Chapter – 4
Surveys and Investigations

4.0 General

The proposed Ponnaiyar (Nedungal) - Palar intra state link project envisages diversion of 86 Mm$^3$ of flood water available in Ponnaiyar river at Krishnagiri dam to the water-short Vaniyambadi taluka of Vellore district in Palar basin for irrigation and drinking water supply in Krishnagiri and Vellore districts. The preparation of DPR essentially involves carrying out various topographical surveys and other field / laboratory investigations in respect of the project. The present chapter deals with various topographical surveys and other investigations carried out for the proposed Ponnaiyar (Nedungal) - Palar link project.

4.1 Topographical Surveys

Surveys and Investigations provide necessary field data required for proper planning and designing of various components of a Water Resources Development Project. A project can be designed optimally and techno-economically, only when necessary field data at specified standards are available readily. NWDA has taken up collection of data required for the preparation of Detailed Project Report (DPR) of Ponnaiyar (Nedungal) - Palar Link Project during the period from September 2012 to December, 2014. The surveys & investigations work for preparation of DPR of the link project has been carried out as per the ‘Guidelines for preparation of Detailed Project Report of Irrigation and Multipurpose Projects’ of the then Ministry of Water Resources, Govt. of India (2010).

To examine the feasibility of the project, detailed surveys & investigations such as topographical surveys, geology, geo-physical and geo-technical investigations covering soil investigations along the canal alignment including borrow area survey, foundation investigations/drilling works at cross drainage and cross masonry structures for obtaining rock core samples for laboratory investigations, construction materials investigations for coarse and fine aggregates, mineral survey, archeological survey, communication survey, ground water survey etc, have been under taken departmentally and through various specialized organizations.
Survey for Transferring the GTS Bench Marks

The Great Trigonometrically Survey (GTS) Bench Mark (BM) which is a primary protected Bench Mark of Geodetic and Research Centre of Survey of India (SOI) located at Permanent Way Inspector's (PWI) Office at Tirupattur Railway Station in Vellore district of Tamil Nadu has been connected to the Permanent Bench Mark (PBM) situated at Krishnagiri dam site for establishing Bench Mark Levels at various locations i.e., major road crossings/road and railway bridges/culverts/in the vicinity of high school buildings etc. along/nearer to the link canal alignment of Ponnaiyar (Nedungal) - Palar link project by conducting Double Tertiary (DT) Leveling over a length of about 75 km. Adequate numbers of Permanent / Temporary Bench Marks (PBM / TBM) as per the specified guidelines, in the project area at different locations have been established with reference to the above GTS Bench Mark.

Topographical Survey - Connection of GTS BMs in Krishnagiri District, Tamil Nadu on 18.10.2012

The locations of various PBM / TBMs established in the project area are given at Annexure - 4.1.
4.1.1 River Surveys

(i) Ponnaiyar River

The river survey was carried out along the fair weather deep channel of the Ponnaiyar river at the existing Nedungal Anicut (FPL 434.68 m) from where the proposed link canal takes-off, by NWDA. The longitudinal section along the Ponnaiyar river has been surveyed for 1.050 km upstream up to RL 439.857 m (MWL +3 m) and 0.500 km downstream of the existing Nedungal Anicut by taking levels at an interval of 50 m. In addition to the above, Cross sectional survey has been carried out at 50 m interval for a distance of 1.050 km upstream and 0.500 km downstream from the axis of the existing Nedungal Anicut i.e., upto the point corresponding to the length of L-section on both sides. Each cross-section has been extended up to 2.40 km, (i.e., MWL +3), covering the area beyond the firm bank. Levels were taken at 50 m grid basis in the river portion surveyed. In addition, five more cross-sections were also taken along the axis of the Nedungal Anicut, toe and heel of the Anicut and two cross sections at 10 m away from the toe and the heel of the Anicut.

The L-section and cross-sections of the Ponnaiyar river and its contour plan at Nedungal Anicut as surveyed above are at Plates - 4.1, 4.2.1 to 4.2.17 and 4.3 respectively.

(ii) Godd Ar of Kal Ar (A tributary of Palar river)

Survey work of Godd Ar of Kal Ar and Kal Ar, a tributary of Palar river were also carried by NWDA. The longitudinal survey of river Godd Ar and Kal Ar was carried out by Double Tertiary Leveling (DTL) for a length of 16 km (Godd Ar: 7.400 km, Kal Ar: 8.600 km) upto the confluence of Kal Ar with Palar river and existing Check dam across Godd Ar to fix the position of exit / out-fall point of the link canal. Over all about 35 cross sections were taken along both the rivers at 500 m interval. Single Tertiary Leveling (STL) at 50 m interval was carried out for all the above cross sections for a length of 500 m for each cross section.

