil and electrical works would be required to be undertaken for the proposed powerhouse.

Civil works

(i) 4 Nos. of trash rack structures
i) Powerhouse civil works
ii) 4 Nos. of penstocks of 6 m dia. and 133 m length.
iii) Intake gate shafts
iv) Powerhouse pit to accommodate 4 Nos. of turbines and generating units
v) Draft tube gate shaft to connect the runner to the tail race
vi) Switch yard
vii) Tail race pool

Electrical works

i) Power station, generation & control equipment
ii) Power station auxiliaries
iii) Power station transformer and outdoor equipment

The design particulars of the powerhouse are furnished in **Annexure 6.6.3** The lay out, plan and sectional elevations of the powerhouse are shown in **Plates 6.15 to Plate 6.17.**

6.5.7 Description of soil profile along the link canal

Soil samples are collected along the link canal alignment by digging pits or drilling auger holes. The report and results of the soil profiles are furnished by the outsourcing agencies.

6.5.8 Evaluation of design parameters

Various expert agencies viz. JNTU,APERL,CSMRS etc., suggested that the link canal can be taken up along the proposed alignment, based on geophysical and geotechnical investigations (soil) carried out. However, in reaches where very weak soil such as soil of MH and CH group are present, it was suggested to deviate route slightly based on the soil availability or else the designers may design the canal based on investigated data.

6.5.9 Transmission Losses

The transmission losses in the canal occurs in the form of seepage through the canal lining and evaporation from the surface of water. 0.6 cumec per million square metre of wetted area is considered as transmission loss along the canal.

6.6 Canal structures

6.6.1 Cross drainage/Cross masonry works / regulators

Various canal structures, bridges and cross drainage structures have been proposed. In all, there are 751 structures proposed all along the link project. There are 105 structures in all in Reach I, 328 structures in Reach II and 318 structures in Reach III.

6.6.2 Layout and foundation

Detailed laboratory tests for finding the suitability of soils for foundations of all cross-drainage works have not been carried out except for few major rivers. However, based on the soil samples collected, it is inferred that hard rock can be met with at reasonable depths below the stream bed levels. This is required to be confirmed at pre-construction stage.

6.6.3 Cross drainages works

The type of cross drainage structure to be provided depends on the physical features of the stream crossed such as position of bed level of stream in relation to canal bed level. Loss of head at each structure is computed based on the 100 years design flood and the drain/canal details. The head loss in the structure mainly depends upon the length and fluming adopted, more the length and fluming more is the head loss. Fluming of canal at the structures is considered to an extent of 60 to 70% wherever possible to achieve economy in cost of structure.

a) Flood estimation of various streams

In its entire course of 1210.841km, the link canal has been provided with 751cross drainage works. The design flood value of each drain has been

worked out using the empirical formulae given in **Table 6.8**, which are adopted by the Irrigation Department of the Government of Andhra Pradesh.

Table 6.8: Formulae for computing design flood

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

Where A is the catchment area of the drain

b) Aqueducts

Aqueducts have been proposed along the link canal at the major stream crossings where the bed level of the link canal is above the highest flood level of the drain with sufficient free board. In all, 130 aqueducts are proposed. The hydraulic design of aqueduct across Akeru river at RD 153.590 km is furnished in **Annexure 6.6.1**. Typical plan and section of aqueduct is shown at **Plate 6.9.**

c) Super passages

Super Passages have been proposed along the link canal at the major stream crossings where the bed level of the drain is above the FSL of the canal with sufficient free board. In all, 120 super passages are proposed. The hydraulic design of super passage across Salivagu at RD 81.60 km and across Peddavagu at RD 563.541 km is presented at **Annexure 6.7.1 and Annexure 6.7.2** respectively. Typical plan and section of superpassage is shown at **Plate 6.10.**

d) Syphon aqueducts

Syphon Aqueducts have been proposed along the link canal at the major stream crossings where the bed level of the link canal is just at the highest flood level of the drain. The bed of the drain is depressed to an extent of about 1.0 m below the actual drain bed level. In all, 18 syphon aqueducts are proposed. The design particulars of the siphon aqueduct across river Hallia at RD 260.700 km is given at **Annexure 6.8.1**.

