HOGENAKKAL WATER SUPPLY AND FLUOROSIS MITIGATION PROJECT
PACKAGE – I

General and particular Specification

(Volume 2)

HOGENAKKAL WATER SUPPLY AND FLUOROSIS MITIGATION PROJECT

PACKAGE I

NAME OF WORK: Operation and Maintenance of Hogenakkal Water Supply & Fluorosis Mitigation Project in Dharmapuri and Krishnagiri District for a period from 01.10.2019 to 31.03.2024 – Package I

DESCRIPTION OF WORK:

Operation and Maintenance of Intake works, Raw Water Pumping Station at Hogenakkal, 160 MLD Water Treatment Plant at Yanaipallam in Bevanur Reserve Forest area, Booster Pumping Station at Kanavai in Bevanur Reserve Forest area, 240 Lakh litre capacity Master Balancing Reservoir at Madam (near Pennagaram), 1500 mm diameter Raw Water and Treated Water Transmission main from Intake at Hogenakkal to Master Balancing Reservoir (MBR) at Madam for providing water supply to Dharmapuri and Krishnagiri Districts through pipeline networks and appurtenances under Packages-II, III, IV & V and SCADA works in Package-I and SCADA interconnectivity work at 74 Locations in Packages-II, III,IV & V and Under Ground Sewerage Scheme (UGSS) to Hogenakkal village with collection System, Pumping station and 0.35 MLD FBBR type STP at Hogenakkal and allied works under Package-I of Hogenakkal Water Supply and Fluorosis Mitigation Project for a period from 01.10.2019 to 31.03.2024.

VOLUME – 2

SPECIFICATIONS

PART A - GENERAL SPECIFICATION

PART B - PARTICULAR SPECIFICATION

VOLUME 2

GENERAL SPECIFICATIONS

CONTENTS LIST

PART A – GENERAL SPECIFICATION

A1.0 DESCRIPTION OF THE WORKS

A1.1 General

The location of the Works is shown on the Drawings.

The principal elements of the Works are:

(a) Intake works and raw water pumping station at Hogenakkal, upstream of river Cauvery a 45 km west of Dharmapuri;
(b) Raw water pipeline is of 6.15 km length to connect the raw water pumping station stated in the above item (a) and the Water Treatment Works;
(c) The water supply handling capacity of the Water Treatment Works is 127.6 Ml/d on completion of this project and at ultimate year of 2036 will be 155.82 Ml/d;
(d) The treated water is pumped by the treated water pumping main of length 1.567 km to the inlet sump of the booster tank and then through the booster pumping station to MADAM Master Balancing Reservoirs for a distance of 3.422 km;
(e) The Supervision, Control And Data Acquisition System (SCADA System) and the communication network for the whole of package I, including the 74 tapping points located at Packages II, III, IV and V;
(f) 0.35 MLD capacity Sewage Treatment Plant and sewer network of Hogenakkal Village; and.
(g) Operation and maintenance the whole of the Works for 54 months.

A1.2 Scope

The Contractor shall maintain and commission the works described in items (a) to (f) above under the Contract. The contractor shall take over the whole works from the present contractor maintaining the works through the Employer to conduct 54 months of operation and maintenance and the whole Works will be under the possession of the Contractor. Therefore, the obligation of the Contractor shall have no difference to "the Contractor" as mentioned in the Conditions of Contract. The Contractor shall be responsible for all insurances vide clause 55 of General conditions of Contract, where the cost of providing that shall be reimbursed on production of payment vouchers and original policies. After the Contractor has satisfactorily completed the 54 months operation and maintenance works the Employer will take-over the whole Works.

The Works contain a 3 months Defects Notification Period. During the Defects Notification Period, the Contractor has to rectify all defects and complete all minor outstanding works that are agreed by the Contractor and the Engineer after the Test on Completion. The scope of the tests to be done in the aforesaid Test on Completion is detailed in Clause A10 and A11 of this General Specification. Prior to handover the whole Works to the Employer, the Contractor has to conduct and satisfactorily complete the Test on Completion. The scope of the tests to be done in this Test on Completion is detailed in Clause A15 of this General Specification.

A1.3 Design

The Contractor shall take design responsibility for the Works, notwithstanding the level of detail provided in any of the drawings or other items comprising the Employer's Requirements.

A1.4 Source

The raw water supply shall be derived from River Cauvery, at a distance of 45km west of Dharmapuri. The raw water shall be conveyed to the Water Treatment Works via pipeline of length 6.15 km.

A1.5 Raw water intake, pumping station and pipeline

(a) Raw water intake/pumping station structure

A combined intake and pumping station structure provided including:

(a) Trash screens,
(b) Penstocks,
(c) Stop logs,
(d) Pump house,
(e) Pump sets and electrical switchgear,
(f) Pipe work and valves,
(g) Surge suppression devices,
(h) Overhead travelling crane,
(i) Ventilation system.
(j) Transformer sub station

(b) Raw water main

A coated mild steel raw water main provided to deliver raw water from the raw water pumping station the treatment works; the length of the raw water main is about 6.15km.

A1.6 Capacity

The water supply handling capacity of the water treatment works is 127.6 Ml/d on the intermediate year 2023 which will increase to 155.82 Ml/d in the ultimate year of 2036.

The losses from the works due to desludging of clarifiers shall be less than 2.5% of the input. The input shall therefore be the sum of output and the losses due to clarifier desludging. The works shall therefore, be designed to a handle normal input of 131 Ml/d on the intermediate year 2023 which will increase to 164 Ml/d by the ultimate year 2036.

Used filter wash water shall be recycled to the works inlet at a rate less than 5% of the input. Therefore the normal throughput of the works averaged over 24 hours, which includes the return of the used wash water at a maximum rate of 5% of the inflow shall be not greater than 138 Ml/d upon intermediate year 2023, which will increase to not greater than 172.2 Ml/d by the year 2036.

The works shall have a hydraulic capacity equal to 172.2 Ml/d. The hydraulic capacity of the primary process units shall be such as to allow works output to be maintained with units out of service for maintenance.

Variations in throughput shall be limited to diurnal and seasonal variations in demand. The minimum throughput of the Works is expected to be 50% of maximum throughput.

A1.7 Raw water quality

The raw water supply for the treatment works will be derived from the River Cauvery at Hogenakkal. Preliminary raw water quality data is entered in Appendix B1 at Part B1 – Capacity of Water Treatment Works of the Particular Specification. These raw water quality data are meant to be used as a preliminary reference by the Contractor only and the Contractor shall obtain their own raw water quality data.

A1.8 Treated water quality

When operated in accordance with the Contract instruction at flows up to the required maximum throughput, the water treatment works treating raw water from the river Cauvery shall be capable of producing a reliable and continuous supply of potable water free of waterborne pathogenic organisms. The water quality from the works sampled after treatment at the treated water reservoir outlet or as otherwise stated shall comply with the following standards:

(a) 100% of the sample results shall have:

Turbidity	Not exceeding 1.0 NTU**
Taste and odour	Unobjectionable
Colour	Not exceeding 5° Hazen
Aluminium	Not exceeding 0.2 mg/l as Al
Iron	Not exceeding 0.3 mg/l as Fe
Manganese	Not exceeding 0.1 mg/l as Mn
Free chlorine	Not less than 0.5 mg/l*
pH	7.0 to 8.5
Total coliform bacteria	Nil in any 100 ml sample

*At the contact tank outlet
**Before final pH correction

(b) 95% of the sample result shall have:

Aluminium	Not exceeding 0.03 mg/l as Al
Iron	Not exceeding 0.1 mg/l as Fe
Manganese	Not exceeding 0.05 mg/l as Mn
pH	pH_s + 0.3; pH_s being the saturation pH value.

A1.9 Performance Guarantee

Performance guarantees are specified in technical schedules for the following:

- Treated water output;
- Clarified, filtered and treated water quality;
- Guarantee of filter run time;
- Clarifier sludge discharges;
- Wash water consumption;
- Used wash water return;
- Raw water pump sets;
- Treated water pump sets;
- Booster pump sets;
- Plant control system;
- Chemical consumption;
- Electrical power consumption;
- Overall plant performance including plant and equipment warranty.

A1.10 Treatment process

The sequence of treatment processes proposed for the treatment works is summarised below. Where aluminium sulphate is mentioned as a coagulant the Contractor may use polyaluminium chloride (PAC) instead at his sole responsibility subject to the approval of the Engineer.

Location / Process	Function
Works Inlet Parshall flume	Flow measurement
Hydraulic mixing with the addition of aluminium sulphate. Hydraulic mixing with the intermittent addition of chlorine.	Coagulation. Biological control
Flocculation Hydraulic and contact flocculation.	Agglomeration of coagulated particles.
Clarifiers Sedimentation	Removal of flocculated particulate matter.
Rapid gravity filtration Filtration through sand media.	Removal of flocculated particulate matter carried over from clarifiers.
Contact tank Mechanical mixing with the addition of chlorine. Retention in contact tank to maintain a pre-set residual for an effective contact time.	Chlorination. Disinfection.
Treated water storage Hydraulic mixing with the addition of lime. Storage in treated water reservoir.	Final pH correction to give a positive Langelier Index Balancing treated water inflow to treated water pumped outflow to master balancing reservoir.
Used washwater recovery Sedimentation of used filter washwater.	Separation of supernatant for return to inlet works from sludge discharged for further treatment.
Sludge thickeners Thickening of clarifier sludge and sludge from used filter wash water.	Reduction of volume of sludge for further treatment
Sludge drying beds Removal of excess water.	Increase in dried solids concentration to facilitate handling for removal from site.

A1.11 Control and operation of the Works

Overall control and monitoring of the raw water pumping station, the water treatment works, the treated water pumping station, the booster pumping station, the master balancing reservoir at MADAM and monitoring the works at Packages II to V shall be done from the central control room in the filter building. Operation of plant and treatment processes shall normally be from local control centers in various buildings associated with the process units and chemical and chlorine buildings.

Instruments shall be used to monitor critical plant states and alarm plant faults, failures and abnormal operations on local panels. Information essential to the overall running of the treatment works shall be presented in the central control room in the filter building.

The treatment works shall be arranged for manual operation with the following exceptions:

(a) Automatic desludging of clarifiers;

(b) Automatic filter flow control;

(c) Automatic filter washing following manual initiation;

(d) Automatic changeover of chlorine drums;

(e) Automatic operation of chlorine building ventilation system;

(f) Automatic operation of, water supply pumps, used washwater transfer pumps and thickener feed pumps.

(g) Automatic desludging of sludge thickeners;

(h) Automatic operation of some drainage pumps as specified.

All automatic operations shall have manual override facilities as specified.

A1.12 Ability of processes to meet variations

The treatment processes are required to deal effectively and efficiently with the variations in raw water quality and in the throughput which are likely to occur, due both to seasonal changes in the water quality and consumer demands

A1.13 Hydraulics

The hydraulic loss through the Treatment Works for the maximum flow from the normal TWL at the inlet to the Parshall flume to the TWL in the treated water reservoir shall not exceed 5.0 m.

A1.14 Unit processes

(a) Mixing

The downstream section of the inlet flume shall provide for the dosing of aluminium sulphate or polyaluminium chloride and chlorine at the point of maximum turbulence.

Aluminium sulphate shall be dosed at M1 by a perforated pipe distributor located above the water surface just upstream of the hydraulic jump. Chlorine shall be dosed at M1 by a submerged pipe distributor at the inlet to the flume.

Dosing of chlorine at M2A/B shall be by an injection pipe terminating close below the eye of the impellor.

Dosing of lime at M3A/B shall be by perforated distributor channel.

(b) Clarification

Clarifiers are of the sludge blanket type.

Each clarifier shall treat the same proportion of the throughput and shall be hydraulically capable of taking the same higher rate of flow to enable the throughput to be maintained when one clarifier is out of service for maintenance.

In Sludge bracket clarifiers, the maximum surface loading rate or rise rate computed in the clear water section of the clarifier at a depth of approximately 1.25 m below the water surface shall not exceed 2 $m^3/h.m^2$ when all tanks are operating at the rated throughput.

The depth of 1.25 m is the straight side depth within the clear water section which is below any inlet and draw-off channels or pipes and above any sludge extraction devices to give an uninterrupted horizontal plane for measurement of area for calculation of the rising velocity. Net area equivalent to a surface loading rate or rise rate is of 2 $m^3/h.m^2$.

There shall be a delay time of about five minutes between the mixing of coagulant and the entry of the dosed water to the clarifier to allow initial flocculation to occur. The residence time in the inlet channel before the entrance to the first clarifier included in the delay time.

When the raw water turbidity exceeds 25 NTU, modified starch (starch with NaOH) has to be dosed. The dosage has to be decided according to jar test results.

(c) Flocculation

Flocculation shall be hydraulically induced in the clarifier and completed within the sludge blanket. The Contractor shall maintain all devices, provided for inducing flocculation including all pipe work, distributors, injectors and baffle systems.

(d) Filtration

Filters are of the constant rate rapid gravity sand filters designed for combined air-water washing and arranged to operate on the influent flow division constant level principle.

The treatment works provided with ten filters. Each filter designed and equipped for a maximum filtration rate of 7.5 m/h at the throughput corresponding to the nominal capacity of the treatment works with two filters out of service, one for washing and one for maintenance.

The filters are of the duplex type comprising two equal size beds separated by a central used wash water collection channel and operating at constant rate on the principle of influent flow division and constant water level. The under drain system comprises of nozzles set in a plenum concrete floor.

The filters arranged in two banks located on either side of a covered central gallery containing a walkway and filter wash consoles at high level and filter pipe gallery and filtered water channel complete with walkway at low level.

(e) Contact tank and treated water reservoir

The contact tank is designed to provide a minimum effective contact time t of 30 minutes, between the time of entry into the tank and the time of discharge of disinfected water from the tank into the treated water reservoir, at the rated throughput.

The effective contact time is defined as the detention time at which 90% of the water passing through the contact tank is retained within the tank. The `C.t' value (= free chlorine residual concentration C mg/l at the end of the effective contact time t x t minutes) shall not be less than 15 mg.min/l.

The tank is covered and constructed with a central division wall, so that either compartment may be drained down for maintenance, the other compartment remaining operational. The hydraulic design of the contact tank is to allow the full throughput to pass through one compartment.

Each compartment of the contact tank is provided with valved drainage facilities for completely draining down a compartment, and access manholes and ventilators raised to a level above the free water surface.

Each compartment is provided with an overflow.

The freeboard of the contact tank is 500mm and 150mm during normal operation and during overflow at the maximum rate respectively.

Baffle walls of `around the end' type provided in each compartment of the contact tank to minimise short-circuiting and to ensure maximum effective contact time.

Chlorine solution shall be mixed into the filtered water at the inlet to the contact tank by mechanical means. The inlet jet shall be baffled if the inlet pipe discharges directly into the contact section of the tank.

Free fall weirs provided on the outlet of the contact tank, or at the inlet to the treated water reservoir where this is adjacent to the contact tank to ensure the effective contact time is maintained under all draw-down conditions in the treated water reservoir and to provide for mixing of lime at the exit of the contact tank if this is required.

The contact tank is provided with all process pipe work, inlet isolating valves, ventilators and washouts required, access arrangements, ladders and all necessary fixtures and fittings.

The treated water reservoir is covered. The effective storage capacity of the reservoir is sized to provide 1.0 hours storage at a flow of 160.7 Ml/d. The reservoir is provided with a division wall to provide two equal capacity compartments, so that a compartment may be drained down for maintenance, whilst the other compartment remaining operational. Each compartment of the reservoir is designed to ensure through circulation of water in the reservoir.

The freeboard of the treated water reservoir is 500mm and 150mm during normal operation and during overflow at the maximum rate respectively.

The floor of the reservoir is sloped for drainage at a minimum fall of 1 in 200.

Each compartment is provided with inlet and outlet isolating valves, drainage and overflow to the site drainage system and water level transmitters. Each compartment of the treated water reservoir is provided with an overflow .

A1.15 Electricity distribution system

(a) General

The supplies derived from the Tamil Nadu Electricity Board (TNEB) supply via the dual dedicated 33kV or 11kV feeders. The site provided with a 33 or 11kV works sub-station which shall house the 33kV or 11kV switchboards provided. The incoming supply voltage depends on the demand capacity.

The 33kV or 11kV supplies to the site via overhead cables. Outdoor disconnectors provided for each 33kV or 11kV overhead line near the works sub-station. The 33kV or 11kV switchboard provided fed from the 33kV or 11kV disconnectors by underground cables. The scope of the TNEB terminate at the 33kV or 11kV outdoor disconnectors.

Electricity supplies to the process plant and site infra-structure are as detailed within this Specification.

(b) High voltage Switchgear

High voltage switchgear equipped with vacuum circuit breakers provided as detailed herein.

(c) Transformers

Transformers of the oil filled and naturally air-cooled type with primary and secondary cable boxes as detailed in the Standard Specifications. Transformers of rating below 630kVA located indoor dry-type encapsulated winding cast resin transformers.

(d) Low Voltage switchgear

Switchboards and motor control centres are multi-compartment type incorporating circuit-breaker or switch-disconnector incomer units, circuit-breaker or fuse-switch type outgoing units and motor starters as appropriate.

(e) Power factor

The power factor shall be corrected at each load centre by means of individual or automatically controlled multistage capacitor banks.

(f) Cables

33/11/6.6/3.3kV and 415V cables of the cross-linked polyethylene insulated, single wire armoured and polyvinyl chloride over-sheathed type of appropriate voltage grade. Conductors are of copper.

(g) Earthing

The 433V transformer winding neutral solidly earthed. The 7.2kV and 3.6kV main transformer winding neutral earthed through resistance. The selected value of resistance should restrict the earth fault current below the full load current of the largest drive/motor in the system. Time rating of neutral earthing resistor shall be 10sec. Necessary provisions in the protection systems made to avoid adverse impact on sensitivity of protection relays. The Works high and low voltage earthing systems interconnected.

A1.16 Power failure

On simultaneous mains power failure on both the independent dedicated feeders, the Works shall shut-down to a safe-mode. On failure of one supply, the second supply shall automatically supply the complete Works.

A1.17 Instrumentation and control

The monitoring and control system based on programmable logic controller (PLC) at field level and distributed control system (DCS) at the Control Room level, which shall allow operators to monitor the process remotely from the Central Control Room at the filter building of the Water Treatment Works . Control of processes shall be from the individual field-mounted Local Control Panels (LCPs), that shall be installed at the raw water pumping station, the various plants at Water Treatment Works, the treated water pumping station, the booster pumping station, the master balancing reservoir at MADAM and those required signal acquisition and control site at Packages II to V. The PLCs and the distributed control system of the same manufacture, and shall report through a data communication network to the Central Control Rooms.

A2.0 GENERAL REQUIREMENTS

A2.1 Scope

This part of the specification covers certain duties of the contractor in connection with the administration of the contract; it includes also some of the general responsibilities of the contractor in carrying out the works which may become necessary to execute additionally under this contract which are in addition to or in furtherance of the requirements of the Conditions of the Contract for the works. These specifications which are relevant to operation and maintenance are also applicable.

The requirements of any clauses of this specification herein or compliance with the requirements of the Engineer shall not limit any of the Contractor's obligations or liabilities under the contract.

A2.2 Clause references

Except where stated to the contrary, references herein to Clauses are reference to Clauses numbered in the Specification.

A2.3 Issue of documents

The Contractor will be supplied with one copy of the Contact Documents for his own use.

A2.4 Materials: general requirements and manufacturer's experience

The term materials shall mean all materials, goods and articles of every kind whether raw, processed or manufactured and equipment and plant of every kind to be supplied by the Contractor for incorporation in the maintenance of Works.

Except as may be otherwise specified for particular parts of the Works in Volume One of the Specification, the provision of the Standard Specifications in Volume Two and Three shall apply to materials general requirements for any part of the Works.

All materials shall be new and of the kinds and qualities described in the Contract and shall be at least equal to approved samples.

The Contractor shall as far as possible use materials available in India for the maintenance of the Works, subject to compliance with the Specification.

Materials shall be transported, handled and stored so as to prevent deterioration, damage or contamination.

The Contractor shall procure pipes from reputed manufacturers with at least 3 years of manufacturing experience of the equipment and the respective ISI Certification. For pumps, mechanical and electrical equipments, 10 years manufacturing experience is required with the respective ISI Certificate. For instruments and SCADA system (conforming to B7 of the Particular Specification and Part G, H of the Standard Specification), the manufacturing experience of the manufacturers, quantity of components sold in the past years, working experience of the programmers etc have to conform to the requirements entered in the Instruction to Tenderers Clause IT31.2. Experience of collaborators, if any, for satisfying these criteria will be acceptable subject to documentary evidence.

A2.5 Substances and products

Substances and products used in the Works which may be applied to or introduced into water which is to be supplied for drinking, washing or cooking shall not contain any matter which could impart taste, odour, colour or toxicity to the water or otherwise be objectionable on health grounds. Only the substances and products which have been approved by a national or international regulatory body shall be used.

After award of Contract, from time to time the Contractor shall submit for the approval of the Engineer a schedule of substances and products he proposes to use in the Maintenance Works giving the following information as applicable:

- Item of plant;
- Substance/product in contact with water;

- Manufacturer of plant/substance/product;
- Point of use in the Works;
- Name of the regulatory body, which has approved the substance/product;
- Date of approval (for use on water quality and on health grounds);
- Approval (with respect to water quality and health) reference number.

For all other products and substances to be used in the Works in such situations, the Contractor shall at his own expense obtain the necessary approval and follow the procedure set above and obtain the approval of the Engineer before use.

A2.6 Plant to be safe in use

The Contractor shall ensure that the Plant is safe in use, and that any safety regulations imposed by law or by any authorised body empowered to make such regulations are complied with.

A2.7 Design life

"Design life" means the period for which an item is designed to operate at full design output without major overhaul involving extensive dismantling, serious corrosion or necessity for substantial renewal of any anti corrosion system, reduction of efficiency in excess of 5%, or replacement of major components essential to the functioning of the item etc except for consumables and for any limited-life components explicitly agreed at the time of the Contract award.

Minimum design live are as follows:-

(a) Roads, pipelines including associated pipework and valves and other buried or built-in pipework (other than PVC), structures of concrete, brick or blockwork - 60 years

(b) PVC pipelines, structures of steel (including tanks), exposed Pipe work and valves - 30 years

(c) Machinery including pumps, valve actuators, generating sets, transformers, switchgear, cabling, air blowers, compressors, process plant, electrical installations, building services, etc - 20 years

(d) Instrumentation, control and automation telemetry equipment - 10 years

(e) Computer systems - 5 years

All items and systems are designed to allow replacement or major overhaul at the end of the design life without requiring major work or dismantling of other items and systems which interrupt operation of independent items and systems.

A2.8 Interfaces with other contracts

A2.8.1 General

This Contract is the “Operation and Maintenance of Hogenakkal Water Supply and Fluorosis Mitigation Project, Package I – Intake Works, Raw Water Pumping Station, Treatment Plant, Treated Water Pumping Station, Booster Pumping Station, Pumping Mains, MADAM Master Balancing Reservoirs and allied works and 0.35MLD capacity STP of FBBR technology” and the Employer will be procuring the remaining works under Packages II to V. These packages are to operate and maintain:

(a) Package II - Treated water trunk mains from Master Balancing Reservoir at MADAM to Uthangarai Union, branch pipelines, union reservoirs, panchayat reservoirs, sumps, overhead tanks, chlorination stations, booster pumping stations, instrumentation, electrical and mechanical works for Pennagaram, Nallampalli, Dharmarpuri, Mathur & Uthangarai Unions;

(b) Package III - Treated water trunk mains branching to Harur Union, branch pipelines, union reservoirs, panchayat reservoirs, sumps, overhead tanks, chlorination stations, booster pumping stations, instrumentation, electrical and mechanical works for Morappur, Mallapuram, Pappireddipati and Harur Unions;

(c) Package IV –Treated water trunk mains from Booster Pumping Station near Palacode to Hosur, branch pipelines, union reservoirs, panchayat reservoirs, sumps, overhead tanks, chlorination stations, booster pumping stations, instrumentation, electrical and mechanical works;

(d) Package V - Treated Water Trunk Mains from Main Balancing Reservoir at MADAM to Bargur Union, Branch Pipelines, Union Reservoirs, Panchayat Reservoirs, Sumps, Overhead Tanks, Chlorination Stations, Booster Pumping Stations, Instrumentation, Electrical and Mechanical Works for Pennagaram, Palacode, Karimangalam, Kaveripattinam, Krishnagiri and Bargur Unions.

The Works under this Contract will interface directly with all these Packages. The nature of these interfaces will be, as a minimum but not limited to, the scope entered in the table below:

Interface with	**Nature of Interface**
Packages II, III, IV and V	<u>SCADA System</u> The Contractor has to maintain the control and monitoring system (the SCADA System) at the works of Packages II to V. The Contractor shall acquire/send all the signals, specified elsewhere in the Specification, that are necessary for the monitoring of the whole Project by the SCADA System. The contractors at Packages II to V will maintain the necessary cable ducts and all the signals at their sites that are required by the SCADA system to the Contractor. Also, these contractors will make provision at their control devices to accept the signals from the SCADA System to activate the necessary control action at their sites. The contractors of Packages II to V will maintain all the housing for Local Control Panels at their sites and provide the power supply and the building services facilities therein. The Contractor shall coordinate with the contractors of Packages II to V for all interface works that are to incur. The contractors of Packages II to V will allow the Contractor to access their sites to carry out the necessary work. <u>Instrumentation</u> At the tapping points from the trunk mains at the sites of all other packages of the Project, the Contractor has maintain the electromagnetic flow meters and the pressure transmitters at these branching pipelines sites. At the union reservoirs sites of all other packages of the Project, the Contractor has to maintain the ultrasonic level transmitters.

Package II	Pennagaram Union booster pumping station The contractor of Package II of this project will need to access the Master Balancing Reservoir at MADAM to maintain Pennagaram Union booster pumping station. The signals for the SCADA System acquiring from/sending to this pumping station will be connected to the Local Control Panel at the Telemetry and Power House at the Master Balancing Reservoir at MADAM. The Package II contractor will be responsible to maintain dual electricity feeders from Tamil Nadu Electricity Board to supply a 400V Switchboard of the Pennagaram Union booster pumping station. From this switchboard, feeder panel compartments provided for the Contractor to supply the "Power and Telemetry House" at MADAM. Treated Water Trunk Main connection The contractor of Package II has to maintain connection of their treated water trunk mains to the mild steel treated water discharge pipe from the Master Balancing Reservoir at MADAM at an interface point abo compound wall of the site.

Interface with	**Nature of Interface**
Package V	Treated Water Trunk Main connection The contractor of Package V has to maintain connection of their treated water trunk mains to the mild steel treated water discharge pipe from the Master Balancing Reservoir at MADAM, at an interface point about 1m outside the compound wall of the site.

A2.8.2 Interface with Packages II and V contracts

Interface with Package II and V for connections of their trunk mains to the Master Balancing Reservoir at MADAM

The Engineer will arrange meetings among himself, the Contractor and the contractors of Packages II and V to agree a programme for the maintenance of connection of the treated water trunk mains of Package II and V to the treated water mild steel pipes of Package I at the site of the Master Balancing Reservoir at MADAM. The connection interface point will be about 1m outside the boundary wall of the Master Balancing Reservoir at Madam.