Out of cross sections of Godd Ar surveyed, the cross sections which are smaller in size and having similar cross sectional areas are selected for computing the carrying capacity of Godd Ar. Similarly, the carrying capacity of Kal Ar was also computed. Based on the L-sections and average cross sectional areas of the Godd Ar and Kal Ar and by adopting the co-efficient of Rugocity (n) as 0.035 (natural streams), the average carrying capacity of Godd Ar and Kal Ar has been computed as 60 cumec and 87 cumec respectively.
The L-section and cross-sections of the Godd Ar and Kal Ar and its contour plan at outfall point as surveyed are given in Plates - 4.4.1 to 4.4.6, 4.5.1 to 4.5.9 and 4.6.1 to 4.6.3 respectively.

4.1.2 Reservoir Surveys
Since existing Krishnagiri reservoir along with Nedungal Anicut is contemplated to be used in the present proposal, no reservoir survey is taken up.

4.1.3 Surveys for Head Works

Nedungal Anicut
The existing Nedungal Anicut located at about 16 km d/s of the existing Krishnagiri dam (controlling structure) across Ponnaiyar river has been considered as head works for the proposed link canal project. The link canal off-takes from the left flank of the river adjacent to the existing Barur Feeder Channel.

The flood waters will be released at Krishnagiri Dam. The existing Nedungal Anicut across Ponnaiyar river will act as head works to divert this flood water in to the link canal.

4.1.4 Plant and Colony Layout Surveys
The Plant and Colony layout survey will be carried out at pre-construction stage of the project. There are suitable locations available for installation of various plants near off-take and out-fall locations of the link canal.

4.1.5 Surveys for Canal and Water Conductor System and Canal Structures

a) Canal and Water Conductor System
Alignment of the link canal was marked on the ground by taking into account the actual site conditions for a length of 54.150 km such that cutting is minimum. R.C.C pillars of size 0.15 x 0.15 x 0.75 m were fixed at 200 m interval along the link canal alignment. R.C.C Temporary Bench Marks (TBM) of size 0.40 x 0.40 x 1.10 m were also erected at every 2 km along the length of the canal/change of bearing at turning point (TP). All the above pillars were painted red and chainage along with name of the project were written with white paint. The bearing statement of the canal alignment is given in Annexure - 4.2.

L-section of the link canal is carried out by Double Tertiary Leveling (DTL) by taking levels at 50 m interval.
Cross-sections of the link canal were taken at every 50 m interval by single leveling from RD 0.000 to 41.700 km and beyond RD 41.700 km upto out-fall point at RD 54.150 km cross sections were taken at 250 m interval as the terrain is almost flat nature. Cross section levels were taken at every 50 m upto 150 m on either side of the canal alignment.

The strip contour plan and L-section of the link canal alignment has been prepared with 1 m contour interval and appended as Plates - 4.7.1 to 4.7.27. Condensed L-section of the link canal is appended at Plates - 4.8.1 to 4.8.4.

b) Canal Structures

The link canal on its way crosses a number of small rivers, streams/tributaries/rivulets and nallas, besides State Highways, district roads, Village roads and Railway lines. In total, 62 Nos. of cross drainage/cross masonry structures are identified along the link canal. Out of 62 structures, grid surveys have been carried out for 8 Nos of major representative CD/CM structures. List of the 62 CD/CM structures across the link canal is given in Annexure - 4.3.

Grid Surveys at 50 m x 50 m interval were carried out at each proposed major canal structure site to cover an area up to 300 m on either side of the centre line of the canal, upto 100 m d/s of the point of exit of water and 100 m u/s of the point of water inlet. Contour plans were prepared in 1:2500 scale with 1 m contour interval to facilitate the designs of cross drainage structures, besides marking of final link canal alignment. Cross sections of the rivers/streams/rivulets/nallas have also been taken along the centre line of the canal and the same have been plotted to the scale of 1: 2500 horizontal and 1:100 vertical.

The contour plans, longitudinal section and cross section of 8 Nos. of major canal structures along the link canal are at Plates - 4.9.1 to 4.9.8.

4.1.6 Command Area Survey

The 86 Mm$^3$ of flood water proposed to be diverted through Ponnaiyar - Palar link will be utilized to stabilize a total existing command area of 9850 ha consisting of about 1900 ha enroute in Krishnagiri and Vellore districts by filling the enroute existing system tanks and 7950 ha in Vaniyambadi taluka of Vellore district in Palar basin through ground
water recharge, besides to provide 3.882 Mm$^3$ drinking water to the people of enroute villages benefitting about 1.52 lakh people at 70 litres/capita/day.

As the project envisages to stabilise the existing command area and no new area is proposed to be brought under the command of this project, the command area survey has not been carried out.