e) **Canal syphon**

Canal syphons have been proposed along the link canal at the major stream crossings where the full supply level of the link canal lie between the drain bed and the highest flood level of the drain. However, the choice of canal syphon depends upon the discharge capacity of canal vis a vis the design flood and physical characteristics of drain. The top of the canal syphon barrel is kept about 1 m below the river/drain bed to avoid damages from the rolling stone. A total of 21 canal syphons are proposed. The hydraulic design of canal siphon across Paleru nadi at RD 576.776 km is given as **Annexure 6.8.2**. Typical plan and section of canal syphon is shown at **Plate 6.11.**

f) Cross regulators / canal regulators

Cross regulators are provided at regular intervals in order to ensure effective water regulation to the command area as well as change in canal sections. In all, 27 cross regulators are proposed along the link canal. The hydraulic design of cross regulators at RD 97.50 km and RD 529.406 km is furnished at **Annexure 6.11.1 and 6.11.2 respectively.** Typical plan and section of cross regulator is shown at **Plate 6.14.**

f) Head regulators

The link canal is provided with head regulators at Nagarjunasagar and Somasila. These head regulators are normally considered as part of headworks.

g) Canal escapes

The canal escapes are provided to release the water from the canal to streams to safe guard the canal during emergency conditions like breaching of canal, excess water flow in the canal etc. The canal escapes are designed to drain 50 % of canal discharge. The escapes are usually to be provided at the u/s of aqueducts or at the u/s of HR/CR junction. The canal escape regulators are similar to branch canal regulators. There are 7 nos. of canal escapes provided in the link canal.

h) Under tunnels/ Over pass

The link canal crosses about 335 nos. of small streams/ existing canal distributaries all along its path. Under tunnels/over passes are provided at these crossings. Box type culverts are proposed for under tunnels/over passes for which head loss is not considered. Piped under tunnels/over passes are also provided where the streams carry insignificant discharge and the elevations are not permitting for box culverts. The hydraulic design of under tunnels at RD 183.950 km and RD 632.421 km are furnished at **Annexure 6.9.1 and Annexure 6.9.2 respectively**. Typical plan and section of undertunnel is shown at **Plate 6.12.**

(j) Bridges

The project area is well developed as far as communications are concerned. There are several roadways and railways encountered by the link canal alignment. Hence, to maintain the existing communications intact and to provide additional communications in anticipation of the developmental activities due to the link canal, several road bridges and railway bridges are proposed. In all, 417 nos. of bridges comprising of 339 of SLRB, 68 of DLRB and 10 of railway bridges are proposed along the length of the canal. The hydraulic designs of road bridges are presented in **Annexure 6.10** Typical plan and section of double lane road bridge is shown at **Plate 6.13.**

6.7 Cost curves for cross drainage and cross masonry works

The cost curves developed for preparing feasibility studies of various components of Godavari (Inchampalli) - Cauvery (Grand Anicut) link project are considered in the study. The cost curves adopted while estimating cost of structures in feasibility studies are updated to 2020-21 price level and made use for estimation of cost of structures of the link project.

6.8 Integration of link canal with the existing reservoirs and canals

The link canal system will be operated as an integral part of existing / proposed reservoirs and existing canal net work for optimum utilization of the created infrastructure and storage capacity.

6.9 Canal automation and branch canals

The canal automation technology being adopted for the contemporary projects considering technological updation, will be adopted for the link project as well.

6.10 Instrumentation

The requirement of special instruments for the construction of barrage, tunnels and pump houses shall be assessed during the pre-construction stage.

6.11 Other studies

The studies required at DPR stage have been carried out and included in the report. The other studies which are not covered in the DPR, if any, will be carried out at preconstruction stage.