The Contractor will maintain the two mild steel discharge pipes (one of Package II and the other for Package V) from the Master Balancing Reservoir. The size of the pipe for Package II contractor is 1m whilst that for Package V is 1.5m.

Interface with Package II at Pennagaram Union booster pumping station

The Engineer will arrange meetings among himself, the Contractor and the contractor of Package II to agree a programme for the maintenance of the Pennagaram Union booster pumping station by Package II, within the site of the Master Balancing Reservoir at MADAM. At the end of the inlet pipes connecting to the two sumps of the Master Balancing Reservoir, a tee pipe with flange end provided. The contractor of Package II shall maintain the suction pipe of the Pennagaram Union booster pumping station connected to this flange end.

A2.8.3 Interface with Packages II, III, VI and V contracts for SCADA System

Instrumentation

The Engineer will arrange meetings among himself, the Contractor and the contractors of Packages II, III, IV and V to agree a programme for the instrumentation, data acquisition and control system (SCADA System), and communication network to be maintained by the Contractor at the sites of Packages II to V.

The electromagnetic flowmeters, the pressure transmitters at the tapping point from the trunk mains and the ultrasonic level sensors/transmitters at the union reservoirs, at the sites of Packages II to V, shall be maintained by the Contractor.

SCADA and communication network

The Contractor will be allowed by the contractors of Packages II to to access their sites to maintain the Local Control Panels (LCP) for the acquisition of signals and to activate the control command from/to the instruments, electrical and mechanical equipment at the sites of Packages II to V.

The signals will be transmitted from these LCPs back to the Central Control Room (CCR) at the Water Treatment Plant via redundant communication media, GSM mobile lines and satellite supplying from one service provider.

The Contractor has to act in conjunction with the contractors of Packages II to V to:

(a) Verification that all the signals from the primary devices (the Contractor to be responsible for the instruments maintained by them at the sites of Packages II to V) shall be able to be transmitted to the SCADA system and be able to be displayed at the Human Machine Interface (HMI) display pages at the LCPs, the Central Control Room (CCR) at the Water Treatment Plant;

Cable ducts, drawpits and cable laying from local devices to the LCPs

The contractors of Packages II to V will maintain all the cable ducts, draw pits for the laying of cables from each of the devices, including instruments, electrical and mechanical equipment, to the LCPs at each site of these Packages.

For those instruments that are maintained by the Contractor, he shall be responsible to maintain the cables to the LCPs and the cable ducts, draw pits and the like that will be maintained by the contractors of Packages II to V. For other devices that will be provided by the contractors of Packages II to V, these contractors shall be responsible to maintain the cables.

A3.0 STANDARDS

A3.1 Reference standards

The Works shall be carried out in accordance with the relevant quality standards, test procedures or codes of practice, collectively referred to as Reference Standards, listed in the relevant Part of the Specification. In many places, British Standards or other International Standards are stipulated. During the submission of that works for the approval of the Engineer, the Contractor shall also provide one copy of such Standard that the works is conforming to for the use of the Engineer. The Contractor shall familiarise himself fully with the requirements of such standards. Applicable Indian Standards may be offered. If no standard is indicated then the relevant Indian or British Standard or, in the absence of such standard, internationally recognised standard shall apply.

British Standards are published by the British Standards Institution, 389 Chiswick High Road, London W44AL, United Kingdom, www.bsi-global.com.

Other national standards may be considered provided that they are, in the opinion of the Engineer, no less exacting than the corresponding standard quoted in the Specification. The Contractor shall demonstrate to the Engineer that the alternative standard is suitable and equivalent to the specified standard, and shall provide proof of previous successful use. The Engineer will decide whether or not the use of such alternative will be permitted as a Reference Standard. When an alternative standard is proposed, the Contractor shall supply the Engineer with a copy of that alternative standard that the equipment is conforming to and also a copy of the standard as required to be complied by the equipment in the Specification, as part of that equipment submission for the Engineer's approval.

A3.2 Applicable issue

The applicable issue of any Reference Standard shall, unless otherwise stated in the Specification, be the issue current at the date three months preceding the date for submission of the tenders for the Contract.

A3.3 Abbreviations for Reference Standards

The following abbreviations where used in the Specification refer to standards, codes of practice and other publications published by the organisations listed:

ACI	American Concrete Institute
ANSI	American National Standards Institute
API	American Petroleum Institute
ASA	American Standards Association
ASCE	American Society of Civil Engineers
ASME	American Society of Mechanical Engineers
ASTM	American Society for Testing and Materials
AWS	American Welding Society
AWWA	American Water Works Association
BS	British Standards Institution
CP	British Standards Institution (Code of Practice)
DIN	German Industrial Standards
HMSO	Her Majesty's Stationery Office
BIS	Bureau of Indian Standards
ISO	International Organisation for Standardisation
JIS	Japanese Industrial Standards
SI	International System of Units
SIS	Swedish Standards Commission
WHO	World Health Organisation

A3.4 Reference Standards for Part A

Reference Standards are referred to in the text of the Specification in abbreviated form (e.g. BS 8l2). The version of the reference standard at that date three weeks prior to the tender closing date shall be used for the Contract. The full titles of some which are relevant to this Part are given below for convenience:

Standard	Subject
ISO 2l6	Writing paper and certain classes of printed matter-trimmed sizes - A and B series.
BS 4884	Technical manuals. Specification for presentation of essential information
BS 1133	Packaging code. Introduction to packaging
BS	EN ISO 5198 Centrifugal, mixed flow and axial pumps. Code for hydraulic performance tests. Precision class
BS EN ISO 9906	Roto dynamic pumps. Hydraulic performance acceptance tests. Grades 1 and 2
BS EN 1171	Industrial valves. Cast iron gate valves
BS 5163	Specification for predominantly key-operated cast iron gate valves for waterworks purposes
BS 6755	Testing of valves. Specification for fire type-testing requirements BS EN 593 Industrial valves. Metallic butterfly valves
BS 1042	Measurement of fluid flow in closed conduits. Pressure differential devices. Guide to the use of devices specified in Sections 1.1 and 1.2
BS1041	Measurement of fluid flow in closed conduits. Pressure differential devices. Guide to the use of devices specified in Sections 1.1 and 1.2
BS EN 12334	Industrial valves. Cast iron check valves
BS 5158	Specification for cast iron plug valves
BS EN 13397	Industrial valves. Diaphragm valves made of metallic materials
BS 5159	Specification for cast iron and carbon steel ball valves for general purposes
BS EN 13789	Industrial valves. Cast iron globe valves
BS 7775	Specification for penstocks
BS 466	Specification for power driven overhead travelling cranes, semi- goliath and goliath cranes for general use
BS 6754	Specifications and testing of compressed air dryers
BS 6759	Safety valves. Specification for safety valves for steam and hot water
BS1123	Safety valves, gauges and fusible plugs for compressed air or inert gas installations. Code of practice for installation
BS 3274	Specification for tubular heat exchangers for general purposes
BS 5168	Glossary of rheological terms
BS 1571	Specification for testing of positive displacement compressors and exhausters. Methods for simplified acceptance testing for air compressors and exhausters
BS 5500	Specification for unfired fusion welded pressure vessels
BS 4871	Specification for approval testing of welders working to approved welding procedures. Arc welding of tube to tube-plate joints in metallic materials
BS 4999 Part 143	General requirements for rotating electrical machines. Specification for tests
BS 171	Specification for power transformers
BS 148	Specification for unused and reclaimed mineral insulating oils for transformers and switchgear

4.0 CONTRACT ADMINISTRATION

A4.1 Contractor's organisation and administration of the Contract

For the purposes of this Contract the term 'Plant Manager' shall be used instead of the term 'Contractor's Representative.'

The Contractor shall submit to the Engineer a diagram showing the structure of the organisation for his administration of the Contract. This structure shall include a project managing organisation which may be part of the Contractor's organisation, or an outside body which shall be named by the Contractor.

The Plant Manager and an assistant capable of deputising for the Plant Manager, both belonging to the Project Managing organisation shall be appointed. The duties of the Plant Manager shall include responsibility for programming, progressing and co-ordinating:

- operation and maintenance of the plant for not less than 54 months
- Maintenance of all civil works;
- Updation of Operation and Maintenance Manuals.

The Plant Manager shall also be responsible for ensuring that all codes, standards and any other technical requirements of the Contract are complied with by all subcontractors.

All correspondence and communication between the Engineer and the Contractor shall be directed through the Plant Manager.

The structure diagram shall state the names of the firms to be employed to carry out the maintenance of following portions of the Works:-

- Process plant;
- Mechanical plant;
- Electrical plant;
- Instrumentation, control and automation systems;
- Civil works.

The specialist firms and the specific engineers to perform the maintenance of the process plant, mechanical plant, electrical plant, the civil works and the instrumentation, control and automation systems shall possess of relevant experience in his specialist field for projects similar to the degree and nature of work as this Contract. The Contractor has to submit relevant details of this specialist firms and the specific engineers to the Engineer for approval prior to the commencement of work.

Designs, drawings and documents that are required to be submitted to the Engineer for approval shall be considered as bona fide by the Engineer only if they have been submitted by the Plant Manager. Prior to submission to the Engineer, the Plant Manager shall have reviewed the design, drawing or document. Each item submitted shall be stamped "checked by Plant Manager", dated, and shall be clearly identified as to its final location and function.

A4.2 Progress reports and meetings

Each month the Contractor shall submit to the Engineer progress report showing the stage reached in the maintenance of the Works.

The report shall show all activities required by the Contract such operation and maintenance of all items of plant.

The Engineer/Employer may call meetings in his office, at the Contractor's office, or at the Site, to review the progress of the Contract. The Contractor's Plant Manager shall attend such meetings.

In addition to the above, the Employer shall convene periodical meetings with Contractor/Engineer for reviewing progress and for necessary co-ordination among Contractor(s) for smooth construction implementation and maintain the time schedule.

A4.3 Method statements

The Contractor shall prepare and submit to the Engineer detailed method statements for aspects of his work which may affect the operations of the Employer, the activities of others outside the site, the work of other contractors on the Site or other potentially hazardous activities. The method statements shall be submitted for review by the Engineer at least 21 days before the work covered by the method statement is programmed to start. Aspects of work for which method statements are required include:

- work which may affect access to the Works;
- work which may have an effect on the operation of any existing works;
- work which involves any other aspect of the Contractor's operations, as may be requested by the Engineer;
- any work which might in the opinion of the Engineer be potentially hazardous;
- any work pertaining to the operation and maintenance for all equipments to supply under the Contract, which in the opinion of the Engineer reckon there is a necessity to have a detail method statement.

Each method statement shall comprise a step-by-step schedule of specific operations and activities with descriptions, dates, times and durations for each step. It shall highlight specific points in the programme, and include contingency plans for emergency reinstatement of plant including "point of no return" and "earliest start time" of modified or new plant. The statement shall clearly state who and what organisation will carry out work and precisely when and what support or provisions are to be made by others outside the Contract. The statement shall include all supportive detail to enable a clear understanding of the method and significance of each step of the operation. The statement shall provide details of the Health and Safety measures to be taken in carrying out the proposed activities.

No work which affects the operation of any existing works, or the work of other contractors, or work which may be deemed by the Engineer as presenting a significant hazard shall be carried out until the method statement has been agreed by the Engineer. Those equipment installation works that the Engineer needs to know the detail method statement, shall not be carried out until the method statement has been approved.

The Contractor shall revise the method statement as necessary if the Engineer requests it and the Contractor agrees with the Engineer’s comments. If the Contractor disagrees and chooses not to amend a method statement he shall write to the Engineer clearly stating his reasons.

No agreement by the Engineer of the Contractor’s method statement shall relieve the Contractor of his obligation to do the Works safely and in accordance with the Specification.

A4.4 Subcontract orders

Where the Engineer has approved the supply of Plant or execution of work by manufacturers or subcontractors proposed by the Contractor, such manufacturers or subcontractors shall not be changed without the prior approval in writing of the Engineer. A copy of every sub-order shall be sent to the Engineer at the time the order is placed, each clearly marked with the title of the project and the Contract number.

A4.5 Delivery and storage of plant

A4.5.1 Packaging and marking

Upon the successful completion of the prescribed off-Site testing and inspection and prior to despatch from the place of manufacture, all items of plant shall be thoroughly protected against corrosion and incidental damage from any cause. Packaging shall be carried out to BS 1133.

Items intended to be painted shall receive the treatment specified and all unpainted parts liable to corrosion (with the exception of the electrical equipment) shall be thoroughly coated with high melting point grease or other approved protective substance, which is easily removable.

Electrical equipment shall be suitably protected against corrosion and incidental damage to the satisfaction of the Engineer. Temporary leads shall be fitted to electrical equipment to enable anti-condensation heaters to be energised when the plant is in store. The heaters shall be energised by the Contractor when conditions require.

Items shall be packed to withstand rough handling in transit. Packages shall be suitable for exposure to the atmosphere and storage in the open. The Contractor shall be responsible for items reaching the destination undamaged. The Contractor shall provide all necessary packing, cases and crates, properly strengthened. Packages containing dangerous or breakable goods shall be packed and marked in accordance with any statutory rules and orders applicable. Crates and packages shall be correctly and adequately marked as follows:-

- Employer's name;
- Title of scheme;
- Title of contract;
- Contractor's name;
- Designation site and item number matching approved schedules;
- Commercial markings.

The Contractor shall keep the Engineer informed of the state of deliveries. The Contractor shall send copies of all shipping documents to the Employer and to the Engineer. Shipping documents shall be accompanied by copies of test certificates as required.

A4.5.2 Delivery

The Contractor shall be responsible for the safe delivery of items to the Site. Delivery of items shall comprise any of the following, which may be necessary but not be limited to:-

- Obtaining the necessary permits for all plant and equipment from relevant Authorities;
- Loading and transporting items by whatever means, including insurances;
- Taking charge of items at the port of entry or rail or air terminal in India, including payment of all handling charges, off-loading at terminal points, reloading and transporting to the Site;
- Taking delivery of items at the Site, off-loading and temporarily storing in store buildings or under cover until they are required for installation in the Works.

The Contractor shall examine items to the extent possible at the port or air or rail terminal, and more thoroughly whilst taking delivery at the Site. If the Contractor discovers that any item of Plant has been damaged in transit, he shall forthwith inform the Engineer who will inspect and may give instructions for its disposal.
Any item condemned by the Engineer shall be immediately removed and replaced by the Contractor.

Items with short shelf-life shall be delivered in the shortest possible time before use with the Plant.

A4.5.3 Storage

The Contractor shall provide all facilities for the safe storage of Plant as recommended by the manufacturer.

Stored items shall be laid out by the Contractor to facilitate their retrieval as required.

Stacked items shall be protected from damage. No metalwork shall be stacked directly on the ground.

Small items shall be held in suitable storage and shall be clearly labelled.

Items shall be handled and stored so that they are not subjected to excessive stresses and their protective coatings are not damaged.

The Contractor shall comply with manufacturers' recommendations concerning the use of lifting arrangements.

A4.6 Erection of Plant

A4.6.1 General

The Contractor's site personnel shall include at least one approved skilled supervising erector to supervise the erection of the Plant and enough skilled, semi-skilled and unskilled labour to ensure completion of the Works in the time required. The Contractor shall not remove any supervisory staff or skilled labour from the Site without the Engineer's approval.

The supervising erector shall mean the engineer in charge responsible to the Contractor for completion of the erection, installation, setting to work, commissioning, operation or maintenance of the Works. Where different engineers are in charge of separate stages or sections of work, the Contractor shall state their names and responsibilities to the Engineer in writing.

Plant shall be erected in a neat and workmanlike manner on the foundations shown on the approved drawings.

The Contractor shall be responsible for setting-up and erecting Plant to the line and level required and shall ensure that all equipment is securely held and remains in correct alignment during grouting-in. This responsibility shall not be passed to any other contractor.

Where the Works are associated with are in physical contact with plant supplied under a separate contract, the Contractor shall satisfy himself that the work carried out by the other contractor is consistent with the correct operation of the plant. If the Contractor considers any work being done, or any work completed, to be detrimental to the plant, he shall report the matter at once to the Engineer.

The Contractor shall make all holes and openings in building structures required for fixing small plant items and shall provide any associated supports. If any other openings or holes or additional loads applied to the structures are found to be required, after approval of the drawings prepared by the Contractor, their locations and sizes and method of cutting shall be submitted by the Contractor to the Engineer for approval. Approval will be dependent on an assessment by the Engineer on whether the structural integrity of the building will be compromised and whether they will be detrimental to the appearance of the finished Works. If the Engineer refuses permission for these reasons, the Contractor shall make fresh proposals, and shall have no claim for delay. All additional holes or openings shall be cut by the Contractor at his own expense.

A4.6.2 Foundations

Foundations shall comply with the details shown on the approved drawings. Where floors and plinths require to be cut away and prepared to accept foundation bolts or mounting frames and plates, the approval of the Engineer shall be obtained before any work begins.

A4.6.3 Foundation bolts and fixings

The Contractor shall supply all anchor bolts, holding down bolts, fixing bolts, washers, nuts, straps, supports, brackets, spacers and fixtures, which are needed for the satisfactory installation of the Plant. All fixing anchors, nuts and washer shall be made of stainless steel.

A4.6.4 Fixing to structures

No holes in concrete, brick, timber or structural steelwork for fixing devices shall be drilled without the prior approval of the Engineer. Holes shall preferably be made with a rotary drill of the non-percussion type. A single-shot cartridge tool may be used only at the discretion of the Engineer.

Any damage caused by the Contractor to any surface during erection shall be made good by the Contractor at his own expense to the satisfaction of the Engineer.

The Contractor shall be responsible for the provision of any scaffolding required and the cost shall be deemed to be included in the Contract Price.

A4.6.5 Plant protection on Site

Plant shall be adequately protected during and after installation against damage to finished surfaces and fitted components and against ingress of dust, moisture and the effects of humidity. Structural finishing operations may have to be done near installed plant before it is taken-over and the Contractor shall take this into consideration in complying with the requirements of this Clause. The cost of all protection shall be included in the Contract Price.

A4.6.6 Cleaning and preparing surfaces at Site

On arrival at the Site all Plant shall be examined by the Contractor and the Engineer for damage to protective coatings. Damaged portions shall be cleaned down, all rust removed by grit blasting, if instructed by the Engineer, and the coating made good with a similar paint within four hours of surface preparation.

After erection and building-in, appropriate items of Plant shall be thoroughly cleaned to remove all debris and filled where necessary.

A4.6.7 Protective coatings applied at Site

The Contractor shall apply the protective coatings for the Plant at Site in accordance with the protective treatment system approved by the Engineer.

The first in-situ coat shall be applied immediately the items of Plant have been erected and built-in.

Painting of Plant shall be completed not later than one month after the satisfact~~ion~~ory completion of the trial operation.

Before the end of the Operation and Maintenance Period~~)~~ all damaged paintwork shall be re painted to the Engineer's satisfaction.

A4.6.8 Connection of electrical power

The contractor shall check all items of electrical plant for correct phasing and insulation resistance. Motors shall be dried out in accordance with the manufacturers instructions and checks on the insulation resistance shall be made at regular intervals. Drying out shall continue until the insulation resistance reaches a steady value as recommended by the manufacturer. After all drying out and checking of insulation resistance is complete the Contractor shall check that all electrical connections to the plant are correct and any errors shall be brought immediately to the notice of the Engineer.

Electric power shall only be applied to any plant item after the individual tests specified for the plant have been done to the satisfaction of the Engineer.

A5.0 HEALTH, SAFETY AND WELFARE

A5.1 Applicable regulations, acts etc.

The Contractor shall comply with the relevant requirements of all local and the national health, safety and welfare acts and regulations issued by the Ministry of Labour (MOL).

Compliance with the requirements of acts and regulations by the Contractor shall not relieve the Contractor from responsibility for the safety of his workers and employees and those of his subcontractors.

A5.2 Failure to comply

In the event that the Contractor fails to comply with the requirements of the regulations or with the Specification in respect of safe working conditions or practices on the Site, the Engineer will have the authority to instruct the Contractor to stop work in any particular location until the unsafe conditions or practices have been rectified to the satisfaction of the Engineer. The Engineer will issue safety violation notices to the Contractor, informing him that he is working unsafely and describing the nature of the unsafe working practice, the time and date and the location. In this event, the Contractor shall be responsible for all costs and delays resulting from complying with such instruction by the Engineer and for the actual costs incurred on rectification of the unsafe conditions or practices.

A5.3 Contractor's health, safety, welfare and security implementation plan

The Contractor shall prepare and submit to the Engineer for review a Site implementation plan specific to health, safety, welfare and security practices of the work to be carried out under the Contract. The Contractor shall carry out all work on the Site in accordance with the agreed Site implementation plan. The Contractor’s plan shall reflect the requirement of the local and national requirements. It will include a methodology for carrying out risk assessments by the Contractor where these are deemed necessary. The plan will be updated from time to time to reflect any significant changes to laws and regulations or site activities.

A5.4 Contractor's health, safety, welfare and security (HSWS) officer

The Contractor shall appoint a qualified and experienced HSWS officer for the duration of the Contract. The full time duty of the officer will be to implement the site implementation plan, to prevent accidents and enforce the requirements of legislation in force. The name and qualifications of the officer so designated shall be submitted to the Engineer by the Contractor for approval within two weeks of the commencement of the Contract. The officer shall attend full time on site during normal working hours and whenever work is in progress during out of hours working, public and national holidays approved by the Engineer and available by phone and mobile during non-working hours.

The Contractor shall engage senior site engineers and foremen that are properly trained in the application of correct Health and Safety practices. These individuals shall liaise closely with the HSWS to maintain safety on site at all times. The Contractor shall submit the details of the Health and Safety qualifications of all such site personnel.

The HSWS officer will be responsible for ensuring all relevant information and posters are displayed at locations throughout the site in accordance with the site implementation plan.

The HSWS officer will be responsible for keeping a site accident book to record all site incidents or any major site rescue events. The book will be available for inspection by the Engineer or any MOL authorised person. Record keeping must also be maintained to comply with any other legal or regulatory requirements.

The HSWS officer will be responsible for ensuring that every site worker and regular visitor is given site HSWS procedure training when they first enter the site and refresher training at an appropriate frequency agreed by the Engineer. All occasional visitors will be trained on arrival and be provided with the appropriate personal, protective equipment. Records of the training will be kept and available for inspection by the Engineer.

A5.5 Contractor's health, safety, welfare and security committee

The Contractor shall set up a safety committee comprising her full-time HSWS officer, Plant manager, site engineers and foremen for the Contract. The committee shall meet weekly and minutes shall be recorded and a copy shall be submitted to the Engineer. The Engineer shall be invited to be present at the meetings.

The purpose of the meetings will be to discuss and resolve health, safety, welfare and security aspects of various parts of the work, including possible areas of conflict or difficulty. Where different contractors are working in the same area or adjacent areas, or where the work of one may impinge upon the work of another, the meetings will consider what action needs to be taken to ensure that each contractor is aware of the safety requirements of others.

A5.6 Site health, safety, welfare and security coordinator

The Employer may oversee the health, safety, welfare and security arrangements of the various contractors working on the Site, to liaise with the Engineer and to draw his attention to any breaches of Contract requirements or the approved safety plans of the Contractor.

A5.7 First aid facilities

The Contractor shall provide a complete approved first aid kit in his site office. The kit shall be in the charge of either the Contractor's HSWS Officer or some other responsible person who will also be on the site during all working hours to ensure that the first aid kit is available without delay. The Contractor shall also provide a first aid kit in the office for the Engineer. Kits shall also be provided at all remote sites. The HSWS Officer and adequate numbers of other senior members of the Contractor's staff shall be trained in occupational site first aid duties including resuscitation to take account of numbers of site workers located on the permanent site and mobile site operations.

The Contractor will make arrangements with the emergency and rescue services to provide adequate support where on site first aid assistance is inadequate to meet the welfare requirements of all site workers.

The Contractor shall comply fully with all rules and regulations from time to time issued and orders given by the Health Service of the Government or the local medical or sanitary authorities.

A5.8 Overhead hazards

Overhead protection shall be provided at any location where there is a hazard of falling objects. This shall particularly be observed around any scaffolding and in excavations.

‘Goalposts’ shall be erected beneath all overhead lines to prevent the arms or jibs of plant from approaching such lines. No plant shall be trafficked beneath overhead lines until the Engineer has inspected and approved the erected goalposts.

A5.9 Excavations or underground hazards

Every excavation or underground space into or through which a person may fall shall be covered by a temporary cover fixed securely in position or guarded by an effective barrier to prevent falls except where free access is required by work actually in progress. In such a case where work is in progress, the barrier shall be maintained in position to the extent possible, and suitable warning signs shall be erected.

A5.10 Drowning hazards

Where the work involves filling tanks with water leaving an open surface, the Contractor shall provide at all times and at suitable locations equipment for promptly rescuing persons from the water and resuscitating rescued persons. The Contractor shall take all necessary steps to prevent any such accidents occurring by providing adequate guarding.

A5.11 Slipping hazards

The Contractor shall not suffer or permit an employee to use a passageway, or a scaffold, platform or other elevated working surface which is in a slippery condition. Oil, grease, water and other substances causing slippery footing shall be removed, sanded or covered to provide safe footing.

A5.12 Tripping hazards

All passageways, platforms and other places of work shall be kept free from accumulations of dirt and debris and from other obstructions that may cause tripping. Sharp projections shall be removed or covered.

A5.13 Access to workplace

Temporary stairways, ramps or runways shall be provided as the means of access to working levels above or below ground except where the nature or progress of the work prevents their installation, in which case ladders or other safe means shall be provided. The Contractor shall not assume that access arrangements provided by the Employer will necessarily remain in place after the time that the Contractor commences work in a particular area.

A5.14 Dust and gases

Dust and gases shall be controlled by ventilation or otherwise so as to prevent concentrations tending to injure health or obstruct vision or from exceeding safe levels.

A5.15 Hazardous and corrosive substances

All alkalis, acids, gases and other hazardous and corrosive substances shall be so stored and used so as not to endanger employees in accordance with national and state regulations. Suitable protective equipment for the use of such substances shall be provided. Clean water supply shall be readily available for washing off any spillage of any corrosive substance on the employees.

A5.16 Eye and ear protection

Suitable eye protection equipment shall be provided for and shall be used by employees while engaged in welding or cutting operations or in chipping, cutting or grinding any material from which particles may fly, or while eng
aged in any other operation which may endanger the eyes. The Contractor shall ensure that fully equipped eye washing facilities are available on permanent and mobile site locations. Ear protectors shall be made available for employees when operating noisy machinery.

A5.17 Respiratory and resuscitation equipment

Where required the Contractor shall provide sufficient numbers of respiratory equipment and the employee shall be trained to use respiratory equipment suitable for the type of operation for which it is to be used. The Contractor shall maintain such respiratory equipment in good condition and shall furnish the means for its continued efficient working condition. The Contractor shall provide regular inspection, cleansing and sterilisation of such equipment. Such equipment, when not in use, shall be stored in an accessible, closed container.

The respiratory equipment shall be either of the escape set type, where it is provided for possible emergency use, or working sets where work has to be carried out in conditions where toxic gases are present or where there may be a deficiency of oxygen identified by the HSWS officer or his appointed staff when a risk assessment is undertaken prior to a site operation commencing. Risk assessments will be available for inspection by the Engineer immediately on request.