4.2 Other Surveys

4.2.1 Archaeological Surveys along the Canal Alignment

The Department of Archaeology, Chennai, Govt. of Tamil Nadu vide letter No.C1/4076/2014 dated 14.07.2014 communicated that none of its monuments are hindrance to the project area of Ponnaiyar (Nedungal) - Palar link canal Project. Copy of the letter is at Annexure - 4.4.

The Archaeological field explorations have also been carried out for the entire Ponnaiyar (Nedungal) - Palar link project by the Archaeological Survey of India (ASI), Govt. of India, Chennai Circle, Chennai and their detailed report was received vide Letter No.1/50/Tech/NWDA/2014-15/3698 dated 05.08.2014. ASI informed that no Archaeological remains were identified on the surface except in Peruhalli village. It is informed that a Hero Stone (16th Century CE) broken into three pieces was found on the left bank of the Ponnaiyar river in Peruhalli village, at a distance of about 110 m from the canal alignment. The proposed canal alignment area mostly passes through the mango and coconut plantation. Copy of the report is at Annexure - 4.5. The historical Hero Stone identified as above by ASI, will be protected by providing a steel case around the stone to safeguard it during construction stage of the project. This Hero Stone will not be affected by the link canal as the total width of the canal way is about 45 m only.
4.2.2  **Mineral Surveys along the Canal Alignment**

The Director, Engineering Geology Division, Geological Survey of India (GSI), SU:TNP, Chennai, after due investigation, communicated vide letter No. 5546/06/IB/EGD/NWDA/2013-14 dated 19.12.2013 that no major mineral deposits of economic importance gets affected or falling within the proposed project area of the link canal alignment. A copy of the above letter submitted by GSI, Chennai is at Annexure - 4.6.

4.2.3  **Right of Way Survey for the Reservoir**

No right of way survey has been carried out since the existing reservoir / Anicut is proposed to be used as head work of the proposed link canal.

4.2.4  **Communication Surveys**

The Ponnaiyar (Nedungal) - Palar link canal traverses through Krishnagiri and Vellore districts of Tamil Nadu state. The existing Krishnagiri dam and Nedungal Anicut across Ponnaiyar river are the head works of the proposed link canal and are located in Krishnagiri district. The Krishnagiri district Hqs is situated on Bengaluru-Salem National Highway-7. There is a good bitumen road (about 3 km long) maintained by PWD, Tamil Nadu connecting Krishnagiri dam with NH-7. The Krishnagiri dam is situated at a distance of
5 km from Krishnagiri town. The Nedungal Anicut and the off-take point of the link canal are situated 16 km downstream of Krishnagiri dam and about 14 km from Krishnagiri Municipal Corporation and are well approachable from all the places by a good network of PWD Roads.

Bengaluru city is the nearest Airport to the link project at a distance of about 100 km. Tirupattur and Jolarpet are the nearest major railway stations. The link canal crosses the NH-66 connecting Bengaluru and Uttangarai at RD 24.000 km and NH-46 connecting Bengaluru to Chennai also traverses very closely to the outfall point of the link canal at Natrampalli village at RD 54.150 km.

The out-fall point of the canal is at a distance of 2 km from Natrampalli village, 5 km from Jolarpet railway junction and 12 km from Tirupattur taluka Hqs in Vellore district. The link canal passes at a distance of about 2 km from Pochampalli town and Taluka head quarters, 1 km from Sandur, a developed big village, 1 km from well developed Attiganur and Kannadahalli villages. The canal alignment is at a distance of about 1 km from Kandili, 2 km from Pudupet, 7 km from Tirupattur enroute. The entire link canal traverses in the vicinity of many villages and towns and therefore, the head works and canal alignment is well approachable by means of National Highways, State High ways, major district roads and village roads of bituminous top. The existing road network can be used during the period of constructional activities of the link project. However, necessary provision is kept in the cost estimate for widening of some village roads along with new approach roads, if any required, at the time of execution of the project.

All the villages/towns in the vicinity of head works, link canal alignment and outfall point are fully electrified and connected by telephone lines. Further, suitable provision is made in the project estimate towards electrification and telephone lines for project area on site conditions during the execution of the project.

The map showing the communication network in the vicinity of the link canal project is appended at Plate - 4.10.

4.2.5 Drainage Surveys

As already mentioned, the diversion of water through the link canal is intended for stabilisation of the existing command area being irrigated through open wells/bore wells, by recharging the ground water enroute the link canal in Krishnagiri and
Vellore districts as well as in Vaniyambadi taluka of Vellore district in Palar basin. The existing command area enroute the link canal has good drainage facilities by a network of rivers/streams and a number of small nallahs. The command area to be stabilised under the link canal in Vaniyamabadi taluka of Palar basin too has good drainage system and hence no drainage problems are anticipated.

4.2.6 Soil Surveys

Since the link canal project is proposed to divert water to stabilize the existing command areas which are already under irrigation by recharging ground water, fresh soil surveys are not required.

Soil map of the command area based on the publication of National Bureau of Soil Survey and Land Use Planning (NBSS & LUP), Nagpur is given at Plate - 4.11. From the map, it could be seen that brown clay loamy soils and red soils are predominant in the command area of the project where the existing areas under irrigation are proposed to be stabilized.

4.3 Geology, Geo-physical and Seismic Investigations

4.3.1 Regional Geology

The Ponnaiyar (Nedungal) - Palar intra state link canal project traverses through Krishnagiri and Vellore districts of Tamil Nadu. The geological formations of Krishnagiri district mainly characterized by Archaean age with rock of proterozoic age. The former is represented by Khondalite group of rocks while the latter is represented by alkaline rocks. The major part of Vellore district is covered by metamorphosed crystalline rocks of Charnockite group and the migmatite complex of Archaean age. The proterozoic alkaline group of rocks are seen in the Koratti and Elagiri hills.

4.3.2 Local Geology

The command area of Ponnaiyar(Nedungal) - Palar Link Project is mostly covered by charnockite of Southern Granulitic Complex, Hybrid granite gneiss/grey hornblende biotite gneiss of Peninsular Gneissic Complex-II, epidote hornblende gneiss, pink granite, dolerite dykes, etc.. In general various geological sub-surface details encountered along the canal alignment consists of the top soil (red sandy soil and sandy clayey soil of thickness of about 1 m), a highly weathered zone and semi-weathered/fractured formation below top soil, with basement as hard rock.
4.3.3 Geological and Geotechnical Investigations

The Preliminary stage geotechnical investigation of Ponniayar (Nedungal) – Palar Link Project was assigned to Geological Survey of India (GSI), Chennai to carry out the Geological and Geotechnical Investigations and mapping along the link canal and at major CD/CM structures. The Geological mapping of the proposed canal alignment was carried out on 1:10,000 scale covering a cumulative area of 11.4 sq. km from R.D.0 to 15.965 km and from R.D.24.7 km to 45.20 km covering 150 m on either side of alignment. The reach from 15.965 km to 24.70 km and from 45.20 to 54.15 km could not be carried out due to public hindrances.

Geological Investigations of Nedungal Anicut by Geological Survey of India, Chennai on 18.08.2014
Geological mapping of project area by officer of GSI, Chennai at RD 26.000 km on 18.03.2015

The mapped area of the alignment is mostly covered with overburden consisting only scattered outcrops and indicate an average depth of bed rock around 3 to 4 m from ground level, as observed from the surficial mapping, exploratory bore holes and data from open dug wells located near by the proposed canal alignment. However, the reaches from R.D. 30 km to 31.3 km are predominated by small hillocks of grey hornblende biotite gneiss consisting commercial granite quarries. On a whole, the mapped reaches did not indicate any major geological problem, expect the reaches between RD 43 to 44 km, where the proposed canal alignment passes through sand horizon and intercepting CBL. Therefore lining of canal in this reach was recommended by GSI to avoid loss of runoff water through permeability and to stabilise the side slope to avoid failure.

In addition, Geotechnical studies including drilling were also made at proposed major Cross Drainage (CD) works at the river/stream, road and railway crossings, upto the outfall at Godd Ar to evaluate the depth and nature of bed rock, overburden and bed characteristics. NWDA has carried out sub surface exploration at 15 nos. of bore holes by double tube diamond core drilling, consequently bore logging and assessment of the cores have been made by GSI for a cumulative depth of 134.10 m.
In general, most of the study area is covered with overburden consisting of soil and weathered rock, embedded in soil and completely weathered rock by calrete / kankar formations.

The report on the Preliminary stage geotechnical investigation received from GSI, Chennai is at Appendix – 4.1.

**4.3.4 Laboratory Investigations of Rock Samples**

Geological assessment and logging of 15 boreholes has been carried out by GSI, Chennai for a cumulative depth of 134.10 m along the proposed canal alignment. The rock types encountered in the mapped reaches include Hybrid granite gneiss, grey hornblende Biotite gneiss, pink granite, doloritic dykes, etc. However, the reach from RD 30 km to 31.3 km is dominated by small hillocks of grey hornblende Biotite Gneiss consisting Granite quarries.

The core samples collected from exploratory drill holes were got tested at CSMRS Rock Mechanics Laboratory, New Delhi. The CSMRS conducted the investigations of Biotite Gneiss and Pink Granite.
The recommended design parameters based on the laboratory investigations of Biotite Gneiss and Pink Granite Rock samples of the proposed Ponnaiyar (Nedungal) - Palar Link Project as suggested by CSMRS are presented in Table-4.1.