All persons who may be required to use such equipment shall be adequately trained and shall have certificates to that effect. Individual certificates will be available for inspection from all authorised workers by the Engineer.

A5.18 Work in confined spaces

Where work is required to take place in a confined space, defined as an enclosed space or excavation with limited access and where there is no natural ventilation, the Contractor shall provide equipment for monitoring the quality of the atmosphere within the space. The equipment will be calibrated to occupational standards to measure the range of gases and atmospheres identified as part of the risk assessment undertake prior to entry. The equipment shall be used to check the atmosphere before personnel enter, and shall remain in place while work is in progress to ensure that the confined space is free of harmful or noxious gases. The Contractor shall not permit anyone to enter or work in a confined space, including personnel from other contractors, the Engineer staff or the Employer's staff if harmful or noxious gases are detected. Under such circumstances, any personnel inside shall be evacuated immediately.

Prior to the commencement of the work, the Contractor will document a safe system of work which will be available for inspection by the Engineer.

All personnel working in such conditions shall be provided with escape sets. The Contractor shall provide a "top-man" who shall be stationed immediately outside the entrance to the confined space, and who shall maintain communication with personnel working inside the confined space. In the event of a tranverse entry, this may require additional personnel to be used to facilitate a reliable line of communication if evacuation has to take place. The top man shall have the means to raise the alarm in case of any emergency inside the confined space.

The Contractor shall provide adequate ventilation for workers carrying out work inside a confined space, pipeline or chamber or other enclosed areas by using blowers or other suitable means.

A5.19 Personal protective equipment (PPE)

Every site worker and visitor shall be provided with a full set of personal protective equipment for use at all times including a luminous vest, helmet of a type tested and approved by the MOL, steel toe-capped boots, gloves and other specific work related clothing offering ear and eye protection. All site workers and visitors shall be required to wear PPE while working on the Site, except in the Engineer’s and Contractor's office. The Contractor shall display a notice on the access to the site stating that entry is for authorised personnel only, and that PPE is to be worn at all times.

Every employee required to work in water, wet concrete or other wet footing shall be provided with suitable safety, waterproof boots.

Every employee required to use or handle alkaline, acid or other corrosive substances shall be provided with appropriate PPE.

A5.20 Electrical hazards

Before work commences, the Contractor shall ascertain by inquiry or direct observation, or by instruments, where any part of an electric power circuit exposed or concealed is so located that the performance of the work may bring any person, tool, or machine into physical or electrical contact therewith. The Contractor shall post and maintain proper warning signs to his employees of the location of such lines, the hazards involved and the protective measures to be taken and shall, if practicable, de-energise the electric power circuit.
The Contractor shall not suffer or permit an employee to work in such proximity to any part of an electric power circuit that he may contact the same in the course of his work unless the employee is protected against electric shock by de-energising the circuit and earthing it or by guarding it, by effective insulation or other means acceptable to the Engineer. The location of underground powerlines that encroach on the Works shall be confirmed using cable detectors, the path of the cable shall be clearly marked. If such cables are adjacent to excavations, the cable location shall be confirmed by finding the cable using carefully controlled hand-dig methods under the supervision of a senior member of the Contractor's staff. No live cables shall be retained within working trenches or other excavations. Any such cables shall be diverted prior to excavation commencing. The Contractor shall at all times liaise with the local electricity supplier with regard to the locating and diverting of any supplies.

A5.21 Power driven saws, abrasive wheels and grinders

All portable power-driven hand operated saws, abrasive wheels and grinders shall be equipped with guards above the base plate which completely protects the operator from contact with the saw blade when in motion and with self-adjusting guards below the base plate which completely covers the saw to the depth of the teeth when the saw is removed from the cut.

A5.22 Public vehicular traffic

Whenever any work is being performed over, on, or in proximity to a highway or any other place where public vehicular traffic may cause danger to men at work, the working area shall be so barricaded as to direct traffic away from it or the traffic shall be specially controlled by persons designated for that purpose.

A5.23 Site traffic

All vehicles used at the worksite must be roadworthy and registered with the appropriate authority. No person shall drive a vehicle at the worksite unless they are a holder of the appropriate driving licence or certificate.

A site internal access management system including all appropriate road signs will be submitted by the Contractor to the Engineer for approval at the commencement of the Contract.

A5.24 Stability of structures

No section of the plant or other structure or part of a structure shall be left unguarded in such condition that it may fall, collapse or be weakened due to wind pressure or vibration.

A5.25 Storage of materials and equipment

All materials shall be stored or stacked in a safe and orderly manner so as not to obstruct any passageway or place of work. Material piles shall be stored or stacked in such a manner as to ensure stability. Hazardous materials shall be stored in secure areas and the HSWS shall maintain an up-to-date list of the persons with a key to those areas.

A5.26 Disposal of debris

Debris shall be handled and disposed of by a method which will not endanger persons. Debris shall not be allowed to accumulate so as to constitute a hazard.

A5.27 Excavations

No employee shall be permitted to enter any excavated area, including areas excavated by other contractors on the Site, unless sheet piling, shoring or other safeguard that may be necessary for his protection is provided. In most cases, excavations will be considered to be confined spaces and the appropriate procedures followed.

Where any employee in an excavation is exposed to the hazard of falling or sliding material from any bank or side more than 1.5 m high above his footing, adequate piling and bracing shall be provided against the bank or side to eliminate such hazard. The excavation and its vicinity shall be checked by a designated person after every rain, storm or other hazard-increasing occurrence and the protection against slides and cave-ins increased if necessary.

Shoring adequate to support the overhanging material shall be provided where banks are undercut.

Excavated material and other superimposed loads shall be placed at least 1 m back from the edge of open excavations and trenches and shall be so shored or retained that no part thereof can fall into the excavation, or cause the banks to slip or cause the upheaval of the excavation bed. Banks shall be stripped of loose rock or other materials which may slide, roll or fall upon persons below.

Open sides of excavations where a person may fall more than 1.5 m shall be guarded by adequate barricades, and suitable warning signs shall be put up at conspicuous positions.

No employee shall be allowed to work where he may be struck or endangered by an excavating machine with which his activity is not directly related.

A5.28 Ladders, step ladders and access platforms

Every ladder, step-ladder and access platform shall be of good construction, sound material and adequate strength for the purpose of which it is used. Ladders, step-ladders and access platforms shall not stand on loose bricks or other loose packing, but shall have a levelled and firm footing. Ladders of over 2m in height shall be securely tied to the structure it is propped against. Free-standing, portable ladders over 4m in height shall not be used.

A5.29 Working at height

All site workers who work at height shall be provided with appropriate PPE to prevent an accident by slipping or falling.

A5.30 Positioning of machinery

No person shall be permitted to position or operate machinery in a manner likely to endanger himself or others.

A5.31 Fixed and mobile cranes

Fixed and mobile cranes shall be so constructed, positioned and operated as to be stable. No crane shall be loaded beyond the safe working load except by an approved person or an inspector for the purpose of testing such machine.

Every crane including all blocks, shackles, sheaves, wire ropes and the various devices on the mast and jib shall be thoroughly inspected by an approved person at intervals not exceeding 12 months. Cranes shall be inspected before being first erected or operated on each job or after any major repair. Inspection and repair of crane jib shall be made only when the jib is lowered and adequately supported.

Outriggers and counter-weights shall be provided and used as specified by the manufacturer of the crane or by an approved person. Counter-weights shall be properly placed and secured. Levelling jacks or other suitable means shall be provided and used with outriggers of truck-mounted mobile cranes.

Firm and uniform footing shall be provided for cranes. When such a footing is not otherwise supplied it shall be provided by substantial timber, or other structural members sufficient to distribute the load so as not to exceed the safe bearing capacity of the underlying material.

Every power-operated crane shall be provided with efficient brake or brakes or other locking devices which will prevent the fall of the load when suspended and by which the load can be effectively controlled whilst being lowered. Hand or foot-operated bakes shall be provided with a substantial locking device to lock the brake in engagement.

No load-bearing part of any crane shall be replaced by another part, and no such machine shall be modified by the addition thereto or removal therefrom of any load bearing part, unless the replacement or modification shall be certified by either the manufacturer or the approved person who tested the crane.

A capacity chart shall be provided for every crane. Such chart shall be posted and maintained in a place clearly visible to the operator and shall set forth the safe loads for various lengths of jib at various jib angles and radial distances. Where outriggers are provided such loads shall be set forth with and without the use of outriggers.

Unless furnished by the manufacturer or builder of the crane, a capacity chart shall be prepared and certified by an approved person. Cranes shall have audible overload warning alarms.

A crane shall not lift any load that exceeds the corresponding safe working load specified by its capacity chart.

Every crane having a jib shall be provided with an accurate indicator which shows, clearly to the operator, the radius of the jib and the safe working load corresponding to that radius at all times and gives warning signal when the radius is unsafe.

Before hoisting any load at a new job site, the jib shall be operated to its maximum height.

Crane cabs shall be locked when the operator is not present and no unauthorised person shall enter the cab or remain immediately adjacent to any crane in operation. If locking of a crane cab is impracticable, the operating mechanism shall be locked as to prevent the crane from being operated by an unauthorised person.

No crane shall be operated in such a location that any part of the crane or of its load in any position of jib or swing may come within 3 metres of live power line.

All the lifting equipment used at site shall be registered with the appropriate GOI Ministry and shall have a valid certificate at the time of usage.

All crane operatives should be authorised to operate the particular type of fixed or mobile crane. Valid certificates will be available for inspection by the Engineer. All banksmen will be formally trained to undertake their duties and refresher training will be given at an appropriate frequency agreed by the Engineer.

A5.32 Attachment of loads

Where a sling is employed to hoist long-length material, a lifting beam shall be used to space the sling legs for proper balance. When load is suspended at two or more points with slings, the eyes of the lifting legs of the slings shall be shackled together and this shackle or the eyes of the lifting legs may be shackled directly on the hoisting block or balance beam. The eyes may be placed on the lifting hook without shackles if the hook is of the safety type.

Each container or receptacle used for raising or lowering filter media or other loose material of any kind shall be so enclosed, constructed or designed as to prevent the accidental fall of such material.

Crane loads shall be raised vertically so as to avoid swinging during hoisting.

No crane shall travel with a suspended load except upon a safe runway. During travel without loads, crane's falls shall be secured or placed so as to prevent accident or damage by swinging.

A6.0 SITE WORKS

A6.1 The Site

The 'Site' as defined in the Conditions of Contract shall also include the Contractor's works areas, the Engineer's compound within the Contractor's works area and any temporary working areas described herein.

Possession of the Site, or parts thereof, to be given by the Employer shall be subject to any restrictions mentioned in the Contract.

Prior to any commencement of any site works, the Contractor shall undertake a survey of the site condition and provided detailed digital record photographs of the Site.

A6.2 Site road and access

Except as may be otherwise provided in the Contract the Contractor shall arrange for, construct, maintain and afterwards remove and reinstate all temporary site roads and accesses required for and in connection with the execution of the Works. Reinstatement shall include restoring the area of such roads and accesses to at least the degree of safety stability and drainage that existed before the Contractor commenced work.

A6.3 Data for setting out the Works

Unless otherwise stated any levels and co-ordinates shown on the drawings or given in the Specification are related to 'GTS' survey of India. Stated levels are given to AMSL (Above Mean Sea Level) with regard to GTS. The Contractor shall be responsible for checking any levels given on the drawings or given in the Specification and providing copies of the survey data to the Engineer.

The Contractor shall carryout all survey and levelling work to establish reference points in order to fulfil his obligation under the Contract.

The Contractor shall provide all survey and measuring instruments of every kind necessary for his own use in the execution of the Works.

A6.4 Geological, hydrological and meteorological information

Any geological or hydrological information given hereunder or elsewhere in the Specification or shown on the drawings is to assist the Contractor at the time of tendering. Such information shall be deemed to be information provided by or on behalf of the Employer under the Contract. The information is not warranted by the Employer or the Engineer and the Contractor shall make use of and interpret the same on his own responsibility. The meteorological information of Dharmapuri is entered in Appendix A-2.

A6.5 Special hazards

The Contractors attention is drawn to the following special hazard.

- Intense monsoon season rainfall, lightning storms and consequent flooding.

The above is an example only and is not complete. The Contractor shall be deemed to have made, before tendering, his own examinations and inspections of the site and all interpretations of all relevant climatic and physical conditions and their impact on the
works.

A6.6 Temporary working areas

Where any parts of the Works are to be constructed on, over, under, in or through land other than the Site or public highways, and subject to any proviso stated below, the Employer will arrange for temporary occupation by the Contractor of temporary working areas and such areas shall be deemed to be part of the Site during the period of occupation.

The work in such areas shall be subject to method statements, which shall be prepared by the Contractor and will be subject to review and approval by the Employer and the Engineer.

The Employer will arrange also for the serving of any Statutory Notices in connection with temporary working areas but the Contractor shall give to the occupier of each such area seven days written notice of his intention to enter and shall ensure that his methods of working cause the minimum of disturbance to the land and to its owners and occupiers.

Where necessary, similar arrangements shall apply to provide the Contractor with access routes to temporary working areas and such routes shall be deemed to form part of the temporary working areas.
The extent of each temporary working area and the period of time for its occupation shall be such as the Engineer considers necessary having regard to the Contractor's reasonable requirements, which shall be submitted to the Engineer's Representative as soon as practicable after commencement of the Works and having regard to the Contractor's programme furnished pursuant to the Contract.

A6.7 Temporary buildings etc. classified as Temporary Works

For the purposes of the Contract everything provided by the Contractor in compliance with sections A4 and A5 of the Specification inclusive or Contractor’s Equipment (whether it is owned by or is on hire to the Contractor) shall be deemed to be part of the Temporary Works. The permission of the Engineer for removal of temporary works from the Site may be withheld until the issue of the Performance Certificate.

A6.8 Reinstatement of temporary working areas

The Contractor shall reinstate temporary working areas to the standards specified in the Contract as soon as possible after other work in those areas has been completed so as to keep the period of occupation to a minimum. If the standards of reinstatement are not so specified the Contractor shall in any event restore the areas to a tidy, workmanlike and "as found" condition and shall carry out such additional reinstatement work as may be ordered by the Engineer.

A6.9 Existing services

The Contractor shall be responsible for the security of all water, electricity, telephone and other services, drains, pipes and other apparatus belonging to or under the control of any public authority, company or person, which may be, or be liable to be, interfered with, by or in connection with the execution of the Works. The Contractor shall be responsible for organising or providing all temporary service diversions. The Contractor shall fully indemnify the Employer against any claim, action, expense, loss, damage or injury arising in this respect.

The Contractor shall ensure that the location of all existing cables is identified using proprietary cable detection equipment by personnel qualified to carry out such work.

The Contractor shall obtain copies of all up-to-date services records for the Site prior to commencing the Works, and supply one copy to the Engineer.

A6.10 Amenities to be preserved

The Contractor shall cause the least possible interference with existing amenities, whether natural or man-made. No trees shall be felled except as authorised by the Engineer and clearance of vegetation of any sort shall generally be kept to the minimum necessary for the Works and Temporary Works. Permissions required for tree cutting shall be obtained by the Contractor and the Employer shall provide necessary letters as requested by the Contractor.

A6.11 Security on the Site

The Contractor shall provide, maintain and remove secure temporary fences of 2m height around works areas, storage yards and compounds. The Contractor shall submit details of the proposed temporary fencing to the Engineer for approval prior to any works.

Access into the Site will normally be restricted to employees of the Employer, the Engineer and his staff and the Contractor for the Works. Where one Party wishes to bring visitors on Site, he shall discuss and agree any relevant procedures before such a visit takes place.

The Contractor shall be responsible for the security and safety of all his operations, including storage of his own materials, tools and equipment, protection of completed work in place, site offices and the like.

The Contractor shall allow for providing security guards on a 24 hrs basis for the Site. At any time there should be three guards – one for the Site entrance and two for patrolling. The Contractor shall consider either two shift or three shift operation for the Security guards.

A6.12 Work in public highways

Where any work is to be carried out in or adjacent to a public highway (which for the purposes of the Specification shall be deemed to mean any street, road or footpath maintainable at public expense) the Contractor shall comply with, among other things, any requirements and recommendations of the police or other authority regarding traffic safety measures for roadworks.

Wherever single file traffic is necessary on a highway by reason of the construction of the Works the Contractor shall provide and maintain a minimum carriageway width of 2.5 metres, or wider where necessary at curves and junctions, and shall provide, operate and maintain sufficient suitable traffic signs. When alternative one-way working of traffic is required, the Contractor shall also provide trained operatives with 'Stop-Go' signs for the duration of those works.

No provision has been made for the closure of any public highway but if the Contractor wishes to apply for any such closure he shall make all the proper arrangements for the same with the appropriate persons and authorities. The Contractor shall not be entitled to any extra payment as a result of permission for such closure being refused.

A6.13 Access and trespass to adjoining property

If the Contractor's work will cause unavoidable interference with access to adjoining property the Contractor shall first give seven days notice in writing to the occupier of such property and shall provide temporary means of access for vehicles, animals and pedestrians.

In carrying out the Works due regard shall be paid to the amenities of adjacent property and to the interests of owners, tenants and occupiers. The Contractor shall take adequate steps to prevent trespass by his employees and shall be wholly responsible for making good any loss or damage caused by such trespass.

The Contractor shall take all necessary steps to ensure that the activities of his employees (and those of his subcontractors) do not have any detrimental effect on the surrounding environment.

A6.14 Claims for damage to persons or property (procedure)

Any claim received by the Employer in respect of matters in which the Contractor is required under the Contract to indemnify the Employer will be passed to the Contractor who shall likewise inform the Employer of any such claim which is submitted directly to him by a claimant. The Contractor shall do everything necessary, including notifying the insurers of claims received, to ensure that all claims are settled properly and expeditiously and shall keep the Employer informed as to the progress made towards settlement, failing which the Employer shall be entitled to make direct payment to claimants of all outstanding amounts due to them in the Employer's opinion and without prejudice to any other method of recovery to deduct by way of set-off the amounts so paid from sums due or which become due from the Employer to the Contractor. If the Contractor receives a claim which he considers to be in respect of matters for which he is to be indemnified by the

Employer under the Contract he shall immediately pass such claim to the Employer. All information as aforesaid shall be given in writing and shall be copied to the Engineer's Representative.

A6.15 Advertisements

The Contractor shall not except with the written authority of the Engineer exhibit or permit to be exhibited on the Site any advertisement board. Any such advertisement may also be subject to the approval of the local planning authority before it is put up and it shall be removed if the Engineer so demands.

Site sign boards shall be erected, typically of 3m x 2m, to bear the logos and text as specified by the Engineer. Costs shall be deemed to be included in the site establishment items in the Price Schedules.

A6.16 Site Welfare

A6.16.1 Sanitation

The Contractor shall maintain the Site and all working areas in a hygienic condition and in all matters of health and sanitation shall comply with the requirements of the local requirements.

The Contractor shall be responsible for providing all sanitary services necessary to keep all offices and stores in a clean, neat and hygienic condition.

The Contractor shall provide all proper temporary sanitary facilities for the Contractor’s employees and sub-contractor’s. The sanitary facilities provided within the Site shall be of the portable type. The Contractor shall provide septic tanks as necessary for the disposal of sewage. Waste water and septic-tank effluent shall discharge into properly designed French drains. Where the construction of septic tanks or water-borne sewerage is not feasible, the Contractor shall construct conservancy tanks and arrange for the removal and disposal of sewage. All such arrangements shall meet all the requirements as stipulated by the relevant local Health Authority and the Contractor's proposals shall be submitted to and approved by the Engineer.

In particular, the Contractor shall ensure that his employees (and those of his subcontractors) only use the toilet facilities provided by him as part of his site establishment. Any person found urinating or defecating elsewhere on the Site shall be removed from the Site immediately, and shall not be re-employed on the Site.

The Contractor shall also provide for the removal and legal disposal off the Site of all rubbish and solid waste from offices and other areas of the Site, with collections being made at least twice weekly.

A6.16.2 General hygiene and medical examination of Contractor’s employees

Before commencing work on the Site, the Contractor shall ensure that all his employees are instructed about the necessity for the prevention of pollution. The Contractor shall immediately dismiss and remove from the Site any of his employees or representatives who have been polluting or fouling the Site or any of the water supply installations and shall take appropriate remedial measures to prevent a repetition of the occurrence and to disinfect the areas concerned all to the satisfaction of the Engineer.

During commissioning and subsequent operations the Contractor shall not employ upon the Site, or on periodic visits thereto, persons who are known to have any disease which could be water-borne or who is suffering from an illness associated with looseness of the bowels or who are carriers of typhoid bacillus or other potential pathogenic organisms or who are otherwise unsuited on medical grounds to be employed in or around water supply installations.

The Contractor shall if and when required to do so, arrange for his employees to be examined and tested in the manner approved by the local medical officer.

The Contractor shall immediately remove from the Site any such employees who as a result of such examination and testing may in the opinion of the medical officer or the Engineer constitute a danger to water supplies or who refuse to undergo an examination.

A6.16.3 Works to be kept clear of water

The Contractor shall keep the Works well drained until the Engineer certifies that the whole of the Works is substantially complete and shall ensure that so far as is practicable all work is carried out in the dry. Trenches shall be kept well drained and free from standing water. All other excavated areas shall be treated similarly except where this is impracticable having regard to methods of Temporary Works properly adopted by the Contractor.

The Contractor shall construct, operate and maintain all temporary dams, watercourses and other works of all kinds including pumping and well-point dewatering plant that may be necessary to exclude water from the Works while construction is in progress. Such temporary works and plant shall not be removed without the approval of the Engineer.

Notwithstanding any approval by the Engineer's Representative of the Contractor's arrangements for the exclusion of water the Contractor shall be responsible for the sufficiency thereof and for keeping the Works safe at all times particularly during any floods and for making good at his own expense any damage to the Works caused by the fault or inadequacies of his arrangements.

Costs incurred by the Contractor in complying with the requirements of this clause shall be deemed to be included in the Contract Price.

A6.16.4 Discharge of water and waste products

The Contractor shall make provision for the discharge or disposal from the Works of all water and waste products howsoever arising and the methods of disposal shall be to the satisfaction of the Engineer and of any authority or person having an interest in any land or watercourse over or in which water and waste products may be so discharged.

A6.16.5 Dust hazard and nuisance

The Contractor shall take necessary measures including the spraying of water in order to keep down dust, which would otherwise be raised by the carrying out of the Works.

A6.16.6 Fire hazard (naked lights)

No naked light shall be used by the Contractor on or about the Site without the consent of the Engineer. If in the Engineer's opinion the use of naked lights may cause a fire hazard the Contractor shall at no extra cost to the Employer take such additional precautions and provide such additional fire fighting equipment (including breathing apparatus) as the Engineer considers necessary.

The term "naked light" shall be deemed to include open fires, electric arcs and oxy-acetylene or other flames used in welding or cutting metals.

A6.16.7 Water supplies

All water for use in the Works shall be fresh and free from harmful impurities to the satisfaction of the Engineer. The Contractor shall make adequate arrangements to deliver sufficient water to the Site for drinking, washing, sanitation and general cleaning down, in addition to any required for the construction, erection, testing, setting to work, testing for performance and guarantees at Site, commissioning and maintenance of the Works.

A6.16.8 Environmental Monitoring Plan

The Contractor shall enforce an Environmental Monitoring Plan during the 54 months operation and maintenance period, which shall conform to the requirements as entered in Appendix A-3 of this Specification. During the operation and maintenance period, the water quality at the intake and the noise level at the potential noise generation plant, e.g. the pumping stations, shall be monitored. The measurements stated above, shall meet the minimum frequency and duration as stated in Appendix A-3. However, under special situation, the Engineer's Representative has the discretion to take measurement records in higher frequency than that stated in Appendix A-3.

The Contractor shall be responsible for environmental monitoring at the sites of Package I only, whilst those sites at Packages II to V where the Contractor will be required to install the SCADA System equipment, the environmental monitoring work will be responsible by the respective contractors of these Packages. Notwithstanding of that, the Contractor shall be responsible for all the necessary rectification work should any non-compliance of any parameter as entered in Appendix A-3 is recorded, and the causes of such non-compliances are identified to be the responsibility of the Contractor.

The Contractor has to appoint a competent monitoring agency that shall possesses all the necessary calibrated testing equipment to conduct the measurement as entered in Appendix A-3, with the presence of the Engineer's Representative. The Contractor shall submit a rolling time program to the Engineer and proposes the date and time for each of the measurement record to be taken. After the time program being approved by the Engineer, the Engineer's Representative shall still be entitled to have the final discretion to rearrange the actual day for the record to be taken to cope with the site activities that is to incur. The record of the measurement shall be submitted by the Contractor to the Engineer within 2 working days after the measurement is completed. Should any non-compliance be recorded, the Contractor shall provide his remedial measures with this submission. Rectification work has to be done immediately subsequent to the approval of the proposed remedial measures by the Engineer.

A6.17 Work in the vicinity of electrical equipment

Any permanent fencing or other safeguards required to be erected around electrical equipment shall be completed as far as practicable before connection is made to the electricity supply. In so far as this is not practicable the Engineer's Representative may permit the use of temporary fencing or other safeguards.

If further work adjacent to electrical equipment is necessary after connection has been made to the electricity supply the Contractor shall put into operation a "Permit to Work" system to the approval of the Engineer.

A6.18 Electricity supplies

The Contractor shall install, operate, maintain and subsequently remove temporary supplies of electricity for the heating, lighting and ventilation of all offices, stores and other temporary buildings used by the Contractor and by the Engineer's staff in addition to any supplies he may require in connection with the maintenance of the Works. Such electricity supplies may be obtained either from Tamil Nadu Electricity Board and backed up with diesel generating plant provided by the Contractor.

The Contractor shall, at his own expense, supply, install, maintain and remove on completion, a temporary site electrical distribution system including wiring, cabling and distribution boards for power services, welding, lighting and all other electrical requirements in a safe and efficient manner. The Contractor shall submit details of the proposed temporary electrical distribution system to the Engineer. The Engineer may require the disconnection or alteration of any part of the electrical distribution system which, in his opinion, is dangerous or otherwise unacceptable. The Contractor shall not remove any of the installation without the approval of the Engineer.

A6.19 Compressed air

The Contractor shall supply any necessary compressed air plant and equipment required for erection, testing and commissioning of the Works.

Diesel engine driven compressors shall not be sited within buildings or in a location that may cause a health hazard to personnel due to exhaust fumes.

A6.20 Cleanliness of the Site

During the period of erection/maintenance, the Contractor shall maintain the area of his operations in a clean, tidy and safe condition. All disused materials, packages and other debris in connection with the Works shall be removed from the Site by the Contractor at his expense and at the earliest opportunity.

If, in the Engineer's opinion, at any time the Site or part of it are not sufficiently clean and tidy, the Contractor shall take all necessary steps to rectify the situation as directed by the Engineer. This shall be done at the Contractor's own cost.

A6.21 Contractor's offices etc

For the use of his own staff and work force the Contractor shall provide erect construct, maintain and subsequently remove all temporary offices, sanitary arrangements, stores, workshops, compounds, parking areas and the like necessary for the completion of the Works and maintenance of the Permanent Works and the siting and layout of these shall be to the approval of the Engineer.

The Contractor may if he chooses, include a workers canteen within the Contractor's office and storage compound. The Contractor shall not erect labour lines and canteens elsewhere on site.

Details and layout of such buildings and services shall be to the general approval of the Engineer's Representative and the Contractor shall also obtain any necessary approval from any local or other authorities concerned.

The Contractor shall maintain all offices, buildings, tanks etc referred to in this and other clauses in good condition. As the Engineer's office shall be located within the Contractor's office block, the Contractor shall ensure that he provides all the shared facilities mentioned below concerning Engineer's offices.

A6.22 Equipment for use by the Engineer

The Contractor has to provide the equipment as entered in Appendix A-1 for the use by the Engineer and the Engineer's Representative. Should any of the equipment could not be used due to normal wear or failed to function as a result of equipment defect during the course of the Contract period, the Contractor shall replace the defective equipment for the Engineer and the Engineer's Representative.

All the equipments entered in Appendix A-1 shall be submitted to the Engineer for approval immediately after the award of the Contract and shall be available within 2 weeks after approval to the proposal is granted by the Engineer.

A8.0 PROGRAMME OF WORK

In preparing the programme required to be furnished the Contractor shall take into account any restrictions on possession of the Site or of Temporary Working Areas imposed by the Contract.

The Contractor shall also take account of the availability dates for the different portions of the site.

The programme shall be in the form of a Critical Path Network, together with bar charts.

Particulars to be shown on the programme shall include:

- Submission of designs, drawings and documents
- Engineer's approval procedures/review procedures
- Re-submission of drawings etc as necessary and review
- Civil construction of each major structure
- Placing of orders for Plant
- Plant manufacture
- Plant tests at place of manufacture
- Plant deliveries to Site
- Plant erection
- Plant tests at Site
- Final commissioning tests
- Trial operation
- Plant operation and maintenance for 54 months

The programme shall make reasonable allowance for any work to be carried out by other contractors employed by the Employer. The Time for Completion of the Works and Sections thereof shall correspond to the periods prescribed in the Contract.

Approval of the Contractor's programme by the Engineer shall not relieve the Contractor of his duties and responsibilities under the Contract.

The programme shall be updated monthly and when requested by the Engineer to show actual progress and any revisions necessary to achieve completion.

A8.1 Allow access for other contractors

The Contractor shall liaise with other contractors and allow their access to the Plant and to advise these contractors when the Contractor will need to access their sites. The Contractor has to take into account that the work of these contractors might be carried out during the Operation and Maintenance period of the Contractor.

A8.2 Measurement for payment

All work to be done and goods and services to be provided by the Contractor under the Contract and other general obligations of the Contractor shall be valued for payment by reference only to such items as are provided therefore in the Schedule of Prices and (where permitted by the tendering procedure) to such further items as may have been added thereto by the Contractor when tendering. The cost of any work, goods, services and general obligations as aforesaid which are not so itemised shall be deemed to be included in the rates and prices for other items in the Schedule of Prices.

A9.0 DRAWINGS AND DOCUMENTATION FOR PLANT

A9.1 Drawings furnished by the Employer / Engineer

Drawings submitted as part of the Employer's Requirements are listed in the Schedules of Technical Particulars. They illustrate an overall conceptual layout of the Works, and are not binding on the Contractor. These drawings shall not be taken as the limiting responsibility of the Contractor for the detailed design /operation and maintenance of the Works.

A9.2 Site constraints

The Contractor shall note the constraint in terms of land available for the Works as shown in the drawings. No additional land than that shown in the drawing will be provided.

A9.3 Site information

The Contractor shall carry out such surveys, studies and analyses of any kind as are necessary for the purpose of his general and detailed designs and to verify the information shown on the Tender drawings and other data furnished by the Employer. The Employer shall not be liable for any claim by the Contractor on account of incompleteness or inaccuracy of the data furnished by the Employer irrespective of when the Contractor shall discover such incompleteness or inaccuracy.

A9.4 The Contractor's Documents

A9.4.1 General

Clauses below describe the various engineering documents to be submitted by the Contractor to the Engineer and the procedures for submitting and obtaining approval of them.

A9.4.2 Design

The design of the Works shall be an integral part of the Contract. Such design shall include site investigation, temporary works designs and drawings, functional plans and general designs, diagrams, detailed designs and working drawings for all aspects of the Works, together with any and all other studies, investigations, computations, analyses and evaluations necessary to comply with the requirements of the Specification.

Functional plans and designs shall be based on the proposals submitted with the Contractor's Tender, subject to such modifications as the Employer and the Engineer may require under the terms of the Contract.

All designs, drawings and documents relating to design of the Works shall be submitted by the Contractor to the Engineer for review and approval in accordance with the Condition of Contract. Submissions shall be accompanied by corroborative information and computations as necessary to enable the Engineer to check the Contractor's designs.

All submissions shall be in English.

The Contractor shall be fully responsible for the content of all submissions to the Engineer irrespective of the source or origin of information contained in such submissions. All submissions irrespective of the source or origin of information shall be checked by the Contractor and endorsed as such before submission to the Engineer. The Engineer will not accept submissions for review unless these requirements have been met.

Approval by the Engineer of a submission by the Contractor shall mean that the Engineer has no objection in principle to the content of the submission, drawings, calculations, certificates samples and the like and that the Engineer finds the content of the submission good enough to allow the work relating to the submission to proceed. Approval by the Engineer shall not relieve the Contractor of his responsibility under the Contract. Approval will be given only on the basis of information available at the time to the Engineer on the understanding that subsequent events may require withdrawal or modification of such approval.

The Contractor shall carry out the Works only in accordance with designs, drawings and documents that have received the Engineer's approval.

A9.4.3 Documents in electronic format

All documents submitted for approval shall be provided in both electronic format as well as paper copies of sufficient number as specified elsewhere. Each electronic submission shall be provided on read/writable CD clearly marked with the project title, submission reference and a description of the contents.

The Contractor shall provide the following electronic formats as a minimum:

Word-processing documents	- Microsoft Word/Adobe acrobat
Spreadsheet documents	- Microsoft Excel/Adobe acrobat
Databases	- Microsoft Access
Programme of works	- Primavera Suretrak
Drawings	- Autocad as .dwg or otherwise as .dxf format

The Contractor shall submit details of the proposed software versions for the Engineer’s approval.

A9.4.4 Drawing standards

Drawings submitted by the Contractor shall be clearly printed with black lines on white paper, and shall be resistant to fading on exposure to light.

Prints shall be on durable paper of good quality and 80gm/m^2 minimum weight.

Sheet sizes shall be in accordance with A series to ISO 216, and be drawn electronically at A1 size unless otherwise stated in the Contract or agreed with the Engineer.

All drawings submitted by the Contractor shall use the English language and SI units.

All drawings shall be clearly and fully cross referenced to the Specification and the Engineer's drawings as relevant.

Where drawings are revised, the revision letter or number shall be incorporated in the title block and the revision shall be clearly indicated on the drawing with the revision letter or number shown in an adjacent triangle.

When drawings are revised, this shall be done electronically and not manually, and CDs containing the revised files of all drawings, which have been supplied in electronic format, shall be submitted at the same time as the paper prints.

A9.5 Production, submission and approval

The production, submission and approval procedure for designs, drawings and documents shall comply with the following requirements:-

A9.5.1 Meanings

The following meanings shall apply:-

- "Preliminary drawings" means drawings which the Contractor submits to the Engineer for comment and any drawings returned by the Engineer marked "Preliminary" or not marked "Approved".

- "Drawings for Approval" means drawings which the Contractor submits to the Engineer for approval, and which shall be clearly marked as such.

- "Approved" drawings means drawings which the Engineer so endorsed accordingly and returned to the Contractor. Approved in this context means that the work described thereon may proceed as long as it complies with the Contract.

- "Preliminary", "For Approval" and "Approved" as applied to designs and documents shall have the same meanings as applied above to drawings. A drawing which forms part of an "Approved" design or document shall not be an "Approved" drawing unless it has been so marked.

Approval to a design, drawing, or document may be partial or conditional. Such documents will, for example, be marked "Approved in respect of.....certain parts...." or "Approved subject to.....actions to be taken by the Contractor before the work described can proceed.....". In such instances the Contractor shall carry out the Works only in accordance with approved parts or after the conditional actions have been carried out and confirmed to the Engineer in writing.

A9.5.2 Form of drawings

Every drawing shall have a title box in the bottom right corner showing:-

- Employer's name;
- Title of scheme;
- Title of Contract;
- Contractor's name;
- Title of work location;
- Title of drawing;
- Drawing number;
- Date;
- Author;
- Signature of Contractor (to the effect that the drawing, whether his own or from any other source, has been checked by him before submission to the Engineer;

Each drawing shall also have a separate revision box with space for up to 10 revisions, and including revision number, revision date, revision description and revision check. It shall also include adequate clear space for the Engineer's markings.

Drawings submitted for comment shall bear the word ‘PRELIMINARY’ either as an electronic watermark or as an ink stamp. Drawings submitted for approval shall bear the words ‘FOR APPROVAL’ either as an electronic watermark or as an ink stamp. Drawings submitted as record drawings shall bear the word ‘RECORD’ in similar fashion.

Drawings shall be drawn to specified scales or to such scales as are appropriate for clearly detailing and conveying the Contractor's proposals. Scales shall generally be 1:2, 1:5, 1:10 or multiples of 10 thereof. The appropriate measuring scales used shall be shown on the drawings.

Drawings shall include cross references where appropriate and key information such as vital levels and dimensions. All plans shall show the "north" direction. All drawings shall clearly indicate the level datum used and its value.

The Engineer will not approve any unclear or ambiguous drawings.

A9.5.3 Form of designs and documents

Designs and documents submitted by the Contractor to the Engineer for approval shall comprise generally:-

- Contents list;
- Scope (description of the contents and purpose of the submission);
- Conclusions and recommendations;
- References, Specification requirements, codes, manuals and supporting documents used, drawing numbers, and titles of drawings which are based on the design;
- Description of design approach;
- Criteria, parameters and methods used;
- Test procedures, analyses and results;
- Calculations and schedules;
- Qualitative description and comments on results;
- Any other relevant information;
- Appendix.

Designs and documents shall be presented on A4 size paper with every page numbered and bound in order between covers formed of a transparent front and stiff back. The title of the submission shall be given on the front sheet beneath the transparent cover together with a reference number, Employer's name, title of scheme, title of Contract, Contractor's name, title of works location, author's reference, date, Contractor's signature, revision box and space for Engineer's markings as for drawings and any other relevant information. Drawings submitted as part of the design or document shall be folded into pockets at the back.

A9.5.4 Numbering and titling

The Contractor shall institute a reference numbering system for designs, drawings and documents so that each number used is unique. The numbering and title information on designs, drawings and documents shall be designed so that management, transmittal and communication in connection therewith can be carried out expeditiously. The Contractor shall submit to the Engineer for approval, a comprehensive register of the Contractor’s Documents he intends to submit prior to the submission of any drawings for approval.

A9.5.5 Submission procedures

Every drawing submitted by the Contractor to the Engineer for review and approval shall be based on previously approved designs or documents. Interrelated drawings shall be submitted at the same time in a complete and self-sufficient set. Copies shall be collated into ordered bundles each with a list of contents and accompanied by a letter from the Contractor (not from subcontractors or suppliers). Revisions of previous submissions shall be highlighted and the reasons for these shall be stated in the covering letter.

All designs, drawings and documents submitted by the Contractor to the Engineer for approval shall be checked by the Contractor before submission. The Contractor shall likewise check submissions from his subcontractors or from any other source before passing on such submissions to the Engineer for approval.

On completion of checking, the Engineer will return the submission with one of the following comments:-

"Approved"	to allow work to proceed;
"Approved subject to"	to allow work to proceed subject to stated amendments and conditions;
"Not Approved"	revised submission required to include stated requirements.

Drawings with “Not Approved” and “Approved subject to” statuses shall be revised and re submitted within a maximum of 14 working days from the date of return.

Subject to any specific requirements in the Contract, all submissions shall be made sufficiently early to allow the Engineer time for review and approval, and for the Contractor to provide and submit revisions or alternatives.

Unless otherwise specified or agreed before submission, the Contractor shall allow not less than 14 working days excluding week ends and public holidays for review by the Engineer of designs documents and samples which are required to be approved and 10 working days for review of re-submissions before manufacture or construction commences as part of the Works. The Contractor shall have demonstrated in his submissions that he has coordinated submissions by his subcontractor or suppliers to confirm that the Contractor is satisfied that they are acceptable for incorporation into the Works.

If the Engineer does not respond to any submission within the specified number of days, then the Contractor may proceed with the work but shall inform the Engineer in writing that he is proceeding with the work. Absence of response from the Engineer will not relieve the Contractor of his obligations to meet all the requirements of the Specification.

The Engineer will designate the address of his review office in respect of particular disciplines or work from time to time during the Contract. All submissions shall be made sufficiently early to allow the Engineer time for review and approval of drawings, documents and samples which are required to be approved before commencement of manufacture of plant or of installation or construction on site as the case may be and for the Contractor to provide and submit revisions or alternatives, or carry out further tests if, in the opinion of the Engineer, the initial submissions do not meet the requirements of the Contract.

Whichever status - “Approved”, “Approved subject to” or “Not Approved” the Engineer assigns to any particular drawings designs or documents submitted for his review, will be based on the information provided in the submitted drawings designs or documents. It shall be the responsibility of the Contractor to ensure that all relevant information is provided to enable the Engineer to easily determine whether or not a submitted design complies with the specific requirements or intent of the Specification. Where the Engineer assigns an inappropriate status due to lack of clarity or incomplete or incorrect information submitted by the Contractor, this shall not relieve the Contractor of his obligations to provide the Works in compliance with the Contract. Any costs for abortive works or redundant equipment provided as a result of such situations shall be borne by the Contractor.

A9.5.6 Programme of submissions

In addition to showing the submission of designs, drawings and documents on his programme for the works, the Contractor shall submit a specific programme for submitting designs, drawings and documents to the Engineer for approval. The programme shall provide for the Engineer's review of the Contractor's submissions to be undertaken at a reasonably steady rate of working. The programme shall also make reasonable provision for re-submission of not approved designs, drawings and documents and for the time needed to transmit such designs, drawings and documents. No designs, drawings and documents will be accepted by the Engineer for review until the programme for their submission has been approved by him.

The Engineer may withdraw or modify his approval to an "Approved" design drawing or document as a result of subsequent submissions. In this circumstance, he will inform the Contractor in writing of the withdrawal or modification and, upon receipt of such information, the Contractor shall immediately take the necessary action in regard to the Works and confirm this to the Engineer in writing.

Where appropriate and as agreed between the Engineer and the Contractor drawings may be submitted in stages of development so as to allow certain milestones to be achieved or certain elements of the work to be started; the following stages are quoted by way of example and not as requirements to be met:

Stage 1 :Sufficient to allow preparation of foundations (floor slab and beams thickness and levels agreed);

Stage 2 :Structural outlines shown (sufficient to permit ordering of materials and detail up planning for building dates);

Stage 3 :Structural outlines and details shown (sufficient to accommodate and fix all plant and to allow building to proceed).

The programme for submission of designs, drawings and documents shall be based on the following general order, which may need to be adjusted to fit particular circumstances:-

- Topographical survey reports;
- Contoured site drawings;
- Site investigation reports;
- Outline design calculations;
- Hydraulic profile;
- Basic design criteria;
- Process and instrumentation drawings (P&IDs);
- General arrangement drawings;
- General civil works drawings;
- Structural designs;
- Structural drawings;
- Foundation drawings;
- Instrument schedules;
- Electrical single line diagrams;
- Substances and products schedules;
- Functional plans and functional design specifications;
- Fabrication and installation drawings;
- Detailed design calculations;
- General drawings for plant design;
- Plant drawings;
- Architectural drawings.

A9.5.7 Copies for Approval

Drawings submitted for approval shall be submitted as five A1 paper copies, two A3 paper copies, and in electronic format. The Engineer may agree with the Contractor to waive the requirement for A1 copies for certain submissions, for example where drawings are low in detail.

In respect of returning drawings, the following shall apply: One A1 and one A3 original shall be stamped accordingly, signed off and returned, balance A1 original and A3 original shall be stamped as above, signed off, and retained by the Engineer.

The Contractor shall submit to the Engineer for approval five copies of all other submissions. Only one copy generally will be returned to the Contractor.

A9.5.8 Copies of Approved Contractor's Documents

After approval, the Contractor shall submit to the Engineer two A1 copies, and two A3 copies, of all "Approved" drawings with the date of approval marked on the reproducible against a new revision/issue of the document. The drawing shall also bear an electronic watermark, or stamp, with the words "AS APPROVED".

Four copies of all "Approved" designs and documents shall also be submitted.

A9.6 Definition of working days for approval of submissions

In the context of time for approval by the Engineer of submissions by the Contractor, and for no other, "working days" shall mean Monday to Saturday in each week, and shall exclude any public holidays in Tamil Nadu. The number of working days shall be counted from the next working day following the day of delivery to the office of the Engineer until the day before the day of despatch from the office of the Engineer to the Contractor.

A9.7 Working drawings

A9.7.1 Hydraulic profile

Hydraulic profile drawings for the treatment works shows top water levels for all water retaining structures, chambers and channels from the inlet works to the treated water storage tank for normal and peak inputs.

A9.7.2 Plant working drawings

Drawings for all items of plant constituting an operating system includes diagrams showing circuit functioning and details for erection.

Working drawings for chemical, process, mechanical, electrical, instrumentation and similar plant includes :-

- Process and instrumentation drawings (P&IDs);
- Single line diagram for electrical distribution system from point of supply to final plant connection;
- General arrangement drawings of the Works to show Plant layout and dimensions;
- General arrangement drawings for all items of Plant, drawn to scale, fully dimensioned and showing weights, foundation details and all clearances required for installation, operation and maintenance;
- Fascia layout drawings of switchboards and instrumentation and control panels showing controls, instrumentation, mimics and inscription details of all labels;
- Alarm annunciator layout and engraving details;
- Electrical block, circuit and wiring diagrams for switchboards and control boards;
- Supplementary block, circuit and wiring diagrams for integrated control, protection, metering and other schemes as required for a complete understanding;
- Instrument configuration loop drawings which shall identify each element and its location, all wiring and cable connections, and all inputs to and outputs from programmable devices;
- Block diagrams to show power, control and instrumentation cabling systems with each cable, cable core and associated equipment terminals identified as in the cable schedules;
- Installation drawings showing cable routes and cable support system details. For cables installed in ducts and direct in the ground, the drawings include sections to show their disposition and the position of all marker posts, cable joints and drawpits;
- Cable schedules, which include the cable number, type, voltage, conductor size, number of cores and route length;
- Cable termination schedules for all power, control, instrumentation and data cable showing all details of the cable schedule and also incorporate cable core ferrule and equipment terminal numbers and the diagram number(s) of connected equipment;
- Single line diagram showing the electrical system neutral earthing, earth terminal(s) and electrode(s), and all circuit protective and equipotential bonding conductors;
- Earthing installation layout showing conductor routes and the location of earth terminal(s), test links, earth electrodes and associated connecting chambers;
- Earth terminal general arrangement;
- Lightning protection system installation drawings showing air termination details, the location and route of down conductors, the location of bonds, test points and earth electrodes, and the location of bonding points in reinforced concrete structures;

- Building services installation drawings showing the location of distribution boards, luminaires, socket outlets, heaters, ventilation fans and ductwork, air conditioning units, fire detectors and manual call points, intruder alarm switches and detectors, alarm sounders etc, and associated switches, thermostats, control panels and distribution board diagrams and/or schedules;
- Installation drawings for chemicals, waste, sludge disposal, water supply, and sewage and waste water systems;
- Fabrication and installation drawings for metalwork including platforms, floor plates and frames, handrailings etc;
- Diagrams showing flow paths and circuits, descriptions, dimensions and capacities of water treatment process units, and piezometric levels corresponding to average and maximum flow rates and to different or alternative treatment processes, accompanied by proof of computations;
- Complete and detailed schedules listing all items of plant, instruments and ancillary;
- List of safety signs and drawings;
- PLC / Control System I/O (Input / Output) Address Schedules & Fieldbus segment assignment lists shall list all inputs and outputs to the PLC / control system. I/O shall be listed in address order, and grouped into cards or module blocks if applicable. For each address record, the tag number and service description of the connected device, the I/O type (4-20 mA analogue input, 24 V DC digital output, fieldbus etc), the loop diagram/fieldbus segmentation drawing reference and the P&ID reference shall be listed. In the case of analogue parameters the corresponding range in engineering units shall also be listed. Eg 4-20 mA = 0 – 100 l/sec. Spare registers assigned for analogue and digital signals and fieldbus data shall also be listed;
- Instrument Datasheets shall be supplied for each instrument, identified by instrument tag number. The datasheet shall list all information required to replace and re-commission the instrument in the event of damage or failure. This shall include the final settings of all setup parameters stored in the instrument and process conditions (pressure, temperature, flow and other applicable variables);
- ICA Panel Layout drawings for each different panel or junction box a detailed drawing of both the internal and external layout shall be provided. Drawings showing the internal layout shall clearly show how segregation of 230 V AC and 24 V DC wiring has been achieved within the panel. Field connection boxes used solely to terminate flying leads to cables shall not require layout drawings. In the case of multiple identical junction boxes or field motor stop / start stations, a single typical panel layout drawings shall be acceptable provided such drawings are clearly labelled as to all the panels they describe;
- Panel Power Distribution drawings shall clearly show the distribution of power at different voltage levels within each panel. Drawings should be specific including showing which items are supplied from each fuse or MCB. The drawing shall also show the instrument earth connection arrangements;
- Instrument Location drawings for all instruments (including control valves) shall show the location (identified by tag number) of every instrument. The location drawings shall also show the location of major equipment items and routing of main cable trays and ducts. In plant areas where a fieldbus is being used, the instrument location drawings shall show the fieldbus segmentation;
- Instrument Loop Diagrams showing all connections, cables, terminals etc for all devices carrying the same loop number shall be provided for each loop connected using conventional wiring. The instrument loop diagram shall provide all information required to troubleshoot a loop ie. A technician shall be able to trace the electrical signal from field instrument through any junction boxes and signal isolators to the input terminals of a controller, any power supplies shall also be shown. The requirement for loop diagrams is not limited to closed-loop analogue control loops but applies to all instruments and fold devices. These shall be A3 size drawings;
- Fieldbus Segment drawings shall be provided for each fieldbus segment. It shall show the general segment topology and details of devices on that segment. In addition it shall show design constraints such as segment and spur length, voltage drop and current draw, loop execution requirements, and placement of power supplies, power conditioners, and terminators;
- Instrument installation, wiring and piping hook-up drawings, where applicable, shall be submitted. These shall be detailed in every respect;
- Logic Diagrams shall provide a detailed record of how the control system has been configured. That is what sequences and operations the plant performs under both normal and fault conditions the alarms shall be described in detail. These shall follow or at least be similar to the SAMA (Scientific Apparatus Makers Association) format;

- Control System Overview Drawing shall depict the general structure of the control system detailing the various components including detailing the contents of any control equipment racks (processors, I/O modules etc), any communication links between racks, operator interface stations (eg SCADA terminals, touch panels, alarm annunciators). Any communications links shall be labelled as to their protocol and parameters (eg baud rate, parity, stop bits);
- Control System Software Listing showing a full printout from the proprietary control system programming tools shall be provided. This shall include but not be limited to a listing of used and spare addresses, PLC program listing, report generation listing and database listing. The electronic data files (ie. code and documentation databases) necessary to maintain or modify the system configuration shall be supplied with the as-built drawings;
- I/O Connection Diagrams for control system I/O connected to non-field devices (eg to MCC's), connection diagrams meeting the same requirements as Instrument Loop Diagrams shall be provided.

A9.7.3 Civil works drawings

The civil works drawings include :-

- Preliminary works drawings.
- Layout drawings and sectional views.
- Civil works and structural drawings and reinforcement drawings.
- Architectural and builder's work drawings.
- Drainage and other disposal systems drawings.
- Roads and general site works drawings.
- Landscaping drawings
- Co-ordination drawings.
- Bar bending schedules.

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A9.7.4 Process and instrumentation diagrams

The Contractor shall provide process and instrumentation drawings (P&IDs) for the whole of the Works, including those sites at Packages II to V. These shall include but not be limited to showing every line, channel, tank, valve, pump, fan, instrument, system for control or automation or other item of equipment in symbolic form. Any demarcation of contract scope shall be clearly shown as shall be interfaces between future and new plant. All equipment and tag numbers shall be shown. Equipment names shall be shown. Functions and signals embedded within the PLC's and SCADA system shall also be shown in accordance with ISA and other appropriate standards. This shall include a clear depiction of the operation of every analogue control loop and a summarised or indicative indication of the operation of any logic interlocks. The P&ID's shall also indicate the interface between such items as control panels, separate installations, buildings, rooms etc. Every item of equipment and every line shall be numbered in accordance with the specified numbering system. Full use shall be made of varying line thickness and the like to optimise the readability of the P&IDs.

The P&I diagrams shall be the first of the Plant related documents and drawings to be submitted by the Contractor for the Engineer's approval. Until the Engineer has given approval to the P&IDs he will not give approval to other submissions.

The P&I diagrams shall comply with BS 1646 and BS1553. The Contractor shall provide a comprehensive legend sheet detailing the symbols used on the P&IDs with the first submission of the P&IDs.

A9.7.5 Complementary drawings

The Contractor shall submit such further detailed drawings of the Plant and any other equipment being provided under the Contract as the Engineer may require for a proper understanding of the Works.

These complementary drawings will not form part of the approved drawings, but shall be included as appropriate with the record drawings, the operating instructions and the operation and maintenance manual.

Such drawings may include but not necessarily be limited to:-

- Sectional and detail arrangement drawings;
- Circuit diagrams for electrical equipment which shall include wire and terminal numbers and circuit references and ratings for all components;
- Component part schedules for each item of Plant with references to the associated drawings;
- Valve schedule listing each valve with identification number, size, type, connections, rating, figure number and duty.

A9.8 Record drawings

The Contractor shall provide record drawings of the Permanent Works including the water treatment works and pumping stations to show the whole of the Plant as installed and incorporating any modifications made during operation and maintenance. These shall include all such drawings, diagrams and schedules as are necessary for a complete understanding of the Works including details of any "bought-in" items and any items shown as "blocks" on the main drawings.

Information given on record drawings shall include tolerances, clearances, loadings, finishes, materials and ratings of plant. The Contractor shall ensure that the approved and complementary drawings are marked up to show the Plant as installed and two copies of such marked up prints shall be submitted to the Engineer for approval prior to the preparation of record drawings. Submission to and approval by the Engineer of record drawings shall be a condition precedent to the allowance of the Contractor to proceed to the Operation and Maintenance Period, even the Contractor has satisfactory completed the final commissioning tests and trial operation.

Final approved Record drawings shall be submitted to the Engineer not later than three months after the commencement of the Operation and Maintenance Period. The number of copies to be submitted shall be as specified in the Schedule T3.

In addition to the bound sets specified in the Schedules, one copy of each record drawing at reduced scale (A3 folded) shall be included in each copy of the operation and maintenance manuals. The drawings, and particularly dimensions and notes, shall be prepared so that the drawings are still legible at this size.