Table-4.1
Recommended Design Parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Recommended Parameters</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Biotite Gneiss</td>
</tr>
<tr>
<td>Bulk Density (dry), $\rho_{dry}$ (kg/m$^3$)</td>
<td>2710</td>
</tr>
<tr>
<td>Bulk Density (saturated), $\rho_{sat}$ (kg/m$^3$)</td>
<td>2715</td>
</tr>
<tr>
<td>Grain Density (saturated), $\rho_{grain}$ (kg/m$^3$)</td>
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</tr>
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<td>Water Content (at saturation), w.c.(%)</td>
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<tr>
<td>Apparent Porosity, $\eta$ (%)</td>
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<td>Slake Durability Index, I cycle (%)</td>
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<tr>
<td>Slake Durability Index, II cycle (%)</td>
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<td>Uniaxial Compressive Strength, UCS (MPa)</td>
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<td>Tangent Modulus, $E$ (GPa)</td>
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<td>Poisson’s ratio, $\mu$</td>
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<td>Apparent Cohesion, $c$ (MPa)</td>
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<td>Angle of Internal Friction, $\phi$ (Degree)</td>
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<tr>
<td>Indirect Tensile Strength (sat) (MPa)</td>
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<tr>
<td>Point Load Strength Index (dia.) (sat) (MPa)</td>
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</tr>
<tr>
<td>Point Load Strength Index (axial) (sat) (MPa)</td>
<td>7.5</td>
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</tbody>
</table>

The reports on Laboratory Investigations of Rock samples received from CSMRS, New Delhi is at Appendix – 4.2.

4.3.5 Geo-physical Investigations

The work of Geo-physical investigations was carried out by the National Geophysical Research Institute (NGRI) Hyderabad. The NGRI conducted Geo-physical investigations along the link canal alignment of the Ponnaiyar (Nedungal) - Palar link for the entire length of link canal (from off-take point to out-fall point) at an interval of 500 m at 93 cross sections using the latest technology viz., ‘Electrical Resistivity Tomography (ERT) Imaging’. Based on these ERT profiles 9 Nos. of longitudinal cross sections were generated depicting the sub-surface geological features with reference to the Canal Bed Level (CBL).
along the link canal alignment. Each longitudinal cross section is more or less 5 km of the traverse. The details of the geo-physical investigations conducted along the link canal showing thickness of different sub-surface zones and the features encountered are given in **Annexures-4.7.1 to 4.7.9.**

Geo-physical investigations were also carried out at 8 Nos. of proposed major CD/CM structures which include Double Lane Road Bridge (DLRB), Aqueduct / Syphon Aqueduct and Canal Syphon etc. The details of the Geo-physical investigations conducted at 8 major CD/CM structures showing thickness of different sub-surface zones and the features encountered are given in **Annexure - 4.8.**

![NGRI, Hyderabad team conducting Geo-physical investigations at RD 0.500 km on 12.08.2014](image)

The report on Geophysical investigations along with all Electrical Resistivity Tomography (ERT) images received from NGRI, Hyderabad is at **Appendix - 4.3.**

### 4.3.6 Seismic Investigations

No new dams / reservoirs are proposed in the present study, since the existing Krishnagiri dam and Nedungal Anicut are planned as head works of the link project. Therefore, seismic studies are not conducted in this study. However, it is to be mentioned that the Krishnagiri dam and reservoir falls under seismic zone-II.
4.4 Geotechnical Investigations (Soils)

The work of Geotechnical investigations (Soils) for DPR of Ponnaiyar (Nedungal) - Palar Intra-state link of Tamil Nadu has been carried out by CSMRS, New Delhi. The geotechnical investigations (Soils) involves:

(i) Soil investigations along the canal alignment
(ii) Laboratory Investigations on soil samples from Barrow area along the canal alignment
(iii) Foundation Investigations of Cross Drainage structures

4.4.1 Soil Investigations along the Canal Alignment

The soil investigation works along the canal alignment involves collection of undisturbed / disturbed soil samples from the trial pits excavated at the regular intervals of four to five km along the canal alignment. The undisturbed soil samples were collected in core cutters from shallow pits of soils 3 m x 3 m x 3 m from the portion where the canal is in cutting.

A total of 9 soil samples (5 undisturbed and 4 disturbed) were collected from the trial pits excavated at nine different locations along the canal alignment, where the canal was in cutting portion for conducting the following laboratory tests accordance with the recommendations of the relevant Indian Standard code and other standard procedure:

- Mechanical Analysis
- Atterberg Limits
- In-situ Density and Moisture Content
- Specific Gravity
- Triaxial Shear
- One Dimensional Consolidation

Based on the findings of the field and laboratory investigations carried out on soil samples collected along the canal alignment, the following conclusions have been arrived at:

- Based on In-situ permeability test, it is inferred that soil strata possess pervious drainage characteristics.
- The grain size analysis indicate that the tested soil samples possess predominately medium sand sizes followed by fine sand sizes and silt sizes.
The plastic index values of the tested soil samples indicate that four soil samples possess the medium to high plasticity characteristics and the remaining four soil samples exhibit non-plasticity characteristics.