Copies of the approved record drawings shall also be submitted on CD ROM disk.

The drawing files on CD ROM shall be in a .pdf and .dxf or .dwg (suitable for Autocad 2008 software) or as advised to the Contractor at the appropriate time.

Record drawings shall include but not be limited to:

- Piping and instrumentation diagrams (P&ID's);
- Single line diagram for electrical distribution system from point of supply to final plant connection;
- General arrangement drawings of the Works;
- General arrangement drawings for all items of Plant, drawn to scale, fully dimensioned;
- Fascia layout drawings of switchboards and control panels showing controls, instrumentation, mimics and inscription details of all labels;
- Alarm annunciator layout and engraving details;
- Electrical block, circuit and wiring diagrams for switchboards and control boards;
- Supplementary block, circuit and wiring diagrams for integrated control, protection, metering;
- Block diagrams to show power, control and instrumentation cabling systems with each cable, cable core and associated equipment terminals identified as in the cable schedules;

- Drawings showing cable routes and cable support system details. These shall show the numbers, position and sizes of cable trays and ducts for major cable routes. The contractor shall detail which cables are on which sections of tray. For cables installed in ducts and direct in the ground, the drawings shall include sections to show their disposition and the position of all marker posts, cable joints and drawpits;
- Cable schedules, which shall include the cable number, type, voltage, conductor cross sectional area, number of cores, origin, destination and route length. The schedules shall additionally incorporate cable core ferrule and equipment terminal numbers and the diagram number(s) of connected equipment. For electrical cables, the voltage drop at full load, current rating, and loading shall also be listed;
- Single line diagram showing the electrical system neutral earthing, earth terminal(s) and electrode(s), and all circuit protective and equipotential bonding conductors;
- Earthing installation layout showing conductor routes and the location of earth terminal(s), test links, earth electrodes and associated connecting chambers including instrument earth system;
- Earth terminal general arrangement;
- Lightning protection system installation drawings showing air termination details, the location and route of down conductors, the location of bonds, test points and earth electrodes, and the location of bonding points in reinforced concrete structures;
- Drawings for chemicals, waste, sludge disposal, water supply, and sewage and waste water systems;
- Diagrams showing flow paths and circuits, descriptions, dimensions and capacities of water treatment process units, and piezometric levels corresponding to average and maximum flow rates and to different or alternative treatment processes, accompanied by proof of computations;
- Civil engineering drawings for all structures drawn to scale, fully dimensioned;
- Structural design drawings for all civil engineering works;
- All pipeline drawings;
- Control Room Layout.

A9.8.1 Instrument Schedule

This shall list all instrumentation items (including actuated valves), including those supply and install at Packages II to V, in loop number order. For each instrument item the Instrument Schedule shall as a minimum list the size, make, exact model, P&ID reference, range and calibration, loop diagram reference, service description, and location drawing reference.

PLC/Control System I/O (Input/Output) Address Schedules & Fieldbus segment assignment lists

These shall list all inputs and outputs to the PLC/control system. I/O shall be listed in address order, and grouped into cards or module blocks if applicable. For each address record the tag number and service description of the connected device, the I/O type (4-20 mA analogue input, 24 Vdc digital output, fieldbus etc), the loop diagram/fieldbus segmentation drawing reference and the P&ID reference shall be listed. In the case of analogue parameters the corresponding range in engineering units shall also be listed. Eg 4-20 mA = 0 – 100 l/sec. Spare registers assigned for analogue and digital signals and fieldbus data shall also be listed.

A9.8.2 Instrument Datasheets

A unique datasheet shall be supplied for each instrument, identified by instrument tag number. The datasheet shall list all information required to replace and re-commission the instrument in the event of damage or failure. This shall include the final settings of all setup parameters stored in the instrument and process conditions (pressure, temperature, flow and other applicable variables).

A9.8.3 ICA Panel Layout drawings

For each different panel or junction box a detailed drawing of both the internal and external layout shall be provided. Drawings showing the internal layout shall clearly show how segregation of 230 VAC and 24 VDC wiring has been achieved within the panel. Field connection boxes used solely to terminate flying leads to cables shall not require layout drawings. In the case of multiple identical junction boxes or field motor stop / start stations, a single typical panel layout drawings shall be acceptable provided such drawings are clearly labelled as to all the panels they describe.

A9.8.4 Panel Power Distribution drawings

These shall clearly show the distribution of power at different voltage levels within each panel. Drawings should be specific including showing which items are supplied from each fuse or MCB. The drawing shall also show the instrument earth connection arrangements.

A9.8.5 Instrument Location drawings

The location of each instrument (including control valves) shall be shown (identified by tag number) on an instrument location drawing which shall also show the location of major equipment items and routing of main cable trays and ducts. In plant areas where a communication protocol, e,g, fieldbus, MODBUS or other equivalent is being used, the instrument location drawings shall show the communication protocol segmentation.

A9.8.6 Instrument Loop Diagrams

An instrument loop diagram showing all connections, cables, terminals etc for all devices carrying the same loop number shall be provided for each loop connected using conventional wiring. The instrument loop diagram shall provide all information required to troubleshoot a loop. A technician shall be able to trace the electrical signal from field instrument through any junction boxes and signal isolators to the input terminals of a controller, any power supplies shall also be shown. The requirement for loop diagrams is not limited to closed-loop analogue control loops but applies to all instruments and fold devices.

A9.8.7 Communication Protocol Segment drawings

A communication protocol (e.g. Field Bus, MODBUS and other equivalent) segment drawing shall be provided for each segment. It shall show the general segment topology and details of devices on that segment. In addition it shall show design constraints such as segment and spur length, voltage drop and current draw, loop execution requirements, and placement of power supplies, power conditioners, and terminators.

A9.8.8 Instrument installation, wiring and piping hook-up drawings

Where applicable, installation, wiring and hook-up drawings shall be submitted. These shall be detailed in every respect.

A9.8.9 Logic Diagrams

These shall provide a detailed record of how the control system has been configured. That is what sequences and operations the plant performs under both normal and fault conditions the alarms shall be described in detail. These shall follow or at least be similar to the SAMA (Scientific Apparatus Makers Association) format.

A9.8.10 Control System Overview Drawing

This drawing shall depict the general structure of the control system detailing the various components including detailing the contents of any control equipment racks (processors, I/O modules etc), any communication links between racks, operator interface stations (eg SCADA terminals, touch panels, alarm annunciators). Any communications links shall be labelled as to their protocol and parameters (e.g. baud rate, parity, stop bits).

A9.8.11 Control System Software Listing

A full printout from the proprietary control system programming tools shall be provided. This shall include but not be limited to a listing of used and spare addresses, PLC program listing, report generation listing and database listing. The electronic data files (i.e. code and documentation databases) necessary to maintain or modify the system configuration shall be supplied with the as-built drawings.

A9.8.12 I/O Connection Diagrams

For control system I/O connected to non-field devices (eg to MCC's), connection diagrams meeting the same requirements as Instrument Loop Diagrams shall be provided.

A9.9 Operation and maintenance manuals

The Contractor shall update the operation and maintenance manuals for approval by the Engineer. Submission to, and approval, subject to comments, by the Engineer of the operation and maintenance manuals shall be a mandatory.

The operation and maintenance manuals shall cover the setting to work, commissioning, testing, operation and maintenance of the Works. The greatest importance is attached to completeness and clarity of presentation. It shall be `user friendly' bearing in mind the training and abilities of the Contractor's and Employer's personnel responsible for operating and maintaining the Works and the time thereafter respectively.

The preparation of the manuals shall be carried out by personnel who are trained and experienced in the operation and maintenance of the Plant described and are skilled as technical writers to the extent required to communicate essential data and are competent to prepare the required drawings and documentation.

A collection of standard pamphlets of a general nature unaccompanied by drawings and descriptive matter relating to items of plant as installed, will not be acceptable. In particular, information supplied by sub-contractors and manufacturers employed by the Contractor shall be co-ordinated into the comprehensive manual. Cross-referencing of descriptive matter, drawings and spare part lists must be complete.

The manuals shall be in English, shall be securely bound, and pages shall be of A4 size to ISO 216 or folded to that size in a loose-leaf hardcover binder, using not more than 70% of the binder capacity.

The format of the manuals shall be white paper for typed pages with neatly typewritten text except for manufacturers' printed data. Drawings shall be provided with a punched reinforced binder tab for binding into the text. Drawings shall be so sized that they may be folded to the size of the text pages.

All pages shall be clear, legible and permanent. Offset printing or multilith is preferable, but electrostatic or photocopies will be acceptable if clear and permanent.

Each volume of the manual shall be identified both on the front cover and on the spine, with the typed or printed title "OPERATION AND MAINTENANCE INSTRUCTIONS", the title of the project, including the Contract reference number, and the identity of the general subject matter covered in the manual. The text and drawings shall be placed in commercial 4-ring binders with durable and cleanable plastic covers. When multiple binders are used, the instructions shall be correlated into related consistent groupings.

The front cover and spine of each volume, shall also bear the Employer's logo, details of which will be provided by the Engineer. The background colour for the cover shall be proposed by the Contractor and agreed with the Engineer.

Each O&M manual volume shall contain a neatly typewritten table of contents arranged in a systematic order giving: name of Contractor, address and telephone number, a list of each item of Plant included, an index to the contents of the volume and a list of each plant item with the name, address and telephone number of any sub-contractor or installer. Only the manufacturer's printed data which is pertinent to the specific Plant shall be included. Each sheet of manufacturers' instructions shall be annotated to identify clearly the specific item or part installed and the instructions applicable to that item or part of the Plant. All inapplicable information shall be deleted. Plant data shall be supplemented with drawings as necessary to illustrate clearly component parts of equipment and systems, control diagrams, flow diagrams, and test procedures covered in the manual. Written text shall be as required to supplement the Plant data for that particular installation. Written text shall be organised into a consistent format under separate headings for different procedures and in a manner to provide a logical sequence of instructions for each procedure.

The operation and maintenance manuals shall describe the installation as a whole and shall give a step-by-step procedure with assembly drawings for any operation likely to be carried out during the life of each item of plant, including its erection, commissioning, testing, operation, maintenance, dismantling and repair. Manuals shall identify and cover aspects liable to affect other installations and shall include all health and safety precautions to be taken.

Maintenance instructions shall include charts showing lubrication, checking, testing and replacement procedures to be carried out daily, weekly, monthly and longer intervals to ensure trouble-free operation. Where applicable, fault location charts shall be included to facilitate tracing the cause of malfunction or breakdown.

A separate section of the manuals shall be devoted to each size and type of equipment and to each item of Plant. It shall contain a detailed description of its construction and operation and shall include all relevant pamphlets, and a list of parts with the procedure for ordering spares. The detailed sections of the manual, if necessary, shall contain further maintenance instructions and fault location charts. Subject to the foregoing, the manual shall generally comply with the recommendations of BS 4884 parts 1 and 2. (Technical Manuals - Content and Presentation).

Any additions, alterations or deletions which may be required by the Engineer following the experience gained during the periods of running and further maintenance shall be incorporated in these copies in the form of additional or complete replacement pages and the cost of these amendments shall be deemed to be included in the Contract Price.

The Contractor's attention is drawn to the need to ensure that the following items are included in the operation and maintenance manuals:-

- All health and safety instructions for chemicals and any precautionary measures necessary for ensuring health and safety and avoidance of misuse;
- General description of the scope, purpose and manner of working of each system or apparatus forming part of the Works, and the final functional design specification (FDS);
- Schedule of equipment supplied giving manufacturers' name and appropriate make, model/catalogue number, description of unit and component parts identified on drawings;
- Maintenance procedures for regular maintenance and preventative maintenance, including frequencies of routine operations, guide to fault diagnosis, fault finding charts, step-by-step procedures for dismantling, cleaning, servicing, part replacement and reassembling, including recommended clearances and tolerances;
- Maintenance procedures for the flushing of chemical tanks, pumps and dosing lines and procedures for dealing with leakages and spillages including neutralisation;
- Schedule of spare parts with ordering reference numbers and parts identified on equipment drawings;

- Schedule of tools;
- Schedule of changeover frequencies for duty/standby equipment;
- Sectional arrangement drawings of major items of plant with dismantling instructions;
- Plant layout drawings showing the "as erected" installation;
- P&I drawings for "as installed" processes;
- Schedules for "as installed" instrumentation;
- Electrical system single line diagrams;
- Electrical system protection grading characteristics and setting data;
- General arrangement and circuit diagrams for switchboards and control panels "as installed";
- Diagrams of all "as installed" connections between electrical plant and instrumentation systems;

  Operating procedures including step by step instructions for pre-start, starting up, including start up following emergency shut down, normal operation and normal and emergency shutting down of the Plant;
- "Do's" and "Don'ts" in plant operation with attention drawn to all operations considered to be hazardous to personnel or likely to damage plant;
- Data on general setting of controls associated with controlling design conditions, monitoring instruments and switchgear, together with the details of initial settings of all adjustable items;
- Test certificates for works and site tests carried out on plant, for site tests carried out on pipework, electrical and instrumentation installations and other items where appropriate;
- Pump performance and calibration characteristics as tested and system characteristics;
- Manufacturers' printed operating and maintenance instructions;
- Lubrication instructions including frequency of application and schedule of recommended lubricants and their equivalents, which must be readily obtainable;
- Typical log sheets for recording plant operating information for each process and chemical plant with instructions for identifying departures for normal behaviour;
- Typical log sheets on which operating staff can record their service/maintenance checks on essential equipment and at periods recommended by the Contractor;
- Instrumentation, control and automation equipment operating instructions for normal procedures in a step by step format including flow charts, control operations, requests for display or printing of data, performance monitoring, response to alarms or failures, changing of operation parameters, and manual data entry;
- Description of the plant control philosophy (a layman's guide for operator assistants) including plant trips and interlocks;
- A schedule of alarms, giving cause and action to be taken;
- Procedures for calibration of instruments, dosing pumps etc;
- Data sheets for process and chemical plant giving design parameters;
- Data sheets for pumps, compressors etc giving capacities.

All drawings incorporated in the manuals shall be presented in such a way that they can be easily referred to whilst reading the associated description in the text.

The Contractor shall submit for the Engineer's approval, not less than one month in advance of the time at which any item of Plant is delivered to Site, two copies of instructions appropriate to the erecting, testing, operation and running maintenance of that item of Plant. These instructions shall form a draft of the relevant parts of the operation and maintenance manual.

Two complete draft copies of the manual for the Works shall be submitted to the Engineer at least one month before the commencement of the final commissioning tests. These copies may be the same copies as those submitted in sections in accordance with the previous paragraph. In this case the Contractor shall check and certify that these two copies are complete before the commencement of the trial operation.

The trial operation shall not be started if the complete draft manual has not been submitted to the Engineer.

All copies of the manual shall be amended as necessary by the Contractor during the period of testing, commissioning and setting to work of the Plant. Following this updating, the Contractor shall check and certify that the copies of the amended manual are the final draft of the manual. The Engineer will review the final draft manual and advise the Contractor of any changes required. This review will be completed by the Engineer within 35 working days of the certification by the Contractor that the final draft manual is complete.

The text of the manual shall also be submitted on CD ROM disc.

If any further revisions are necessary as a result of operational experience all copies shall be revised by the Contractor within a period of thirty days of the need for revision becoming apparent.

A third copy of the draft manual shall also be provided by the Contractor for use by the operating staff and receipt of the final manual. The manual shall be clearly marked "draft". This copy shall also be amended as for the copies provided for the Engineer, and may, after checking and certification of its correctness by the Contractor, form one of the sets to be provided to the Board under the Contract.

Upon approval of the Draft O&M manuals, the Contractor shall submit six sets of the final O&M manuals, two sets of CD ROM discs and pdf/html format to be loaded onto the Workstations of the SCADA system.

A9.10 Hazard and operability study

The Contractor shall carry out a hazard and operability study (HAZOP) in accordance with the recommendations of Chapter 2 of "HAZOP and HAZAN, Notes on the Identification and Assessment of Hazards" by Trevor A. Kletz, published by the UK Institution of Chemical Engineers. The study shall be applied to the process and instrumentation diagrams produced under the Contract prior to the submission of the same for approval.

The HAZOP study sessions shall be held at the Contractor's site office and shall be attended by his Project Manager and the persons responsible for the design of the subject matter. The Contractor shall appoint one of his team to act as secretary responsible for recording, typing and issuing copies of the minutes to each person present at the meeting. A representative of the Engineer will act as chairman.

A9.11 Other submissions

A9.11.1 Contractor responsible for testing

In addition to any specific obligations for sampling and testing, the Contractor shall be responsible for routine inspection sampling and testing of all materials, workmanship, plant and measuring devices, in order to control the quality of work and to ensure compliance with the Specification and with approved samples.

The Contract includes for a laboratory and testing equipment to be provided for the use of the Employer's staff. The Contractor shall be allowed reasonable opportunity to use the same for purposes of quality control, but shall be responsible for the care and maintenance of the equipment. Any damage or breakage shall be made good at the expense of the Contractor. Any consumables used by the Contractor in furtherance of testing specified in the Contract, or which he may require for his own purposes shall be provided by the Contractor at his own expense. The Contractor shall provide all necessary additional test equipment to demonstrate that the guarantees for water quality, energy consumption and the like are being achieved.

A9.11.2 Samples

Where the Contract requires the submission of samples, they shall be submitted by and at the expense of the Contractor not less than 20 working days excluding weekends and public holidays prior to the time that the materials represented by such samples are needed for incorporation into any work. Samples shall be subject to approval by the Engineer's Representative, and material represented by such samples shall not be manufactured, delivered to the site nor incorporated into any work without such approval.

Where samples, including samples of materials and workmanship constructed on the Site, are submitted as a reference for materials and workmanship to be provided as part of the Permanent Works, they shall, after being approved by the Engineer, be carefully preserved for this purpose on site by the Contractor to the satisfaction of the Engineer until permission is given by the Engineer for their disposal.

A9.11.3 Manufacturers' and Contractor's certificates

Where certificates are required by the Specification or relevant Reference Standard, the original and one copy of each such certificate shall be provided by the Contractor, unless otherwise specified. The original and copy certificates shall be submitted to the Engineer.

Certificates shall be clearly identified by serial or reference number where possible to the material being certified and shall include information required by the relevant Reference Standard or Specification clause.

Unless otherwise specified, the timing for submittal of certificates shall be as follows:

(a) Manufacturer's and supplier's test certificates shall be submitted as soon as the tests have been completed and in any case not less than seven calendar days prior to the time that the materials represented by such certificates are needed for incorporation into the Permanent Works.

(b) Certificates of tests carried out during the installation of plant and equipment or on completion of parts of the Permanent Works shall be submitted within 7 days of the completion of the test.

A9.11.4 Progress photographs

Progress of work on Site shall be recorded monthly in one copy of colour photographs of size not less than 175 mm by 125 mm. Each photograph shall be suitably mounted, captioned and bound into a set as directed and approved by the Engineer. In addition one further set of photographs shall be provided on CD ROM disc. The bound set of colour photographs shall be submitted to the Engineer with the Contractor’s monthly progress report. The camera and photographic papers shall be of types to the approval of the Engineer

The photographs and discs shall be the property of the Employer and no prints from these may be supplied to any person or persons except with the authority of the Employer. The Contractor shall also ensure that no unauthorised photography is allowed on the Site.

A suitable typed caption shall be affixed to each photograph (prints and those on disc) describing the detail and date taken.

A10.0 INSPECTION AND TESTING OF PLANT

A10.1 Off-Site inspection and testing

A10.1.1 General

The Contractor shall offer all items of Plant for inspection by the Engineer at all stages of manufacture and shall include for the testing of all Plant as required by the Specification. The Engineer/Employer/Third Party Inspection Agency may witness any test, at his sole discretion.

The Contract Price shall include for the costs of all inspection and off-Site tests including temporary assembly and subsequent dismantling, labour, materials, instrumentation, chemicals and consumable items, provision of test certificates, certified records and curves.

The off-Site tests shall normally be carried out at the manufacturer's works but if the tests are beyond the resources of the manufacturer, the Contractor shall make arrangements for tests to be carried out elsewhere. The off-site testing may be witnessed by the Engineer or by inspectors appointed by the Employer. All travel and out of pocket expenses, eg. air tickets, accommodation, allowances, professional charges, etc. incurred by the inspectors in attending any test will be paid by the Contractor. Details of Inspection Agency and the details of agreement between Third Party Inspection Agency and the Employer will be notified to the Contractor.

No Plant or materials for inclusion in the Works shall be despatched from any manufacturer's works without the written permission of the Engineer. Any Plant or materials despatched without permission shall be returned and tested in accordance with the Specification at the Contractor's expense.

If during off-site testing, any Plant or materials fails to meet the requirements of the Specification, the defects shall be rectified forthwith. The rectified item shall be offered for re-inspection and witness testing, and all resulting additional costs incurred shall be borne by the Contractor.

The Contractor shall carry out all applicable tests required by the Specification and the Reference Standard, together with such tests as are necessary, in the opinion of the Engineer to demonstrate that the Plant or materials comply with the Specification.

When the Contractor is ready to carry out any off-Site test, he shall submit a detailed test procedure to the Engineer. The proposals shall give values, such as test parameters and make reference to Reference Standards, any other standards and manufacturer's literature. The proposed format for the test sheets shall be submitted at the same time. The testing shall not start until the Contractor's proposals and test sheets have been approved by the Engineer. After receiving approval, the Contractor shall notify the Engineer of the place and time of the proposed tests giving not less than fifteen working days notice.

The Contractor shall carry out every off-Site test at the time and place notified. If the Engineer does not attend any test, then the Contractor shall carry out the test in the absence of the Engineer and the certified copies of the test results shall be deemed to be a correct record. The Contractor shall provide the Engineer with three certified copies of the test results within two weeks of completing the tests. Enough information, including the Contract number and title, shall be given on each test certificate to enable the Engineer to check for compliance with the Specification.

No inspection or approval by the Engineer of the Plant or materials covered by the Contract shall release the Contractor from any of his obligations under the Contract.

Where items of Plant are of identical size and duty the Engineer may elect not to witness all tests, but the Contractor shall assume that the performance tests on all items will be done prior to offering any Plant for witnessed testing.

A10.1.2 Calibration of instruments

All instruments used for testing purposes shall have been calibrated by an independent accredited testing authority and shall have a valid calibration certificate.

The calibration validity period shall not be longer than 12 months. Instruments used for tests at site shall have been calibrated not more than 3 months before the start of testing.

The Contractor shall provide the Engineer with three copies of calibration certificates and correction graphs etc at the time of testing.

Any test instruments shall be recalibrated if requested by the Engineer.

A10.1.3 Test procedure

The procedure and requirements for all tests off-Site on all Plant or materials shall be in accordance with the requirements of the Specification and shall in addition be in accordance with the requirements of the Reference Standards applicable to the item being tested.

A10.1.4 Guaranteed performance

The figures entered in the Schedule of Technical Particulars or stated in the Contract for performance and efficiency shall be guaranteed by the Contractor in respect of the Plant offered at the duties specified. These figures will be binding and may not be varied except with the written approval of the Employer. No tolerances are permitted on these figures. Testing to the relevant standards and to prove guarantees given will be required for all Plant and materials and the complete Works.

A10.1.5 Test records

For any test required by the Contract, the Contractor shall produce a written record, in a form approved by the Engineer, certifying that the test has been completed. The Contractor's representative at the test shall sign the test record. The tests witnessed by the Engineer's Representative shall be certified by the Engineer's Representative on the same test record.

A10.1.6 Certificates

Certificates of test in triplicate shall be provided by the Contractor for all off-Site tests. These shall incorporate all test results, calculations, performance graphs and curves and shall be signed by representatives of the manufacturer, Contractor and Inspector. These certificates shall be provided within two weeks after completing the test. Copies of all test certificates shall be included in the operating and maintenance manual.

A10.1.7 Notification

Following any inspection or testing of Plant or materials, the Engineer shall notify the Contractor in writing either that:

- the item has passed the tests;
- the item on any part thereof is defective;
- the item is not in compliance with the Specification; or
- the item has not met guaranteed performance or efficiency requirements not in compliance with the Specification.

The Engineer shall state the grounds on which the decision is based.

A10.2 Site inspection and testing

A10.2.1 Inspection

During erection of the Plant the Engineer will inspect the installation from time to time in the presence of the Contractor to establish conformity with the Specification. Any deviations found shall be corrected forthwith to the satisfaction of the Engineer.

As soon as the Engineer is satisfied that the erection of the Plant in an installation has been completed and the Plant found to be in good working order and that the associated civil works have been substantially completed to an extent permitting the proper operation of the plant, the Contractor shall start testing at Site.

A10.2.2 Testing - general

The scope of the "Test on Completion" at the Site shall be as follows:-

- Individual tests (also called pre-commissioning tests) which shall be at the first opportunity after installation of the Plant;
- Final commissioning tests which shall be on whole systems to demonstrate to the Engineer that a section of the Works is ready to undergo trial operation;
- Trial operation.

Before any testing involving water entering supply, disinfection of all Plant items in contact with water to be supplied shall be undertaken by the Contractor. The disinfection of structure and pipework shall be generally in accordance with Clause A10.5 and subject to the approval of the Engineer.

When water is discharged to waste, the Contractor may, subject to such conditions as the Engineer and Employer may lay down, operate and adjust the Plant as necessary in order to test the operation of the Plant. No water shall be put into supply except with the prior authorisation of the Engineer and Employer and under such conditions as they may lay down.

No part of the Plant shall be set to work until it has been inspected and accepted by the Engineer.

A10.2.3 Testing programme

The Contractor shall submit to the Engineer for his approval a programme for testing up to the commencement of the trial operation, at least 28 days in advance of the proposed start of testing and shall agree the timing with the Engineer and Employer not less than one week before the start of testing.

The programme shall show the quantities of raw water, chemicals and power required. Details of the proposed test procedures shall be submitted by the Contractor, including the manner and order in which each item of Plant and process will be tested. Associated flow rates and durations shall be submitted, and log sheets shall be prepared for recording plant information and other operating, water quality parameters, and presentation and interpretation of test data.

The programme shall be subject to approval by the Engineer and shall take into consideration the extent of progress on other contracts, the availability of water, chemicals and power, and the Employer's requirements for disinfection and discharges either to supply or to waste.

The Contractor and any specialist sub-contractor shall be available to attend meetings at the Site to discuss the testing programme, the test details and the test results.

A10.2.4 Labour, materials, water, electricity and chemicals for tests

For individual tests, final commissioning tests and trial operation, the Contractor shall provide all necessary labour, materials, chemicals, water, electricity, fuel, stores, apparatus, instruments and indicators necessary to carry out the tests. If it is permitted by the Employer, the Contractor may be allowed to use the permanent electricity supply registered under the name of the Employer. However, the Employer has the final discretion to decide whether such permission will be given. If the Employer permits the Contractor to do so, all electricity tariff expense that is to incur to the Employer has to be reimbursed by the Contractor. Electricity used for the tests shall be recorded on suitable meters provided by the Contractor, which shall be read by the Engineer in the presence of the Contractor at appropriate times. Electricity consumed as a result of testing activities shall be paid for by the Contractor. The Engineer will from time to time deduct the cost of supplying electricity to the Contractor from the Contractor's monthly progress claims. The Contractor has to make arrangement for water for carrying out all necessary tests.

During testing and trial operation of the Plant, the Contractor shall be responsible for all work, plant and costs in connection with the commissioning and the trial operation of the Works.

All measuring instruments used for testing purposes shall comply with clause A9.1.2.

The Contractor shall prepare test record sheets for recording of all test results for the approval of the Engineer at least one month before the programmed date for the tests. Three copies of each approved sheet shall be provided to the Engineer not less than one week before the start of testing.

A10.2.5 Individual tests

Individual tests shall be in the presence of the Engineer and shall include the following:-

- Leakage tests for structures and tanks;
- Leakage tests for pipework.

Leakage tests shall be carried out on all pipework. Where pipework is to be built in, these tests shall be carried out after erection and before concreting. The Contractor shall ensure that the pipework is suitably anchored and supported to sustain the pressure in the not-built-in condition.

Pipelines and valves shall be pressure tested to one and a half times working pressure unless otherwise specified.

Pipework and valves through which oil or gas is to be conveyed shall be thoroughly inspected then tested with the oil with which they are to be used or an inert gas and the whole checked for leakage. Hydraulic tests using water shall NOT be applied to this pipework.

Tests on all items of Plant and materials in accordance with the requirements of the Specification shall also be in accordance with the requirements of the Reference Standard applicable to the item being tested.

- Electrical tests to demonstrate compliance of the electrical installation with specified and statutory requirements;
- Operational test for all valves;
- Running test for all pumps, blowers, compressors, etc.;
- Noise and vibration levels measurements shall be carried out for all rotating equipment.

A10.2.6 Functional test of all protective devices.

All individual tests on items of plant or equipment making up a complete system shall be completed to the satisfaction of the Engineer, before starting the final commissioning tests on that system.

A10.3 Final commissioning tests

The Contractor shall carry out such tests and retests on complete systems as are required to demonstrate to the satisfaction of the Engineer that substantial portions of the Works are ready to undergo the trial operation with a minimum of interruption in regular operation.

The final commissioning tests shall demonstrate satisfactory performance of the items of Plant under normal operation and their response to abnormal and emergency conditions.

Each process system shall be set to work under manual control and final commissioning tests shall be carried out for such time as is agreed by the Engineer as being appropriate. Subsequently the automatic control equipment shall be set to work and further final commissioning tests shall be done.

The tests shall include simulation of the full ranges of alarm conditions over the full ranges of operation and include tests of emergency shutdown procedures including electricity power failure.

The period of final commissioning tests shall finish after the Plant has been satisfactorily operated by the Contractor, as certified by the Engineer, for a continuous period of fourteen days or for such extended period in excess of 14 days as may be required by the Engineer to make up for interruptions in operation. However, the Contractor will not be required to run the Plant under the provisions of this clause more than once for one continuous fourteen day period.

The Contractor shall use the 14 day period to optimise the water treatment process.

During the 14 day period or after the trial operation as decided by the Engineer, the Contractor shall demonstrate the hydraulic capacity of the works and overflows at the maximum works throughput with:

- all process units in service
- one clarifier out of service,
- two filters out of service,
- one compartment of contact tank of service, and
- one compartment of treated water reservoir out of service.
- one thickener out of service.

During the hydraulic capacity tests, the Contractor shall measure water levels at various points corresponding to the points where levels are identified on the approved hydraulic profile drawing and shall also measure the free board at these points and at overflow points.

A10.4 Trial operation

A10.4.1 General

The Contractor shall start the trial operation when the following conditions have all been completed:

- Final commissioning tests have been successfully completed;
- the Plant is ready;
- draft operating and maintenance manuals have been submitted; and
- the Contractor and Employer's operation and maintenance staff have received full training as specified.

Trial operation shall be carried out on Sections of the Works and on the Works as a whole, as appropriate.
In addition, certain tests to demonstrate compliance with guaranteed or specified performance of particular items of Plant or parts of the Works shall be carried out independently from the trial operation for the Works or Section of Works. Apart from the results of the trial operation, these independent tests shall also be a condition precedent to the allowance of the Contractor by the Engineer to proceed to the Section of the Works (Operation and Maintenance Period) and the taking-over of Section I of the Works by the Employer.

The trial operation shall demonstrate that the Works can fulfil all the mechanical, electrical, instrumentation, control and automation and process requirements of the Specification in the ambient conditions prevailing, using the raw water available at the time.

The Works shall be tested for performance for a continuous period of 30 days, of which at least the last 15 days shall be uninterrupted by other tests. During the 30 days tests the Works shall be operated at the maximum output for at least 15 days as instructed by the Engineer. The object of the tests shall be to obtain a comprehensive set of data to show that treatment performance meets the Specification and performance guarantees specified over a range of flows within the design capacity limits. Following each flow change and after a period of plant stabilisation all process and water quality parameters shall be measured and recorded for comparison against the Specification and performance guarantees relating to:-

Works output;

Clarified water quality;

- Filtered water quality;
- Treated water quality;
- Filter run duration;
- Clarifier sludge discharge;
- Filter washwater consumption;
- Thickener supernatant turbidity;
- Any other parameter.

During the 30 day performance trial period, the Contractor shall collect samples and carry out analyses for the parameters listed in accordance with the sampling schedule at the end of this section of the Specification.

Every sample taken shall be divided into three equal portions; one portion shall be used for analysis by the Contractor's chemist, in accordance with the schedule. This analysis shall be witnessed by the Employer's chemist. The second portion may be used by the Employer for analysis at the discretion of the Employer. The third portion shall be retained as a check sample. The sample volume shall be at least 3 litres.

The Employer may, at its own discretion, carry out additional sampling and tests at its own laboratories or accredited laboratories as it deems necessary.

The methods to be used to analyse the listed parameters shall be as given in Standard Methods for the Examination of Water and Wastewater; APHA-AWWA-WPCF, latest edition, as follows:-

Parameter	**Method Reference**
Turbidity	2130-B
Colour	2120-C
pH	4500-H^+ B
Alkalinity	2320-B
Aluminium	3500-Al E
Iron	3500-Fe D
Manganese	3500-Mn D
Chlorine residual	4500-Cl G
Bacteriological quality	9222-B and D

Any deficiencies or deviations from the guaranteed or specified performance of plant disclosed by the tests shall be corrected by the Contractor and tests shall be repeated as necessary until acceptable results are achieved to the satisfaction of the Engineer.

These tests shall require provision of facilities and man-power, organisation and a high degree of co-operation between the Contractor and the Employer and it shall be deemed that this has been taken into account in the rates and sums entered in the Schedules.

The Contractor shall be responsible for collecting and collating all data and test results and shall carry out all necessary calculations to confirm compliance with the Specification and Performance guarantees. A report comprising test data, results, calculations and conclusions shall be submitted within one week of the date of completion of the tests, or set of tests.

Satisfactory completion of the trial operation is a prerequisite for the Employer to take-over Section I of the Works and the allowance of the Contractor to commence Section II of the Works (Operation and Maintenance Period).

The test procedures to be used for the trial operation during the specified periods shall be as follows:

(a) Works output

The Works output shall be the difference between the clarified water flow and the filter washwater flow. Clarified water flow shall be measured at the common clarifier outlet using the flowmeter in the pipe connecting the clarifiers and the filters totalised during the period when the works is operated at the maximum flow. Filter washwater flow shall be measured in the washwater outlet pipe from the washwater holding tank totalised during the period when the works is operated at maximum flow.

(b) Water quality

Samples of clarified water, filtered water and treated water shall be taken at the specified frequencies and tested by the methods listed in the Specification. Sampling at clarified water and filtered water shall be separated by about two hours and that between filtered water and treated water by about one hour to ensure that the same parcel of water is sampled in one sampling event. The failure of one or more of water quality parameters in filtered water and treated water shall be deemed to be a failure of the water quality test.

(c) Clarifier sludge discharge

Works input shall be monitored at the inlet flowmeter to the works and shall be totalised throughout the test. Losses due to clarifier desludging shall be the works input less the clarified water flow as defined above.

(d) Filter washwater consumption

The total quantity of washwater used during the test period measured at the washwater flowmeter divided by the total quantity of the Works input as defined above for the same period, multiplied by 100 shall be not greater than the filter washwater consumption as stated in the Schedule of Guarantees.

(e) Works chemical consumption

The chemical consumption on the plant to achieve the specified water quality guarantees during the test period shall be not greater than the chemical consumptions stated in the Schedule of Guarantees.

(f) Works energy consumption

The electrical energy consumption of the Works comprising raw water pumping plant, treatment plant and treated water pumping plant over the test period shall be evaluated on the basis of maximum demand and units used and shall be divided by the volume of raw water treated over the same period.

The electrical energy consumption of the Works shall not be greater than the electrical energy consumption stated in the Schedule of Guarantees.

A10.4.2 Test failures

If the performance during the tests of the Works (or any parts thereof) fails to comply with the Specification or with the Contractor's performance guarantees, the Contractor shall submit his proposals for meeting the requirement of the Specification and the guarantees to the Engineer for his approval and shall carry out at his own expense, whichever measures may be necessary to achieve the specified requirements. Such measures may include improvements, alterations or additions to the plant and/or civil works and the Contractor shall bear the whole cost of such modification including any changes to the civil, electrical, instrumentation or mechanical works.

The tests shall be completely repeated and shall be continued until the Engineer is satisfied that the requirements of the Specification and the guarantees have been met.

Failure of any item of equipment or part of the Works which is tested for performance as a separate exercise during the final commissioning tests will require the Contractor to repeat the complete final commissioning test, as specified.

Failure of any one or more of the tests which forms part of the overall Works trial operation will require the Contractor to repeat the complete trial operation. The duration of repeat trial operation shall be not less than 15 days.

In case of repeated failure of the trial operation, the Contractor shall continue to make adjustments to the Plant and repeat the tests until full compliance is reached, or until the Employer, at its sole discretion, decides to accept the Plant, despite the failure of the final commissioning tests or the trial operation. In this event the Contractor shall pay liquidated damages as a result of failure to achieve the guaranteed values of chemical consumption and electrical energy consumption and delay damages to the Employer, in the amount as guaranteed by the Contractor in the Schedule of Technical Particulars.

A10.4.3 Sampling Schedule

Parameters	Minimum sampling freq/24hrs
Raw water	
Turbidity	Every six hours
Colour (true)	Every six hours
Iron	Every six hours
pH	Every six hours
Conductivity	Every six hours
Alkalinity	Every six hours
Manganese	Every twenty four hours
Total coliforms	Every twenty four hours
Aerated water (where applicable)	
Iron	Every four hours
pH	Every four hours
Alkalinity	Every four hours
Clarified water	
Turbidity	Every one hour
Aluminium	Every four hours
pH	Every four hours
Alkalinity	Every four hours

Parameters	Minimum sampling freq / 24hrs
Filtered water	
Turbidity	Every two hours
Aluminium	Every four hours
Iron	Every four hours
Treated water	
Turbidity	Every two hours
Colour	Every eight hours
pH	Every two hours
PHs	Every twelve hours
Aluminium	Every eight hours
Iron	Every eight hours
Manganese	Every twenty four hours
Chlorine residual	
- total	Every two hours
- free	Every two hours
Bacteriological quality	Every twenty four hours
Thickener supernatant	
Turbidity	Every twelve hours

A10.5 Cleaning and sterilisation of structures

The greatest care shall be taken to ensure that all process unit tanks are kept free from contamination.

In addition the following structures shall be sterilised in accordance with the procedure set out below: -

- Pipes, channels and mixers from filter outlets to treated water reservoir;
- Chlorine contact tank and treated water reservoir;
- Pipe feed to treated water pumping station;
- Treated water pumping station pipework;
- Treated water surge vessels (where applicable);
- Treated water pumping main connecting to the Break Transfer Tank;
- Pipe main connecting the Break Transfer Tank to the MADAM master balancing reservoir;
- MADAM master balancing tank and the outlet main under the scope of this Contract;

The Contractor shall subject all workmen who will be engaged in sterilising structures to a medical examination by a doctor Approved by the Employer. Only workmen considered fit by the examining doctor shall be permitted to enter the structure for carrying out any work associated with the sterilisation procedure. The Contractor shall keep a separate register of all such labour and shall forward a copy to the Engineer prior to commencing such work. The Contractor shall maintain strict supervision over all workmen entering the tanks. The Contractor shall provide rubber boots and means for the workmen to wash their boots clean and sterilise them before entering the structure.

The Contractor's sterilisation procedure shall strictly adhere to Chlorination Method 3 as set out in AWWA Standard C652-92, 'Disinfection of water-storage facilities' and C651-99 ‘Disinfection of water mains’. The Employer will carry out the necessary sampling in the presence of the Contractor, and the subsequent physical and bacteriological analysis. The Engineer will advise the Contractor of the results. Should the tests fail the procedure shall be repeated as many times as may be necessary to achieve satisfactory results.

The Contractor shall make all arrangements necessary for conveying the water from the source to the point of filling and such arrangements shall be subject to the approval of the Engineer. The Contractor shall provide all hoses, pumps and other equipment necessary to carry out the tests. The Contractor shall also provide all water and chemicals necessary to sterilise structures, which shall be of a type and from a source Approved by the Engineer.

The Contractor shall note that these structures are Confined Spaces as defined in the Specification and that during the sterilisation process the levels of chlorine in the atmosphere may exceed acceptable occupational exposure limits. The work shall be subject to the specified requirements for entry and working in Confined Spaces, and the Contractor shall provide all necessary trained personnel and equipment as specified.

A11.0 TESTING OF PLANT

A11.1 General

The requirements for testing shall be as specified below.

A11.2 Pumps, valves and pipe work and general purpose machinery

A11.2.1 Off-site inspection and testing

(a) Pumps

Pumps shall be individually tested in accordance with BS EN ISO 5198 Part 2 (Class and the tests shall be with clean water. Site conditions shall be simulated as nearby as possible including the NPSH condition. Pumps shall be tested with their own prime movers. Where it is impracticable to include the full length of the connecting shaft, the Contractor shall state the allowances to be made for the losses incurred by its omission and shall demonstrate the accuracy of the allowances to the satisfaction of the Engineer.

Pumps shall be tested at the guaranteed duty point and over the full working range from the closed valve condition to 20 percent in excess of the quantity when a single pump runs alone at minimum head. The tests shall provide information for performance curves to be drawn for head/quantity, efficiency/quantity, power absorbed/quantity and net positive suction head/quantity. Readings shall be taken at a minimum of seven points in addition to shut-off condition. Each pump shall also be run at its duty point for at least 30 minutes.

Positive displacement pumps shall be tested in accordance with BS EN ISO 9906.

For eccentric helical rotor pumps the tests shall provide information for performance curves to be drawn for pump speed/flow, input power absorbed/flow differential pressure/flow and pump efficiency/flow.

Pump casings shall be subject to a pressure test at 1.5 times the pressure obtained with the delivery valve closed. The positive suction head when installed shall be taken into account in determining this pressure. During the test, the casing and joints shall show no signs of leakage, distortion or defect.

In addition to confirming the specified hydraulic performance of the pump set, the test shall demonstrate that vibration is within the specified limits, the mechanical performance is satisfactory and the noise level is within the specified limit.

Additionally chemical dosing pumps shall be tested in accordance with API standard 675 and the specified flow linearity, steady state accuracy and flow rate shall be demonstrated.

(b) Valves and Penstocks – General

Valves and penstocks specified as operated by actuators shall be tested with their own actuator. For valves and penstocks fitted with power operated mechanisms, the test shall be carried out to demonstrate correct manual and power operation.

(c) Gate valves

Gate valves shall be tested in accordance with BS EN 1171 or BS 5163 and BS 6755 Part 1 as relevant. Whichever applies, valve seat tests shall be made under open-end conditions, the test pressure being applied to each face of the valve in turn.

(d) Butterfly valves

Butterfly valves shall be tested in accordance with BS EN 593 and BS 6755 Part 1. The seat test shall be for tight shut-off and low leakage. Valves shall be tested under maximum unbalanced water test pressure in either direction.

(e) Air valves

Air valves shall be water tested for drop-tightness at all pressures from 0.2 bar in steps of 2 bar up to the specified pressure. The valve body shall be water tested at 1.5 times the specified pressure, at which pressure no damage or permanent deformation of the valve body, ball or seat shall occur.

Two valves of each type and size incorporating large orifices shall be tested for exhaust of air at a differential pressure up to 1 bar in steps of 0.1 bar and for inflow of air at a differential pressure up to 0.5 bar in steps of 0.1 bar. During the tests the air flow rates shall be measured by orifice plates in accordance with BS 1042. Pressures (positive or vacuum) shall be measured by Bourdon tube gauges or by mercury-in-glass manometers. The temperature of the flowing air shall be measured in accordance with relevant parts of BS 1041. The barometric pressure shall also be measured.

If the manufacturer provides results of independently witnessed air flow tests similar to those specified and these are accepted by the Engineer, the specified airflow tests shall be deemed to be completed.

(f) Check valves

Check valves shall be tested in accordance with the requirements of BS EN 12334 and BS 6755 Part 1.

(g) Pressure and flow control valves

Pressure and flow control valves shall be tested hydrostatically as follows:-

Body strength:	closed-end test, valve open, test pressure 1.5 times working pressure;
Valve element strength:	open-end test, valve closed, test pressure of 1.5 times working pressure applied to each end;
Leak tightness:	open-end test, valve closed, test pressure of the working pressure applied to inlet end, no visible leakage permitted.

(h) Ball float valves

Ball float valves shall be tested hydrostatically in the closed position and a pressure of 1.5 times the working pressure applied to the inlet end.

Valves shall be tested for drop-tightness at the working pressure.

(i) Plug valves

Plug valves shall be subject to hydrostatic shell and seat tests in accordance with BS 5158 and BS 6755 Part 1.

(j) Diaphragm valves

Diaphragm valves shall be tested in accordance with BS EN 13397 and BS 6755 Part 1.

(k) Ball valves

Ball valves shall be tested in accordance with BS 5159 and BS 6755 Part 1.

(l) Globe valves

Globe valves shall be tested in accordance with BS EN 13789 and BS 6755 Part 1. Seating shall be tested hydrostatically at 2400 kN/m^2 and the valve shall be tested for 1500 kN/m^2 working pressure.

(m) Penstocks

Penstocks shall be operated from fully closed to fully open positions to verify correct operation.

Penstocks shall be tested in accordance with BS 7775 and AWWA C501 as relevant.

(n) Electric actuators

Electric actuators shall be tested in accordance with the Reference Standards. Compliance with the specified functional and performance criteria shall be demonstrated.

(o) Pneumatic actuators

Pneumatic actuators shall be tested in accordance with the Reference Standards. Compliance with the specified functional and performance criteria shall be demonstrated.

(p) Pipe work

Pipe work shall be tested in accordance with the appropriate Reference Standards.

(q) Castings

Castings shall be tested hydrostatically to 1.5 times the maximum working pressure for a minimum period of 1 hour.

(r) Surge vessels

Surge vessels shall be tested in accordance with the Reference Standards.

(s) Cranes

Cranes shall be completely assembled and tested for all operations in accordance with BS 466. All slings, ropes, shackles and other lifting equipment shall be tested at 1.25 x their Safe Working Load.

(t) Weighers

All weighing equipment shall be tested for accuracy with standard weights and shall be load tested at 1.25 times the safe working load

(u) Automatic in-line strainers

Automatic in-line strainers shall be tested in accordance with the Reference Standards and with manufacturer's own requirements.

(v) Air supply plant

Tests shall be carried out on all items of plant, vessels, pipe work and valves to demonstrate compliance with the criteria specified and with relevant standards. Unless otherwise specified the tests shall be in accordance with the Reference Standards including BS 6754 for dryers, BS 6759 Part 2 for safety valves, BS 1123 Part 1 for fusible plugs, BS 3274 for after coolers, BS 5169 for air receivers, BS 1571 for compressors and BS 5500 for pressure vessels and the manufacturer's own procedures.

Noise level of all the compressors and blowers shall be tested and shall not exceed the specified limit.

For package units' functional tests of the fully assembled system shall be carried out to demonstrate correct operation with respect to sequence and pressure.

A11.2.2 Individual tests

The following Site inspections and tests shall be carried out as appropriate:

(a) Inspection to check the assembly of the Plant and conformity with the Specification and consented drawings;
(b) Rotational checking of all electric motors;
(c) Hydrostatic testing of all gravity flow pipe work systems and penstocks at the maximum head or differential head that can occur in service. Leakage from penstocks shall be measured and recorded but shall not exceed the maximum value stated in the AWWA C501 or BS 7775 or otherwise required for safe operation;
(d) Hydrostatic testing of all pressurised pipe work systems at 1.5 x maximum working pressure for a period of at least one hour; during this time the pressure shall not change;
(e) Functional testing of each pump, compressor and blower to prove correct operation, absence of fluid leaks, correct bearing temperatures and absence of undue vibration and noise for a period of not less than four hours;
(f) Functional testing of auxiliary items including automatic in-line strainers and valve actuators;
(g) Functional testing of valves to demonstrate correct orientation and operation;
(h) Overhead cranes and slings, ropes, shackles and other lifting equipment shall be tested with a load of 1.25 x Safe Working Load and results recorded in accordance with the Reference Standards. Additionally each complete system shall be tested for all functions including overload safety device;
(i) All weighers shall be tested with standard weights for accuracy and shall be load tested at 1.25 x the Safe Working Load;
(j) The following tests shall be carried out on the installed air supply systems:

- The air pipe work system shall be tested for 1 hour at 1.5 x maximum working pressure using dry air or nitrogen;
- Pressure safety valve operation shall be demonstrated;
- Performance tests shall be carried out on all machinery, coolers and dryers for a minimum period of 48 hours with air demand simulated by purging at measured rates downstream of all plant subject to testing; the purging rates shall correspond to zero demand, maximum demand and at least one intermediate value.
- The tests shall prove correct operation, absence of fluid leaks, correct operating pressures, temperatures and dew point and absence of excessive vibration and noise with due regard to any containment and attenuation provisions.

A11.3 Mixers, flocculators and scrapers

A11.3.1 Off-site inspection and testing

The complete mixer, flocculator and scraper system shall be checked for accuracy of dimensions against construction drawings and all welds inspected.

A11.3.2 Individual tests

The following Site inspections and tests shall be carried out as appropriate:

(a) Inspection to check the assembly of the plant and conformity with the Specification and approved drawings;
(b) Rotational checking of all electric motors;
(c) Tip speed and flight speed, as applicable;
(d) Rotation speed;
(e) Functional testing of the mixers, flocculators and scrapers;
(f) Scraper torque overload protection device;
(g) Head loss across static mixers at maximum works throughput.

A11.3.3 Final commissioning tests

The testing shall incorporate the following requirements.

The performance of the static mixers shall be tested for compliance over a 30 minutes period by dosing the chemical corresponding to each mixer at the specified doses and concentrations. Alternatively a solution of sodium chloride shall be injected continuously at a fixed dose in the range 10 to 20 mg/l or a fluoride solution at 1.0 mg/l as F. The injection velocity shall not be greater than that applicable to the specified chemical dosing. The mixer performance shall be determined by measuring either the conductivity or the chloride or the fluoride ion concentration. The background conductivity value or chloride or fluoride ion concentration shall be monitored during the test. The water shall be sampled continuously at the prescribed sampling points from at least four different positions along a diameter of the pipe using a sampling system specially designed for the purpose.

A11.4 Filters

A11.4.1 Off-site inspection and testing

Upon preliminary approval of sources of filter material supply and within two months of the award of Contract, the Contractor shall submit to the Engineer a 10 kg of representative sample of each filter material for testing and approval as specified.

Filter material (sand and gravel) shall be tested by the Contractor before despatch from source in accordance with the following schedule. Certificates for all tests shall be delivered to the Engineer for approval or rejection before the material is despatched.

(a) For a volume equivalent to the volume in each filter Grading curve, effective size and uniformity coefficient.
(b) Additionally for a volume equivalent to the volume in 2 filters Specific gravity and losses of weight on acid washing and ignition.
(c) Additionally every 500 m3 or every batch, whichever is the smaller Loss due to abrasion.

A method of identification shall be employed to enable test certificates to be related to shipments of media delivered to Site.

A11.4.2 Individual tests

The following Site inspections and tests shall be carried out as appropriate:

(a) On delivery to Site, one kg of filter material shall be taken from a selection of bags until 12 kg is obtained. The samples shall then be mixed and quartered before testing as follows:-

(i) Gravel: a sample shall be taken from each delivery to Site as described above and graded. Samples shall be examined to ensure they are similar to the initial 10kg sample.

(ii) Sand: samples shall be taken from each delivery to Site as described above. Tests shall include a sieve analysis and preparation of grading curves, and shall give effective size, uniformity coefficient and specific gravity. A visual inspection shall also be carried out to ensure it is similar to the initial 10 kg sample.

In addition to the above tests, certificates for each load equal to one filter volume shall include tests to determine loss on acid washing and ignition as applicable to the filter material.

(b) Inspection to check the assembly of plant and conformity with the Specification and approved drawings;

(c) Pumps and valves shall be tested as specified;

(d) Functional testing of each air blower for correct operations, absence of fluid leaks, correct bearing and gearbox temperature and absence of undue noise and vibration;

(e) Relief valve operation and blower unloading device shall be demonstrated.

A11.4.3 Final commissioning tests

Testing shall incorporate the following requirements:

(a) Filter underdrain

Filters shall be tested as follows before any filter material is placed and additionally, in the case of pipes lateral system before placing concrete on the pipes:-

(i) Air distribution test

The empty filter bed shall be filled with water to a level 150mm above the top of the nozzles. Air shall then be passed into the underdrain system at such a rate that the system can be seen to pass air thorough the nozzles over the whole filter area. Any discrepancies in distribution shall be rectified and the test repeated.

(ii) Pressure test with water

All the nozzle outlets shall be plugged. The filter underdrain system shall then be filled with water and a pressure of (a-b+c) applied to the underside of the filter floor or to the piped lateral system as applicable where:

a = twice the normal peak pressure during a combined air and water filter wash, or separate air and water filter wash as applicable to the design, measured under the filter floor or in the filter laterals;

b = the downwards pressure on the floor due to the weight of media and water which would be present during air scouring;

c = the pressure due to any water present in the filter above the floor during the test.

Any pressure relief pipe on the wash water supply pipe work shall be blanked off during this test. The test pressure shall be maintained for one hour. Any leaks detected shall be corrected and the test repeated.

After placing the material in the filters and backwashing to remove fines the Contractor shall take samples of the material from each filter and carry out sieve analysis and the results along with grading curves shall be submitted to the Engineer for approval. Only when the Engineer has given approval to the samples, shall the Contractor bring the filters into service.

(b) Manual and automatic backwashing sequence shall be demonstrated

The sampling of sand in the individual filters shall be repeated in the twelfth month of the Defects Notification Period for compliance with the Specification. The results shall be submitted to the Engineer for approval.

A11.5 Chlorine Plant

A11.5.1 Off-site inspection and testing

Tests shall be carried out on all items of plant, pipe work and valves to demonstrate compliance with the criteria specified, with relevant standards and tests specified.