Based on the results of grain size distribution and Atterberg limit tests, out of 9 tested soil samples, 5 soil samples fall under SM (Silty Sand) and 2 soil samples fall under SC(Clayey sand) and GP-GC(Poorly Graded Clayey Gravel) group of Bureau of Indian Standard Soil classification system.

The In-situ dry density and natural moisture content values of the tested five undisturbed soil samples vary from 1.31 g/cc to 1.69 g/cc and 1.9% to 24.3% respectively. The in-situ density values indicate that the tested foundation strata exhibit loose to medium compactness.

Based on the results of triaxial shear tests conducted on the soil samples, it is inferred that the tested soil samples are likely to exhibit good/very good shear strength characteristics.

Base on the one Dimensional consolidation test conducted on the undisturbed soil samples, it is inferred that the soil strata along the canal alignment is likely to undergo in general medium compressibility depending upon the imposed loads.

The report on soil investigations along the canal alignment received from CSMRS, New Delhi is at Appendix – 4.4.

Collection of Undisturbed Soil sample by CSMRS Team (Soils) at RD 47.000 km on 17.10.2014
4.4.2 Laboratory Investigations on Soil Samples from Borrow Area along the Canal Alignment

To ascertain the suitability of the borrow area material as construction material in filling reaches of canal alignment, representative/disturbed soil samples from trial pits were collected from barrow areas and field and laboratory investigations were conducted by CSMRS, New Delhi.

A total of 7 disturbed samples were collected from the trial pits excavated at seven different locations in the adjoining area of canal alignment, where the canal was in filling reach. The soil samples collected from the 7 different locations along the canal alignment were subjected to the following laboratory investigations:

- Mechanical Analysis
- Atterberg limits
- Standard Proctor Compaction
- Specific Gravity
- Triaxial Shear
- One Dimensional Consolidation
- Laboratory Permeability
- Chemical Analysis
  - pH value
  - Total Soluble Salts
  - Calcium carbonates
  - Water Soluble Sulphates
  - Water Soluble Chlorides

All the above tests were carried out in accordance with the recommendations of the relevant Indian Standard and other standard procedures.

Based on the findings of the laboratory investigations carried out on soil samples collected from the borrow areas along the canal alignment following conclusions have been arrived at:

- The grain size analysis indicate that the tested soil samples possess predominately medium sand sizes followed by fine sand sizes and silt sizes.
- The plastic index values of the tested soil samples indicate that 5 soil samples possess the low to medium plasticity characteristics and the remaining one soil samples exhibit non-plasticity characteristics.
Based on the results of grain size distribution and Atterberg limit tests, out of 7 tested soil samples, 4 soil samples fall under SC(Clayey sand) and remaining 3 samples fall under SM(Silty Sand) group of Bureau of Indian Standard Soil classification system.

Based on the Standard Proctor Compaction tests, it is inferred that soil samples are capable of achieving very good compaction densities.

Based on the results of triaxial shear tests conducted on the soil samples, it is inferred that the tested soil samples are likely to exhibit very good shear strength characteristics.

Base on the one dimensional consolidation test conducted on the soil samples, it is inferred that the barrow area materials are likely to undergo in general low compressibility depending upon the imposed loads.

The results of laboratory permeability test indicate that the tested soil samples possess semi-pervious to impervious drainage characteristics.

The report on laboratory investigations on soil samples from Barrow area along the canal alignment received from CSMRS, New Delhi is at Appendix – 4.5. The map showing the location of soil samples collected is at Plate-4.12.

4.4.3 Foundation Investigations of Cross Drainage Structures

Foundation investigations at 13 Major CD/CM structures involve drilling the drill holes at each side of CD/CM structures and conducted the Standard Penetration tests (SPT) and In-situ permeability tests alternatively at every 1.50 m interval, besides, collection of undisturbed soil samples in Shelby tubes and SPT samples from the drill holes. A total of 14 boreholes were drilled at 14 different locations at the cross drainage structures sites along the canal alignment.
Drilling work and conducting SPT at Bore-Hole No.6, RD 45.518 km on 06.02.2015

A total 12 rock core samples were collected from the cores recovered from the drilled bore holes and sent to CSMRS, New Delhi for laboratory testing for ascertaining the suitability of foundation soil subjected to the following laboratory tests:

- Mechanical Analysis
- Atterberg limits
- In-situ Density and Moisture Content
- Specific Gravity
- Triaxial Shear
- Direct Shear
- One Dimensional Consolidation

All the above tests were carried out in accordance with the recommendations of the relevant Indian Standard and other standard procedures.
Core Logging by the Officer from GSI, Chennai at Nedungal Anicut on 16.03.2015

The recommended design parameters are given in Table-4.2 and the report on Foundation investigations of cross drainage structures received from CSMRS, New Delhi is at Appendix – 4.6. The map showing the location of drill holes at CD/CM structures is at Plate-4.13.