Unless otherwise specified, the tests shall be in accordance with the Reference Standards, the manufacturers' own tests and those set out below:-

(a) Welders of chlorine plant and pipe work shall be tested and approved in accordance with the requirements of the appropriate part of BS 4871;

(b) Non-destructive tests including radiography and/or other methods as specified shall be carried out on all welds in plant and pipe work;

(c) All gas isolating valves shall be tested in accordance with BS 6755 Part 1;

(d) All parts of the drum lifting system and suspended weigher shall be certified for a safe working load of 3.2 t and tested with a load of 4.0 t;

(e) Changeover control panels shall be tested in accordance with tests specified for instrumentation;

(f) Spray catcher shall be subjected to hydrostatic pressure hold test of 1.5 x design pressure for at least one hour;

(g) All gas handling plant shall be subjected to the following tests:-

(i) Vacuum hold test for 1 hour where items normally operate under vacuum;

(ii) Pressure hold test at 1.5 times the design pressure for at least one hour using air or nitrogen. Where items normally operate under vacuum, a pressure hold test at a pressure of at least 1.5 bar g or the highest pressure that can occur under fault conditions whichever is greater shall be carried out.

(h) Functional tests shall be carried out on all shut-off valves, vacuum regulators, pressure relief valves, gas control units, ejectors and related items which shall be temporarily rigged as systems to demonstrate correct operation and calibration. Water supply pressure and solution back-pressure for these tests shall be set to the limiting values anticipated at Site.

A11.5.2 Individual tests

The following Site inspections and tests shall be carried out as appropriate:-

(a) Inspection to check assembly of the Plant and conformity with the Specification and approved drawings;

(b) The pressurised gas pipe work system up to the vacuum regulator inlet connections shall be tested for at least one hour at 1.5 x maximum working pressure at 40°C using dry air or nitrogen; during this time the pressure shall not change. Where necessary, system pressure gauges may be removed prior to testing. On re-instatement of the gauges, the system shall be re-tested at the gauge maximum reading;

(c) The gas pipe work system from the vacuum regulators including gas control units up to the ejector inlet connections shall be subjected to the following tests each for a period of at least one hour:
   (i) Vacuum hold test for one hour;
   (ii) Pressure hold test at a pressure of 1.5 bar g using dry air or nitrogen;

(d) Relief valve operating pressure shall be demonstrated;

(e) The chorine solution pipe work including ejectors and all components up to the point of application shall be tested hydrostatically for at least one hour at 1.5 x maximum working pressure or 5 bar g whichever is greater. Manufacturers' recommended procedures shall be followed prior to execution of this test with particular reference to:
   (i) Elimination of air on filling with cold water;
   (ii) Temperature equilibration;
   (iii) Stepwise application of test pressure starting at not more than 3 bar g for 10 minutes.

(f) The complete drum lifting system shall be tested with a load of 4.0 t and results recorded in accordance with the Reference Standards;

(g) Suspended weigher shall be tested for accuracy with standard weights and shall be load tested at 4 t;

(h) A functional test shall be carried out on the container changeover system using dry air or nitrogen at pressures up to the maximum working pressure of the system.

A11.5.3 Final commissioning tests

Testing shall incorporate the following requirements:-

(a) Functional tests shall be carried out using dry air or nitrogen on the vacuum regulators, pressure relief valves, gas control units, ejectors and related items as a system to demonstrate correct operation;

(b) Following satisfactory completion of the foregoing tests, functional testing with chlorine shall be carried out to demonstrate correct operation and calibration of the Plant.

A11.6 Aluminium sulphate plant

A11.6.1 Off-site inspection and testing

Tests shall be carried out on all items of plant, vessels, pipe work and valves to demonstrate compliance with the criteria specified and with relevant standards and tests specified.

Unless otherwise specified, the tests shall be in accordance with the Reference Standards and the manufacturers' own procedures.

A11.6.2 Individual tests

The following Site inspections and tests shall be carried out as appropriate:-

- Inspection to check the assembly of the plant and conformity with the Specification and approved drawings;
- Rotational checking of all electric motors;
- Functional testing of all auxiliary items including mixers;
- All tanks shall be filled to overflow level and inspected for absence of leaks;
- Hydrostatic testing of all pipe work systems at 1.5 x maximum working pressure for a period of at least one hour; during this time the pressure shall not change;
- Relief valve operating pressure shall be demonstrated;
- Functional testing of each pump to prove correct operation, absence of fluid leaks, correct gearing and gearbox temperatures and absence of undue vibration and noise.

A11.6.3 Final commissioning tests

Testing shall incorporate the following requirements:-

- Functional testing (without aluminium sulphate) of the batching system to demonstrate correct operation with respect to sequence, time, and levels;
- Functional testing of the batching system with aluminium sulphate to demonstrate correct operation and calibration;
- Dosing equipment calibration shall be demonstrated and specified accuracies shall be confirmed.

A11.7 Hydrated lime plant

A11.7.1 Off-site inspection and testing

Tests shall be carried out on all items of plant to demonstrate compliance with the criteria specified, with relevant standards and tests specified.

Unless otherwise specified, the tests shall be in accordance with the Reference Standards and manufacturers own procedures.

A11.7.2 Individual tests

The following Site tests shall be carried out as appropriate:-

- Inspection to check the assembly of the plant and conformity with the Specification and approved drawings;
- Rotational checking of all electric motors;
- Functional testing of all ancillary items including mixers;
- The slurry tanks and saturators shall be filled with water to overflow level and inspected for absence of leakage;
- Water and slurry pipe work and all components up to the point of application shall be tested hydrostatically for one hour at 1.5 x maximum working pressure;
- Relief valve operating pressure shall be demonstrated;
- Functional testing of each pump to prove correct operation, absence of fluid leaks, correct beaming and gearbox temperatures and absence of undue vibration and noise.

A11.7.3 Final commissioning tests

Testing shall incorporate the following requirements:-

- Functional tests shall be performed on the solids handling systems with demonstration of correct operation of safety devices including silo pressure relief valves, all prior to charging with hydrated lime;
- Functional tests (without hydrated lime) shall be performed on the slurry batching systems and saturators demonstrate correct operation with respect to sequence, time and levels;
- Functional tests shall be performed on the solids handling and slurry batching systems with lime to demonstrate correct operation and calibration when handling hydrated lime;
- Functional tests shall be performed on the slurry dosing systems to demonstrate correct operation and calibration when handling hydrated lime and specified accuracies shall be confirmed in operation.

A11.8 Water sampling equipment

A11.8.1 Off-site inspection and testing

Tests shall be carried out on all items of plant to demonstrate compliance with relevant standards. Pumps shall be tested as specified.

Unless otherwise specified, the tests shall be in accordance with the Reference Standards, the manufacturers' own tests where applicable.

A11.8.2 Individual tests

The following Site inspections and tests shall be carried as appropriate:-

- Inspection to check the assembly of the Plant and conformity with the Specification and approved drawings;
- Sample water pipe work and components shall be tested hydrostatically for 1 hour at 1.5 x maximum working pressure or 5 bar g whichever is greater. During the test the pressure shall not change;
- Drain pipe work shall be flushed and inspected visually for absence of leaks;
- Water quality monitoring instruments shall be tested as specified.

A11.8.3 Final commissioning tests

Testing shall incorporate the following requirements:-

- Functional testing of the sampling system (including water quality monitoring instruments);
- Sample lines shall be flushed and delivery rates checked for example by timing water into a calibrated vessel against a stop watch.

A11.9 Works water supply system

A11.9.1 Off-site inspection and testing

Tests shall be carried out on all items of plant to demonstrate compliance with the criteria specified, with relevant standards and tests specified.

Unless otherwise specified, the tests shall be in accordance with the Reference Standards and manufacturers own tests where applicable.

A11.9.2 Individual tests

The following Site inspection and tests shall be carried out as appropriate:-

- Inspection to check the assembly of the Plant and conformity with the Specification and approved drawings;
- Rotational checking of all electric motors;
- Hydrostatic testing of all pipework systems at 1.5 x maximum working pressure for a period of at least one hour during which the pressure shall not change;
- Service water storage tank shall be filled to overflow level and inspected for absence of leaks;
- Testing of safety showers and eye baths for correct operation.

A11.9.3 Final commissioning tests

Testing shall incorporate the following requirements:-

- Functional testing of the hydropneumatic system to demonstrate correct operation with respect to sequence, pressure and level;
- Functional testing of the system including the elevated water storage tank with respect to sequence and level.

A11.10 Miscellaneous tests

A11.10.1 General

Miscellaneous tests shall include tests for hydraulic pallet trucks, safety equipment, and chlorine contact tank and access equipment.

A11.10.2 Off-site inspection and testing

Tests shall be carried out on all items of plant to demonstrate compliance with the criteria specified, with relevant standards and tests specified.

Unless otherwise specified the tests shall be in accordance with the Reference Standards and the manufacturer's own procedures.

A11.10.3 Individual tests

The Site inspection and testing shall incorporate the following:-

- Pallet trucks shall be tested to 1.25 x Safe Working Load;
- Testing of access equipment for stability;
- Inspection of safety equipment to check sufficiency of supply and satisfactory installation.

A11.10.4 Final commissioning tests

The testing shall incorporate the following requirements:-

- Chemical tracer tests using sodium chloride at a concentration of about 20 mg.l (with either conductivity or chloride concentration measurements) or fluoride at concentration less than 1.0 m/l as F (using specific ion electrode for concentration measurement) shall be carried out to demonstrate that the specified effective contact time in the chlorine contact tank has been satisfied at the maximum works throughput;
- Time to completely drain a clarifier from full.

A11.11 Switchgear and control gear

A11.11.1 Off-site inspection and testing

Tests shall be carried out to demonstrate compliance with the Reference Standards and the specified functional and performance criteria.

Unless otherwise specified, the tests shall be Routine Tests in accordance with the Reference Standards and the following additional tests as appropriate to demonstrate:-

(a) 415V switchboards and MCCs

(i) Power frequency test of busbars with circuit breaker connected;
(ii) The interchangeability of withdrawable equipment;
(iii) The correct operation of electrical and mechanical interlocks;
(iv) The correct and accurate functioning of current and voltage operated protection relays by primary and secondary current injection and voltage application;
(v) The correct polarity between current and voltage elements of power operated protective devices, instruments and metering;
(vi) Meters do not creep with the removal of either the current or voltage supply.
(vii) The correct operation of control circuits, indications and alarms;
(viii) Where necessary a suitable test panel shall be provided for simulation of external controls and signals during such tests;
(ix) The calibration of ammeters Voltmeter, KW meter, PF meter, H_Z meter etc at 0.25, 0.5 and full scale deflection by secondary current injection;
(x) The calibration of transducers;
(xi) Type and special tests shall be carried out when specified.

(b) 33kV/11kV/6.6kV/3.3kV switchboards Power frequency voltage tests:-

(i) Power frequency high voltage pressure test with all breakers racked in and closed, between phases and from phase to earth;
(iii) Pressure test on secondary small wiring circuits;
(iv) Milli-volt drop tests - Milli-volt drop (Ductor) test across circuit breaker contacts and between extreme terminals on individual panels, (for comparison purposes, the manufacturer shall state design values for each size and rating of equipment);

(v) Operational closing tests - These tests are to ensure the operation of closing coil or spring release coil and satisfactory closing of the circuit-breaker with the voltage on the coil down to 80% of its rated voltage and to ensure that mal-operation does not occur, with a voltage at the coil of 120% of its rated voltage;

(vi) Operational opening tests - These tests are to ensure the satisfactory operation of the shunt trip circuit, and the tripping of the circuit-breaker at no load conditions with the trip coil energised at 50% of its rated voltage;

(vii) Mechanical tests - All mechanical interlocks on the switchgear panels shall be thoroughly tested to ensure their correct operation, together with mechanical tripping, opening and isolating devices;

(viii) Interchangeability - Withdrawable circuit-breaker panels of identically equipped units shall be capable of inter-changing of circuit-breaker trucks. This facility shall be proved. A check shall also be carried out to ensure that the inter-changeability shall not be possible between incoming and outgoing feeder circuit-breaker trucks;

(ix) Heat run tests - Heat run tests will not be required on panels manufactured under this Contract provided type test figures for heat runs carried out on identical panel types are made available for inspection by the Engineer;

(x) General operation tests;

(xi) In addition to the tests given above, tests shall be conducted, where applicable, for the following purposes-

- to ensure satisfactory tripping of the circuit-breakers with the closing coil energised;
- to prove satisfactory mechanical behavior of the circuit-breaker when the closing coil is energised with the tripping coil also energised;
- to prove that the operation of the power closing device when the circuit-breaker is already closed causes neither damage to the circuit-breaker nor danger to the operator;
- Protection and control circuits;
- For all forms of current transformer protection, the following information shall be made available to the Engineer prior to the time of inspection:-
- Current transformer magnetising curve;
- Recommended relay setting;
- Calculated primary operating current at this setting;
- Calculated through fault stability values, where applicable;
- Values of any stabilising and setting resistors employed in the scheme.

(xii) As far as possible, based on the completeness of the circuits in the final manufactured form within the manufacturer's premises, the satisfactory operation of associated control and protection circuits shall be proved by the following tests:-

- to ensure the correct operation of all current operated protection relays and direct acting coils at the recommended setting by current injection;
- to ensure the correct polarity between current and voltage elements of power relays, meters and instruments;
- to ensure the correct operation of control circuits at normal operating voltage by operation of local control switches and simulation of operation from remote control positions.

Note: The checking of the operation of all protection relays and control circuits is to be carried out with all closing and tripping circuits energised at their normal rated voltage.

(xiii) Instrument and metering equipment-

- Indicating ammeters shall be checked for calibration at 0.25, 0.5, 0.75 and full scale deflection by primary current injection testing;
- Indicating voltmeters shall be checked for normal voltage readings by voltage application;
- Frequency, power factor and kilowatt meters shall be tested for accuracy of indication;
- Integrating kWh meters shall be tested for correct rotation. Creep tests shall be carried out to ensure that the meter is inoperative with voltage alone, if the secondaries of current transformers are left connected with the primary current interrupted;

- All transducers shall be tested for at least 5 different points in the complete working range of each unit.

(xiv) Current transformers;
(xv) Verification of terminal markings;
(xvi) High voltage power frequency withstand test on primary and secondary windings;
(xvii) Over-voltage inter-turn tests;
(xviii) Test for accuracy;
(xix) Voltage transformers ;
(xx) Verification of terminal markings;
(xxi) High voltage power frequency dry withstand test on primary windings;
(xxii) Test for accuracy;
(xxiii) Visual inspection;
(xxiv) Inspection of paintwork and measurement of paint thickness shall be carried out. Dimensional checks shall be also carried out.

A11.11.2 Individual Tests

The following Site inspections and tests shall be carried out as appropriate:-

(a) 415V Switchboard and MCC

(i) Insulation resistance of main connections and secondary wiring using an approved insulation tester. The test shall be carried out between phases and phase to earth. All circuit-breakers, switches and contactors shall be in circuit and closed;
(ii) The correct operation of electrical and mechanical interlocks shall be demonstrated;
(iii) The correct and accurate operation of current and voltage operated protection relays shall be demonstrated by primary and secondary current injection and voltage application. At least two points shall be demonstrated for each relays. Simulation test on the operation of thermal overload relay for motor shall not be acceptable. Actual test on thermal overload relay for motor shall be carried out;
(iv) The stability of unit protection systems shall be demonstrated by primary current injection;
(v) The correct operation of control circuits, indications and alarms shall be demonstrated;
(vi) The continuity of all protective conductors shall be checked;
(vii) The correct operation of intertripping circuits shall be demonstrated;
(viii) Demonstration of accurate operation at 50% and 10% of working range on all measuring devices, meters and transducers;
(ix) Any tests required by the electricity supply company.

(b) 33kV/11kV/6.6kV/3.3 kV Switchboard

(i) Pressure testing - Power frequency pressure test shall be carried out on equipment for use on systems above 1000 volts. For systems up to 1000 volts the insulation resistance of the equipment shall be tested with a 500 volt Megger hand generator. These tests shall be carried out with all circuit phases and phase to earth. All secondary small wiring circuits shall be similarly tested;
(ii) Mechanical tests - All mechanical tests specified and carried out at Manufacturer's premises are to be re-checked to ensure satisfactory operation of the Works in the final erected state;
(iii) Interchangeability - On withdrawable circuit-breaker panels identically equipped units such as incoming and outgoing panels shall be capable of inter-changing of circuit-breaker trucks. This facility is to be proved;
(iv) Protection and control circuits - The satisfactory operation of all current operated protection circuits over their whole operating range and correct connection of CT wiring shall be tested by primary current injection;
(v) The checking of the operation of all protection relays and control circuits shall be carried out with all tripping circuits energised;

(vi) The satisfactory operation of all inter-tripping circuits shall be tested;

(vii) The satisfactory operation of control circuits shall be tested from local and from remote positions;

(viii) Indicating ammeters - Indicating ammeters shall be checked for calibration at 0.25, 0.5, 0.75 and full scale deflection by primary current injection testing;

(ix) Indicating voltmeters - Indicating voltmeters shall be checked for normal voltage reading by voltage application;

(x) Integrating kWh meters - Where possible kWh meters shall be tested for correct rotation. Creep tests shall be carried out to ensure that the meter is in-operative with voltage alone, if the secondaries of current transformers are left connected with the primary current interrupted;

(xi) Other indicating meters - Other indicating meters including frequency, power factor and kilowatt meters shall be tested for accuracy of indication;

(xii) Transducers - All transducers shall be tested for at least 5 different points in the complete working range for each unit;

(xiii) Current transformers - Current transformers shall be tested for the following:-

- verification of terminal markings;
- high voltage power frequency withstand test on primary windings;
- test for accuracy;

(xiv) For all forms of current transformer protection the following information shall be made available to the Engineer prior to the time of testing:-

- current transformer magnetising curve;
- recommended relay testing;
- calculated primary operating current at this setting;
- calculated through fault stability values where applicable;
- values of stabilising and setting resistors;

(xv) Voltage transformers - Voltage transformers shall be tested for the following:-

- verification of terminal markings;
- high voltage power frequency withstand test on primary windings;
- test for accuracy;

(xvi) Operational sequence tests - Tests shall be carried out on all starter panels to test operational sequence and operation of protection devices. Sequential tests for pump- motor shall be able to carry out when putting the VCB at “Test” position without required to modify any control circuit;

(xvii) Continuity of earth conductors - Continuity tests shall be carried out on the earth conductor of the switchboard, such tests being by current injection;

(xviii) This does not include the earth resistance test of the station earthing system which shall be tested as detailed elsewhere in the Specification.

A11.12 Electric motors

A11.12.1 Off-site inspection and testing

Motors shall be inspected and tested to show that they are compliant with the Specification and approved drawings.

Tests shall be in accordance with BS 4999:Part 143. For low voltage standard production motors for general use, the tests shall be routine checks. For high voltage and low voltage motors for main drive application, the tests shall be duplicate.

If the test to determine the locked rotor current of cage induction motors is carried out at reduced voltage, allowance shall be made for the effect of saturation when adjusting for rated voltage. The estimated value of locked rotor current at rated voltage shall be stated on the test certificate.

A Polarisation Index test shall be carried out for high voltage motors.

The requirement for "basic" or "special" tests shall be as specified.

A11.12.2 Individual Tests

Each motor shall be inspected prior to site testing for:-

- Absence of damage during transportation and erection;
- Absence of moisture or other contamination;
- Ventilation openings and drain holes are free of debris;
- Cable glanding and core terminations for tightness and identification;
- Free rotor rotation;
- Free movement of brush gear;
- Remote start/stop/E.stop control box wirings and arrangement;
- Starting interlocks

Unless otherwise specified the following tests shall be carried out on each motor before energising:-

- Winding insulation resistance;
- Polarisation Index for high voltage motors;

- Insulation resistance between motor and heater windings and ancillary devices;
- Calibration of winding and bearing temperature monitoring devices and the operation of alarm and trip initiating contacts;
- Continuity and resistance of winding thermistors;
- Bearing insulation integrity;
- Brush pressure.

Any other tests recommended by the manufacturer or stipulated in the Reference Standards.

On the satisfactory completion of the inspection and tests listed above, motors shall be energised to check for correct direction of rotation, noise and the vibration levels are within the specified limits. The tests shall be carried out with the motor uncoupled from the driven plant.

A11.13 Transformers

A11.13.1 Off-site inspection and testing

Transformers shall be inspected and tested to show that they are fully compliant with the Specification and approved drawings and shall include the following tests as a minimum:-

- Routine tests;
- Measurement on winding resistance;
- Ratio, polarity and phase relationship;
- Impedance voltage;
- Load loss;
- No-load loss and current;
- Insulation resistance;
- Induced over voltage withstand;
- Separate source voltage withstand;
- Magnetic circuit voltage withstand
- Transformer tank oil leakage test (1 kg/cm^2 for 24 hours);
- Transformer noise level measured in accordance with methods and procedures detailed in IEC 551 -Noise level shall not exceed 65dBA;
- Tap changer switching, mechanical and electrical tests according to BS4571;
- Zero sequence impedance measurement;
- Type tests;

- Impulse voltage withstand test;
- Temperature rise test;
- On load tap changer panels;
- Operational tests;
- Sequence tests.

Unless otherwise stated by the Engineer at the time of placing the order, evidence of records of satisfactory type test carried out on identical transformers to those ordered will be accepted in lieu of actual tests on transformers manufactured under this Contract for impulse voltage withstand test. Temperature rise test shall be carried out on one transformer of each size and type. The guaranteed no-load and load losses of each transformer shall be verified at the manufacturer's works. The positive tolerances stipulated in BS 171 shall not be accepted. The Board reserves the right to reject any transformer which does not achieve its declared guaranteed values.

A11.13.2 Individual Tests

The Site inspections and tests to be carried out are as follows:-

- Ratio, polarity and phase relationship;
- Impedance voltage;
- Insulation resistance;
- Oil and winding temperature gauges shall be calibrated and tested;
- Pressure gauges and oil level indicator relays shall be tested with pilot cables connected by mechanical operation of contacts;
- Tap changer equipment including protective devices shall be tested to ensure correct operation;
- Oil tests;

Samples of insulating oil shall be taken and subjected to dielectric strength tests. If the insulating oil fails the site test, the Contractor shall carry out the drying of oil to remove the moisture content or replace the oil and then carry out the oil tests again to comply with BS 148.

A11.14 DC Supply Units

A11.14.1 Off-site inspection and testing

The correct operation of the charger in the float and boost modes and the alarm functions shall be checked.

The following tests shall also be carried out:-

- Insulation resistance test;
- Load stability test;
- Incoming supply line test;
- Ripple voltage measurement with battery disconnected;
- Noise level measurement;
- Dropper diodes functional test;
- Charger automatic changeover test;
- Charger manual changeover test;
- Battery discharge test;
- Burn-in test at 110% load for 8 hours;
- Visual inspection shall be carried out to check the dimensions, paintwork, paint thickness and components inside the enclosures.

A11.15 Instrumentation, Control & Automation

A11.15.1 Tests at manufacturers' works

(a) PLC, SCADA, MMS, Historian, Data Communications

The Contractor shall conduct a full programme of tests of the system at the Contractor's testing facility. The tests shall be carried out in the presence of the Engineer/Employer/Third Party Inspection Agency to verify that all features of the system have been provided, are operating correctly and are in full compliance with the Specification. Unless otherwise specified or agreed by the Engineer, the entire system shall be assembled and tested together as an integrated system, including all servers, all operator's consoles, EICs, field and general access MMI's, all PLC's, data communications networks and telemetry equipment including modems, and uninterruptible power supplies included in this Specification.

Not less than 7 days before the scheduled Factory Acceptance Test (FAT) the Contractor shall give written notification to the Engineer that a complete dry-run of the FAT has been performed successfully, and that in the opinion of the Contractor the system exhibits stable operation and is ready for the formal FAT.

The FAT will be considered successfully completed only when the system has successfully passed all factory tests. The system shall not be delivered to Site until the successful completion of the FAT is certified by the Engineer or unless otherwise approved by the Engineer Delay in the delivery of the system due to failure of the FAT shall not constitute an unavoidable delay. If the system fails the FAT, the test shall be extended or rescheduled at the discretion of the Engineer.

All hardware to be used in the testing of the system shall have passed an agreed preliminary hardware performance test to ensure known hardware operability before software testing begins.

After successful completion of the factory acceptance test, no software changes shall be made to the system without written authorisation by the Engineer. Any changes to the system which effect the system software documentation, such as input scale modifications or changes to the control logic, shall be entered into the system documentation before delivery of the system to Site.

The scope of the tests shall include the proving of every aspect of hardware and software operation and functions as detailed below:-

(i) Hardware tests

- Verify the correct inventory of hardware
- Demonstrate that all spare memory, disk capacity and system expansion requirements have been met.
- Demonstrate that all input and output expansion requirements have been met, including wiring and signal isolation, and verify that power supplies are capable of supporting the increased load for this expansion.
- Demonstrate all hardware and software diagnostics.
- Verify all power supply voltages are within tolerance.
- Verify proper earth connections and isolation of instrumentation earth for all equipment.
- Demonstrate operation of test simulation and indication equipment and its suitability for adequate functional testing of all system functions.

(ii) Software tests

- Demonstrate the editing of all system parameters including set points, timers, etc.
- Demonstrate system configuration capabilities including the addition and deletion of input and output points, outstations, and all data base parameters.
- Demonstrate the addition, deletion and modification of mimic displays and report formats.

- Demonstrate modification of the communications network.
- Demonstrate the capabilities of the communications monitoring and diagnostic facilities.

(iii) Functional tests

The functional tests shall verify proper operation of every specified system function as an integrated system. These tests shall be conducted in conjunction with functional tests of instrumentation and control panels as specified elsewhere. All failures or discrepancies found shall be documented in the test manual.

Following a failure of any functional test, should software or hardware modifications be required it shall be the decision of the Engineer whether the FAT is to continue, restart or be aborted. If testing is allowed to continue any changes which are required shall be described on a system modification document, signed by both Contractor and Engineer and be incorporated into the final FAT documentation. The failed test shall be re-conducted and the Engineer may require the retest of functions which may be affected by the modification.

The functional tests shall include, as a minimum, the following:

- Verification of proper scanning and data acquisition from all PLCs using the actual communications hardware to be used on-site where possible;
- Demonstration that the system meets the requirements of the Specification for response time and speed of screen update;
- Verification of the accuracy of all analogue input points in the system. The procedure shall include applying the appropriate signal to each analogue input at a minimum of three points within the range of the input, checking for expected numerical results, and verifying appropriate update of related mimic displays. Proper sensing and action by the system to high and low out-of-range inputs shall also be verified;
- Verification of the proper logic sense, pulse accumulation and rate computation where appropriate, of all digital inputs and verifying appropriate update of related mimic displays;
- Verification of all control and sequencing operations and proper operation of all digital and analogue outputs. The procedure shall include simulation of all related process variables for both normal and abnormal conditions, including instrument and component failure, and demonstration of fail-safe response of the system. System outputs shall be indicated with appropriate lamps and indicators;
- Simulation of PLCs communications errors and failures and demonstration of error detection and handling, failure detection and handling, and appropriate changes to control actions as designed and specified;
- Verification of fault detection and diagnostics by inducing a sufficient variety of fault conditions in the system to ensure that detection processes and fail-safe operation are adequately tested;
- Demonstration of proper operation of all mimic displays, help pages, reports, operator procedures and historical data accumulation;
- Demonstration of proper operation of maintenance management system;
- Demonstration of proper operation of note book dial-in;
- Demonstration of proper operation of plant historian system;
- Demonstration of proper operation of all servers;
- Demonstration of proper operation of all PLCs and local MMIs following a simulated failure of both SCADA servers;
- Demonstration of proper operation of all equipment during either a system-wide or isolated power failure, and following power restoration. The procedure shall include the demonstration of battery backup PLCs for the full length of time specified, and proper operation of power fail, low voltage warning and all associated alarms;
- Where redundant systems are specified, demonstration of switch-over to backup systems, including automatic switch-over where specified;

- Verification of the accuracy of all calculated variables and parameters;
- Demonstration of the proper operation of all approved changes to the specified system;

(iv) Reliability test

After successful completion of the functional tests a 48-hour continuous run of the system shall be performed. The test shall be passed if no system function is lost or no hardware or software failure occurs. Hardware failure is defined for this test as the loss of a major component such as the computer, a PLC, a VDU or a peripheral device. Non-repetitive mechanical failures of loggers, push buttons, etc are excluded.