**Table-4.2**

The Recommended Design Parameters on Foundation Investigations Suggested by CSMRS

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Average</th>
<th>Average Minimum</th>
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<tbody>
<tr>
<td><strong>In-situ Density and Natural Moisture Content</strong></td>
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<td></td>
</tr>
<tr>
<td>In-situ Dry Density (MDD), g/cc</td>
<td>1.714</td>
<td>1.646</td>
</tr>
<tr>
<td>Natural Moisture Content (OMC), %</td>
<td>8.9</td>
<td>7.3</td>
</tr>
<tr>
<td><strong>Specific Gravity</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Specific Gravity</td>
<td>2.68</td>
<td>2.77</td>
</tr>
<tr>
<td><strong>Tri-axial Shear</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total Cohesion (c), kg/cm²</td>
<td>0.22</td>
<td>0.20</td>
</tr>
<tr>
<td>Total angle of shearing resistance (ø)</td>
<td>22.8°</td>
<td>22.0°</td>
</tr>
<tr>
<td>Effective Cohesion (c'), kg/cm²</td>
<td>0.11</td>
<td>0.09</td>
</tr>
<tr>
<td>Effective angle of shearing resistance (ø')</td>
<td>28.6°</td>
<td>27.1°</td>
</tr>
<tr>
<td><strong>Direct Shear</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cohesion (c'), kg/cm²</td>
<td>0.10</td>
<td>0.05</td>
</tr>
<tr>
<td>Angle of Shearing Resistance (ø') (shear box, 6 cm x 6 cm)</td>
<td>32.5°</td>
<td>31.8°</td>
</tr>
</tbody>
</table>
4.5.1  Construction Materials Survey

The requirement of construction materials of coarse aggregates and fine aggregate (Sand) for the project can be met from nearby identified quarry sites. The quality of the materials available in these quarries have been tested by CSMRS, New Delhi and found suitable for usage in Project construction works. Further, the requirement of construction materials like cement and steel etc. can be obtained directly from the companies/ factories located in the vicinity of the Project in Krishnagiri and Vellore districts either by rail head or road head.

4.5.1.1   Rock and Aggregates

The CSMRS team inspected the rock quarry sites which are located in the vicinity of the proposed project during 6th - 9th March, 2014. Of these quarry sites, it was observed that granite processing units and other mining activities are going on at some quarry sites.

Following 3 probable rock quarry sites have been identified by CSMRS team in Krishnagiri district for coarse aggregate.

1. Near Sulamalai village
2. Near Kondappa Nayanapalli village
3. Near Gundalaguttai village

Out of the above rock quarry sites identified, the quarry site at Sulamalai located at a distance of about 6 km from Krishnagiri and about 12 km from canal off-take point and the Gundalaguttai village rock quarry site situated at 8 km from Jegadevi Palayam and about 12 km from the canal alignment have sufficient quantity of rock for use as coarse aggregate for the construction of the link project. A huge quantity of rock for coarse aggregate is also available at the Kondappa Nayanapalli village rock quarry site, which is situated in Bargur mandal, Krishnagiri district and closer to the Gundalaguttai village rock quarry site. Out of the above quarry sites, the CSMRS team has decided to collect the samples only from two rock quarries situated at Sulamalai and Gundalaguttai.
Two rock samples from Sulamali village rock quarry (RQS) and Gundalaguttai village rock quarry (RQG) were collected and the physical tests viz., water absorption, specific gravity, aggregate impact value, aggregate crushing value, soundness loss (5 cycles of Na₂SO₄), potential alkali reactivity aggregates (Mortar Bar Method) and Petrographic examination were conducted on the representative rock samples as per BIS (BIS : 2386-Part-8) for assessing their suitability as per IS : 383-2002 for use in concrete. Based on the results of the tests, the following rock quarries are found suitable for use in wearing as well as non-wearing surfaces:-

1. Sulamali village rock quarry near Anchur in Krishnagiri district (RQS)
2. Gundalaguttai village rock quarry near Bargur Mandal in Krishnagiri district (RQG)

The Alkali silica reactivity test carried out as per ASTM-C-1260 on the samples show an expansion of less than 0.1% at 16 days after casting indicating the innocuous behavior of aggregate samples.

The CSMRS estimated the quantum of construction material from the above two identified quarries as about 190 lakh m³. The physical tests are conducted by CSMRS on coarse aggregate samples collected from Sulamalai village rock quarry site (RQSS) and
Gundalagutta village rock quarry site (SQPR) and the results are given in Annexures 4.9.1 and 4.9.2 respectively. The petrographic reports of the above two rock quarry sites are given in Annexures 4.10.1 and 4.10.2 respectively.

4.5.1.2 Sand

The CSMRS, New Delhi after visiting the project area have finalised the Palar river sand quarry located near Madanur village in Vellore district at a distance of 48 km from the out-fall point of the canal on NH-46 (Bengaluru-Chennai) towards Vellore. The Authorities of Govt. of Tamil Nadu declared this sand quarry site as authentic, barring other sand quarry sites in the vicinity of Project area. It is observed that no sand is available in the streams/rivers existing in the vicinity of the Project area. The Madanur sand quarry site on Palar river is spread over an area of 1000 m x 150m. In spite of sufficient quantity available at this sand quarry, keeping in view the distance of 48 km from out fall point, CSMRS suggested to make use of crushed sand from the identified Sulamalai rock quarry site.

One natural sand sample from the Palar river and one crushed sand sample from Sulamalai village rock quarry in the required fractions have been collected for ascertaining the suitability for use as fine aggregate in concrete for the proposed project.

Collection of Fine Aggregate sample by CSMRS Team at Palar River near Madanur Village (Vellore District) on 07.03.2014
The physical tests viz., specific gravity, grading and fineness module, materials finer than 75 microns IS Sieve, organic impurities, soundness (5 cycles of Na$_2$SO$_4$), potential alkali reactivity aggregates (Mortar Bar Method) and Petrographic examination etc., were conducted on the representative sand samples as per BIS (BIS: 2386-Part-8) for assessing their suitability as per IS: 383-2002 for use in concrete as fine aggregate:

1. Sulamalai village rock quarry near Anchur in Krishnagiri district RQSS (Crushed sand) falling in Grading Zone-II, with fineness Modules (FM) of 2.38.

2. Palar river sand at Madanur village in Vellore district: SQPR (Natural Sand) falling in Grading Zone-II, with fineness Modules (FM) of 2.96.

Alkali silica reactivity test as per ASTMC-1260 on the above two fine aggregate samples was carried out which shows an expansion of less than 0.1% at 16 days after casting, indicating the innocuous behavior of aggregate samples.

The CSMRS, New Delhi estimated the quantity of natural sand available at Palar river sand quarry at Madanur village in Vellore district as, about 30 lakh $M^3$.

The physical test results of CSMRS on the crushed sand sample as Fine Aggregate collected from the above Sulamalai village rock quarry site (RQSS) and the natural sand sample collected from Palar river (SQPR) are given in Annexures - 4.11.1 and 4.11.2 respectively. The petrographic report is given in Annexure - 4.12.

Report on the Construction Materials Survey for Suitability of Rock/River Bed Material Samples for Use as Coarse and Fine Aggregate in Concrete for Ponnaiyar – Palar link Canal Project– July 2014 received from the CSMRS, New Delhi is at Appendix-4.7. The map showing the location of quarry sites in respect of coarse and fine aggregates is at Plate-4.14.

4.5.1.3 Bricks and Tiles

Cement Bricks/hollow concrete bricks/Red Bricks and tiles are available locally in the vicinity of the Project area.

4.5.1.4 Pozzolona

The pozzolona materials are not considered to be used in the construction of the project.
4.5.1.5 Cement

‘Penna Cement Industries’ is located at Hosur, Krishnagiri district. ‘Tamil Nadu Cement Corporation’ is located at Krishnagiri and L&T in Vellore district. A.C.C, India Cements, Chettinad, Dalmia, Ramco Cement dealers are available in the vicinity of the project area.

4.5.1.6 Steel

The steel required for the Project construction can be procured from the plants located in Hosur (Krishnagiri district), Vellore and other nearby districts of Tamil Nadu and Karnataka.

4.5.1.7 Scarce Material

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

4.5.1.8 Any other Material

Apart from the above, there will be many other items such as iron rods / pillars, iron asbestos sheets, CGI sheets, coal tar, wood, paint, coir ropes etc., which are required for construction of temporary rooms/sheds etc. All such items are available locally at Krishnagiri Municipal Town, Tirupattur, Pochampally, Jolarpet and Vaniyambadi towns, that are within the vicinity of project area.

4.6.8 Evaporation

The monthly pan evaporation data observed at Krishnagiri dam site for calculating the evaporation losses of the reservoir is not necessary for the present study, as the simulation studies are not being carried out at Krishnagiri reservoir and the diversion of water is proposed from flood flows only.