During this test the system shall be exercised with simulated inputs and conditions in a manner which approximates the on-site operational environment. Unstructured testing by the Engineer shall be included during this test. Upon any system failure during this period it shall be the decision of the Engineer whether the reliability test is to continue or be aborted. If testing is allowed to continue any changes to the system which are required shall be described in a system modification document, signed by both Contractor and Engineer and the document shall be incorporated into the final FAT documentation.

(b) Instrumentation

Instrumentation shall be subjected to the manufacturers' own inspection and testing procedures together with a demonstration that an increase or decrease of the measured value at several points over the range of the instrument produces a corresponding increase or decrease in the instrument output signal or reading within the accuracy specified or otherwise required for the application. The factory calibration certificate and test records for all instruments have to be submitted to the Engineer.

Flowmeters shall be factory calibrated and tested on a certified wet test rig. The calibration certificate shall be submitted to the Engineer

Instrument and control panels, electrical interface cabinets inspection and testing shall be carried out to determine that:

- From visual inspection, design and construction are in accordance with the Specification. The engraving, position and fixing of all labels shall be shown to be satisfactory and in accordance with the approval of drawings;
- Power distribution circuits are correctly rated, coordinated and identified;
- Insulation resistance of circuits normally energized at potentials exceeding 50V to earth shall be not less than 10 MΩ between conductors and between conductors and earth using a 500V insulation tester. Any equipment liable to be damaged by the application of the test voltage shall be disconnected prior to testing;
- Each item of equipment within a particular loop and the complete loop function correctly. Each indicator, recorder and controller shall be checked over the whole scale range and there shall be no interaction with any other circuit. Controllers shall be checked for correct operation of control action, auto-manual circuits, cascade circuits, proportional, integral and derivative actions and any special features;
- Alarms function as required. Those initiated from remote contacts shall be tested by opening and closing the circuit at the panel outgoing terminals. Those operated from analogue signals shall be tested by use of a signal injector. Each test shall verify that the correct alarm circuit is operated, the alarm sequence is correct and that there is no interaction with any other circuit;
- Sequence programmes operate as required and that all input and output responses are correct.

A11.15.2 Individual Site tests

(a) PLC, SCADA, MMS, Historian, Data Communications Network

(i) Pre-commissioning tests

The Contractor shall perform pre-commissioning testing of the plant control system in accordance with that specified for instrumentation. The purpose of pre-commissioning tests is to confirm readiness of the system for commissioning.

The scope of pre-commissioning tests shall be generally as specified for FATs but real field inputs and final control elements shall be used wherever practical to provide inputs to the system and to confirm proper outputs. Where this is impractical, simulation signals shall be injected as near as possible to their ultimate sources so as to include in the tests as much of the cabling system as possible.

Pre-commissioning tests for fibre-optic communications networks shall include optical power loss testing and optical time domain reflectometry (OTDR) testing. Should radio or microwave telemetry system be used to connect the raw water pumping station, the water treatment plant and the booster pumping station, the pre-commissioning test shall be carried out with this system be under operation and the Contractor shall demonstrate to the Engineer that the performance of the whole SCADA and PLC system shall conform to the requirements of the Contract at this operation scenario.

Each process system shall be set to work under manual control and the system tested to confirm proper operation.

After proper operation of each manual control mode has be verified, tests of automatic controls for each process system shall be conducted wherever practical.

(ii) Final commissioning tests

The Contractor shall submit all relevant draft operating manuals for the plant control system to the Engineer for approval prior to final commissioning tests. Any faults or failures of the system detected during the previous tests shall be noted and corrected to the satisfaction of the Engineer before final commissioning is allowed to commence.

The plant control system shall be commissioned in accordance with procedures described elsewhere in this Specification, and subject to routine tests as required by the Engineer

The entire control system including field instruments, panels, PLC’s, SCADA system, plant historian and maintenance management system shall be subjected to a comprehensive site acceptance test (SAT).

(iii) Availability test

As part of the commissioning tests prior to the trial operation, the plant control system shall be tested for availability for a continuous period of 30 days. During this period the system will perform the normal functions according to the procedures described in the Contractor's documentation.

The system shall have passed the availability test if all major components have been free from fault or failure and exhibit full error-free functionality for 98% of the total duration of the test, unless otherwise agreed by the Engineer. Major components include all master station equipment, outstations, communications facilities and instrument panel components, excluding push buttons, switches and lamps and any equipment not supplied by the Contractor.

During the availability test, no modifications to the system shall be made by the Contractor without the written approval of the Engineer. Erroneous functioning which requires software modifications or re-configuration to correct, other than set point or parameter changes, shall constitute a failure of the availability test. Any changes to the system which are required and approved shall be described in a system modification document, signed by both Contractor and Engineer and the document shall be incorporated into the final test documentation. The test shall be restarted after corrections have been completed.

During the availability test, a minimum of one power failure for each outstation and for the master station shall be simulated. Improper operation during power down or power recovery shall constitute a failure of 1% of the test duration.
During the availability test, a minimum of one failure for each component with redundant backup unit shall be simulated. Improper switch-over to the backup unit shall constitute a failure of 1% of the test duration.

If a situation arises during the availability test which renders the system unavailable but which, in the opinion of the Engineer, does not accurately reflect the true system availability, the unavailable period shall be ignored and the test extended for an identical time period.

After the availability test period is complete, if the test objectives have not been met the test shall be extended until the required system availability is achieved over a consecutive 14-day period. If the test is extended in this manner for over 8 weeks the Engineer, at his discretion, may discontinue the test and the issues be resolved in accordance with contractual terms.

In order to establish that all failures have been satisfactorily repaired no repeat failure shall have occurred within 72 hours of the failure. The test shall be extended if necessary to satisfy this requirement.

(b) Instrumentation

The following inspections and tests shall be carried out after installation at site:-

- All instrument piping shall be tested for continuity and freedom from leakage;
- All cables shall be tested for continuity and insulation resistance;
- Electrical supply voltages shall be checked;
- Instrument air supply pressure shall be checked;
- The common mode d.c. voltage at each signal input terminal shall be measured and recorded;
- The zero setting of each display instrument shall be checked;
- The correct calibration of each item in each loop shall be checked by introduction of appropriate signals at each source at five cardinal points of the range for increasing and decreasing signals;
- Recorders shall be fitted with the correct charts and drives set in motion, pens inked and check for clear marking. Multi-point recorders shall be checked to ensure they print at the correct stations;
- Every item shall be visually inspected and any damaged part or deficiency made good;
- All safety devices shall be tested for correct operation;
- Control sequences shall be checked with control inputs activated but outputs initially in a monitoring mode;
- The test methods to be used shall be as follows unless otherwise agreed with the Engineer;
- Pressure operated devices shall be tested with dead weight testers or portable calibrators;
- Level operated devices shall be tested by actual level variation or simulation thereof. Zero readings shall be checked against a benchmark where applicable;
- Flow devices of the pressure differential type shall be tested by application of differential pressures. Flow devices of the magnetic type shall be tested with a flow simulator. Where practicable, each flow device shall be checked by an actual displacement test;

- pH electrodes and monitors shall be calibrated by measuring the emf produced in solutions of known composition and strength. Glass pH electrodes shall be given at least 12 hours to stabilise before calibration. pH monitors shall be checked by use of at least three buffer solutions;
- Water quality analysers shall be calibrated using prepared solutions;
- Each control valve shall be checked by operation of the manual output control on the associated controller. Automatic controllers shall be set to the appropriate estimated values of the control terms;
- All systems shall be checked for fail-safe operation as appropriate by simulated failure, open circuiting, disconnection and so forth;
- Instrument and control panels, electrical interface cabinets;
- These shall be tested as part of the tests on the process plant equipment.

A11.16 Cabling

A11.16.1 Tests at manufacturers' works

Unless otherwise specified cables shall be subject to Routine Tests in accordance with the Reference Standards.

A11.16.2 Individual Site tests

The following inspection and tests shall be carried out on the completed cable installation as appropriate:-

- Insulation resistance between cores and core to earth using an approved insulation tester compatible with the voltage grade of the cable under test. For high voltage cables, the test shall be carried out at the highest voltage compatible with the voltage grade of the cable under test. Where cables are jointed, the test shall be repeated after each joint has been completed;
- For multicore and multipair cables, continuity of each core and correct identification and ferruling;
- Supports and cleating arrangements are fitted;
- For power cables, correct phasing and phase colouring;
- Correct bonding and earthing of cable metallic sheaths, core screens and armouring;
- Sealing of cable entries against water and vermin ingress;
- Mechanical glands have been correctly fitted;
- For high voltage cables pressure tests shall be carried out in accordance with the Reference Standards using high voltage d.c. Wherever possible cables shall be energised after the satisfactory completion of the pressure test;
- For high voltage cables, additional checks and tests to the manufacturers' specific instructions shall be carried out;
- For low voltage cables, additional tests as required by the Reference Standard;
- Loop resistance test for each pair of conductors in multipair instrumentation and telephone distribution cables;
- Attenuation test for each pair of conductors in telephone distribution cables;
- Measurement of cross talk across pairs of conductors in telephone distribution cables over a minimum frequency band of 0.5 to 20kHz. The conductors connected to a resistive load equal to that of their characteristic impedance. The injected signal shall have a sinusoidal waveform at a level equivalent to the intended operating level of the modems to be connected (-3dBm).

A11.17 Earthing

A11.17.1 Individual Site tests

On completion of the earthing installation tests shall be carried out in accordance with the Reference Standards and the following requirement:-

- Resistant of each earth point shall be measured;
- Resistant value of the overall earthing system after the connection of linking tapes;
- The earth contact resistance and the earth conductor continuity from each major piece of the Works, i.e. main switchboards and transformers etc., shall be measured by using an earth loop impedance tester and auxiliary return conductor.

A11.18 Building services

A11.18.1 Individual Site tests

The building services installations shall be inspected and tested in accordance with the Reference Standards.

A11.19 Lightning protection

A11.19.1 Individual Site tests

The lightning protection installation shall be inspected and tested in accordance with the Reference Standards and the following requirement:-

- Resistant of each earth point shall be measured;
- Resistant value of the overall earthing system after the connection of linking tapes.

A12.0 TRAINING

A12.1 Training requirements

Training shall be provided on site and at the Employer's premises as applicable, and shall commence at such time as directed by the Engineer/Employer.

Training of the Employer's personnel shall aim at achieving optimum operation of the Works including maximum efficiency of plant, optimum use of chemicals, minimum loss of water, and minimum numbers of operating staff. The Employer's personnel shall be trained in all aspects involved including management, operation of plant, water quality tests, laboratory procedures, control of chemicals, routine and periodic maintenance of every item of equipment and plant, health and safety at work, security and in all other subjects as may be required for satisfactory operation and maintenance of the Works.

The training shall comprise three main aspects:

(a) Formal classroom and practical training in groups;
(b) "Hands-on" training to the Employer's operation and maintenance staff while the Contractor is conducting equipment erection and pre-commissioning;
(c) "Hands-on" training to the Employer's operation and maintenance staff during the first 12 months and the last 12 months of Section II of the Works (Operation and Maintenance Period) while the Contractor's operation and maintenance staff are operating the Works and carrying out maintenance of the Works.

During the period of classroom and practical training, the Employer will make available selected staff for the Contractor to train in the safe and efficient operation and maintenance of the installed plant. The Contractor shall allow for comprehensive training in at least two separate sessions for each of the following disciplines and designed to accommodate the Works shift (24 hour, 3 shift) pattern.

- Staff discipline;
- Management staff;
- Operational staff including Works chemist and laboratory personnel;
- Electrical and ICA maintenance staff;
- Mechanical maintenance staff.

The exact number of personnel attending the training sessions will be finalised prior to the training.

During the last 12 months hands-on training period, the Contractor shall remain fully responsible for the operation and maintenance of the Works, but shall utilise the Employer's staff to the fullest extent possible, commensurate with their proficiency at the time, with a view to providing a smooth transition of responsibility for operation and routine maintenance from the Contractor to the Employer.

During installation of the Plant, the Contractor shall produce videos (CD ROM format) where necessary illustrating all essential aspects of plant installation and testing for use during training of the Employer's personnel.

The Contractor shall provide an experienced training manager (with a minimum of ten years training experience and five years experience in a similar capacity) to organise and supervise the training programme. He shall be based on site and shall remain on site from the commencement of the training programme until the completion of the first 12 months of Section II of the Works (Operation and Maintenance Period).

Training shall be performed by specialist personnel specifically allocated to the task. Such training shall be specific to the trainee's position and discipline and shall be appropriate to staff with the basic skills related to their grade.

The Contractor shall ensure that, training on individual items of plant, equipment or systems such as chemical facilities, instrumentation, control and automation systems (ICA) and similar shall be carried out by the manufacturer or specialist sub-contractor. Provision shall be made for both classroom and hands-on-training in this respect. The Contractor shall be responsible for ensuring that such training is properly co-ordinated into the overall programme, and that the quality of the training is of the type, quality and standard specified.

The Contractor shall submit details of the number of training specialists he shall assign to each phase of training together with details of their duties, qualifications, capabilities and experience to the Engineer for approval.

The Contractor shall maintain a register of attendance at training sessions and the subjects covered and shall carry out assessments jointly with the Engineer and the Employer’s representative to monitor the effectiveness of training.

Based on the assessments, the Contractor shall offer technical advice, organise and conduct special tutorial sessions for any personnel who have jointly been assessed and needing them and ensure that they carry out operations and procedures correctly.

Training shall be based on the relevant approved operating and maintenance manuals and record drawings including P&I Diagrams and flow sheets, which shall be available before training commences.

Training shall be provided for management, operating and maintenance staff and shall cover in detail the areas listed below. At least six months prior to the start of training the Contractor shall provide a draft syllabus of the proposed training and shall then develop in liaison with the Engineer and the Employer an approved syllabus, training programme and training methodology. The approval syllabus programme and methodology shall be submitted to the Engineer at least one month prior to the agreed start date for training. The syllabus to be provided by the Contractor shall be based upon, but not limited to, the following:

(i) Health and safety procedures, with particular respect to toxic and hazardous gas areas, chemical handling, electrical plant use, maintenance, entry/working in confined spaces and similar;

(ii) General plant description:
- General process description and treatment objectives;
- Process design parameters;
- General description of electrical equipment;
- General description of mechanical equipment;
- General description of ICA system.

(iii) Detailed description and demonstration on operation of individual process units, including process chemistry, sampling and laboratory procedures specific to the treatment processes adopted on the Works;

(iv) Detailed description, including operation principles/mechanism and demonstration on operation and control of all electrical, mechanical and ICA equipment;

(v) Operating instructions, including normal operation, actions necessary under varying conditions and abnormal conditions, start-up and shut-down procedures for individual process units;

(vi) Process optimisation;

(vii) Routine inspection and maintenance instructions;

(viii) Fault finding and correction;

(ix) Dismantling and re-assembly of plant, and replacement of consumable parts;

(x) Emergency procedures, including process aspects such as start up after power failure and gas leaks and chemical spillages;

(xi) Set up and calibration of each control, protection, measuring and process equipment/system;

(xii) Spares - strategic and consumables;

(xiii) Special tools;

(xiv) Trouble shooting and programme modifications to ICA systems, PLC and PC software and use of management systems provided under the Contract;
(xv) Review of relevant drawings, P&IDs and O&M manuals.

A12.2 Training methodology

The method of delivery shall be structured to include theory, group discussion and part practical elements supported by audio-visual aids, hand outs, demonstrations and appropriate assessments. Hand outs shall include extracts from operating and maintenance manuals supplemented by specially prepared material and shall be prepared so as to be collated to form a set of course notes for use by attendees for future reference. Audio-visual aids shall include relevant video presentations prepared by plant and equipment manufacturers, as well as those prepared during plant installation and testing.

A12.3 Training duration

Classroom Training shall start at an appropriate time during the erection of plant and shall be completed before the commencement of the trial operation of the Works. “Hands-on” training as specified in Section A12.1(b) shall start prior to the commencement of any final commissioning test of the equipments and shall be completed before the commencement of the trial operation of the Works. During Section II of the Works (Operation and Maintenance Period), the Contractor shall provide "hands-on" training, as specified in Section A12.1(c), and full direction and supervision of the Employer's staff, so that by the last twelve months period of operation and maintenance by the Contractor during Section II of the Works (Operation and Maintenance Period), the Employer’s personnel are sufficiently proficient so as to take over the operation and maintenance of the Works with minimal supervision by the Contractor.

The extent/length of training provided shall also take into account the numbers of Employer’s personnel involved, shift patterns and scope of training or the like.

As a minimum requirement the following number of 8 hour, day shifts shall be allowed for each course in the scope of training (excluding the “hands on” training to be given during the erection and pre-commissioning testing):

Subject	**Days**
Process chemistry	2
Operation of all plant including safety aspects of chemical and other plant	10
Electrical maintenance	4
Mechanical maintenance	4
ICA maintenance	5

The number of trainees per theory and group discussion class shall not exceed ten and the number of trainees per practical and/or “hands on” training session shall not exceed five.

A12.4 Training assessment

The training shall be monitored continuously by the Contractor jointly with the Engineer and/or the Employer’s representative and each trainee will be required to demonstrate their understanding of the instruction received. In order to achieve an acceptable standard of competence, the Contractor shall build into the training, a two-step assessment monitoring programme as set out below or a comparable assessment method approved by the Engineer:

(a) Each session shall include small groups of trainees being given a task/scenario, which will require them to use the knowledge learnt during the session to feed back and demonstrate understanding in such a manner as to promote trainee participation without putting individuals under pressure. This type of assessment shall be adopted for both theoretical and practical sessions and time shall be built into the course programme for this purpose.

(b) Each trainee shall be issued with a training task book which will include sections for recording attendance at individual classroom, practical and "hands-on" training sessions. Each section of the task book shall relate to a session undertaken during the training and will be signed off by the Contractor, Engineer and the Employer on completion of the training session.

A12.5 Training material

A comprehensive overall training manual shall be produced by the Contractor covering all disciplines and shall be submitted to the Engineer for approval six months before the commencement of the training programme. Three copies of the approved manual shall be submitted at least one month before the commencement of training. The presentation requirements of the manual shall be the same as those for the operating and maintenance manual. The manual shall also be submitted in CD ROM with interactive web page format. The manual shall be updated as necessary throughout the training programme.

In addition, each trainee shall receive one set of bound documents including the following:

(a) Course notes;
(b) Training information from the overall training manual appropriate to their particular skill areas (e.g. management, chemist, operator, electrical and mechanical maintenance);
(c) Training task book for recording training and for individual assessment;
(d) Functional task book, to be issued to each trainee shall include a comprehensive schedule of daily tasks to be carried out by the trainee staff member in their allotted position in maintaining satisfactory operation of the plant.

The training material shall be in a user-friendly style and shall cover in general terms the main technical procedures and activities associated with the Plant. The documents shall be in a format suitable for use in future training of Employer's personnel up to operating shift supervisor level.

Training documents shall be securely bound in such a manner that individual pages can be added or replaced so that the documents can be kept up to date.

On completion of the training programme, the training manual and other documentation, updated to take account of changes during the performance of the programme, shall be submitted to the Engineer in CD ROM format (IBM PC compatible).

A12.6 Training programme

The Contractor shall provide an outline training programme indicating target dates for the following associated activities:

(a) Submission of draft training plan, draft training manual, training task book and draft functional task book;
(b) Submission/agreement with the Engineer and the Employer of detailed training plan and syllabus. This shall include agreement of the assessment structure for trainees, training manual, training task books and functional task books;
(c) Submission/agreement with the Engineer and the Employer of training development programme. This will include aspects such as duration of training courses, dates, training venue/arrangements, training content, training materials, confirmation of numbers involved;
(d) Training review updates;
(e) Two week "familiarisation" programme;
(f) Number, dates and duration of courses/sessions within overall training programme;
(g) Relative dates for start of plant tests;
(h) Date for availability of draft operating and maintenance manuals.

A12.7 Training review update

The Contractor shall make available suitable personnel to carry out training updates and assessments at six months from the start of the Operation and Maintenance Period and at six months prior to the end of the Operation and Maintenance Period.

A12.8 Training support

Following satisfactory completion of Section II of the Works (Operation and Maintenance Period), the Contractor shall handover his operation and maintenance responsibilities to the Employer's personnel who will carry out the operation and maintenance of the Works. In the last 12 months of Section II of the Works (Operation and Maintenance Period), the Employer's operation and maintenance staff should be conducting the operation and maintenance of the Works for the Contractor, who is still taking full responsibility of the operation and maintenance of the Works. Therefore, throughout the Section II of the Works (Operation and Maintenance Period), the Contractor shall advise the Employer's personnel on the proper running of the Works, and provide technical support to the Employer to overcome operating and maintenance difficulties.

The Contractor shall attend to all requests for advice and assistance, both oral and written, made by the Employer's personnel and shall keep a written record of these requests with a copy submitted to the Engineer monthly.

Any advice or technical support given by the Contractor to the Employer's personnel, as a result of requests from them, and the action taken by them as a result of such technical support shall be recorded by the Contractor and copies shall be submitted to the Engineer monthly.

A12.9 Training record

The Contractor shall keep a complete record of Plant formal training carried out in the classroom and on the plant on DVD (MPEG2 format) and at the end of the training period shall submit to the Engineer four copies on DVD disks (MPEG2 format).

A13.0 SPECIAL TOOLS, SPARE PARTS, TOOLS AND TEST EQUIPMENT

A13.1 Special Tools

As well as the workshop tools specified, the Contractor shall provide special tools or appliances which he considers necessary for erection, dismantling or testing, operation and maintenance for any part of the Works during the life of the Works.

Special tools provided shall not be used for the erection of the Plant unless the Engineer instructs the Contractor to demonstrate the effectiveness of any special tool. The special tools shall be handed over to the Employer in a new and unused condition. Should the Contractor require any special tools at Site for erection, he shall provide his own.

Tools for each different type of equipment shall be contained in a suitable box clearly marked or labelled with its description. Each tool shall be identified and a list of tools shall be fixed to the inside of the box lid.

Each set of tools shall be supplied with the equipment it serves.

A13.2 Spare parts

The Contractor shall submit a complete list of spares recommended for continuous operation of all items of Plant and the Works for Section II of the Works (Operation and Maintenance Period), in Schedule of Technical Particulars T11. The list shall be based on average servicing requirements and prevention of breakdown for continuous operation of the Plant. Following detailed design of the Plant, the list submitted at the time of tender shall be updated. The list shall contain a description of the spare parts, ordering reference numbers, with parts identified on equipment drawings, quantities, unit price and the total price. The prices entered in this list shall be the prices quoted, except where the items listed at that time have been superseded by the requirements of detail design of the Works. The list shall be re-submitted in a single submission for the approval of the Engineer before any items are ordered.

The sum included in the Contract for provision of those spare parts listed in the Price Schedules is provisional, and the Employer reserves the right to order spares in accordance with the recommendations of the Contractor, or to vary the list and quantity of items to be ordered, or not to order spare parts through the Contract. Should additional quantities be ordered from the Employer, the Contractor shall be obliged to supply based on the unit rates being entered in the Schedules of Technical Particulars. Any spares that are specified elsewhere as part of any plant item shall be provided and the cost shall be deemed to be included in the lump sum for the plant item.

The final approved spare parts schedule shall be submitted in hard copy and CD ROM format. It shall show part numbers, ordering references and equipment drawings showing the spare parts.

Spare parts shall be new original manufacturers' spares. They shall be packed separately from the main Plant in packages or containers designed to preserve the spares from the effects of long term storage under the ambient conditions at the Site. Any items which cannot be packed in this shall be protected from corrosion by applying temporary protective coatings and shielded from mechanical damage. All items shall be clearly labelled with brief descriptions and part numbers, and shall be cross-referenced to the approved spare parts list.

Spare parts shall be delivered to the Site prior to the commencement of Section II of the Works (Operation and Maintenance Period). Spare parts being ordered additionally by the Employer for their use after they takeover the operation and maintenance of the Works, shall be delivered to the Employer 6 months prior to the completion of Section II of the Works. Whether the Contractor can achieve this requirement can be a prerequisite condition for the Employer to issue the Taking-Over Certificate of Section II of the Works.

The Contractor shall not use any of the spare parts for construction, commissioning or rectification of defects without written permission from the Engineer. Parts so used shall be replaced free of charge by the Contractor prior to the commencement of Section II of the Works (Operation and Maintenance Period).

The Contractor shall not use any of the spare parts additional ordered by the Employer for them to carry out future operation and maintenance of the Works without written permission from the Employer or the Engineer. Parts so used shall be replaced free of charge by the Contractor prior to the issue of the Taking-Over Certificate of Section II of the Works.

All packages may be opened for such examination as the Engineer may require and packings shall be designed to facilitate opening and thereafter repacking.

A13.3 Tools and test equipment

The Contractor shall supply two sets of all the standard workshop hand tools necessary for the dismantling and repair of the Plant.

Tools and test equipment for each different type of equipment shall be contained in a suitable hardwood, floor mounted cabinet clearly marked or labelled with its description. Each item test equipment and tools shall be identified and a list shall be affixed to the inside of the cabinet door.

Each set of tools and items of test equipment shall be supplied with the equipment it serves.

A14.0 OPERATION AND MAINTENANCE OF THE WORKS

A14.1 General

Following the Engineer to accept the Contractor has satisfactorily completed the individual tests, final commissioning tests and trial operation of the Works, the Engineer shall issue a “minor outstanding works and defect list”. This “minor outstanding works and defect list” is to provide the details of the defects to be rectified and works that are still outstanding which the Employer can accept the Contractor to finish those works after the Employer has taken-over the Works of Section I. The Contractor shall acknowledge to complete these minor outstanding works and rectifies the identified defects within the Defects Notification Period of Section I. Under this pre-requisite condition and other necessary conditions specified elsewhere in the Contract, e.g. to receive from the Contractor the Performance Security for Section II of the Works, the Engineer will issue the Taking-Over Certificate for Section I and a letter to the Contractor to permit Section II of the Works (Operation and Maintenance Period) to commence. The Defects Notification Period of Section I, which is of 12 months duration, shall commence on the same day.

The Employer and the Engineer will arrange handover of the whole Works to the Contractor, for them to commence the operation and maintenance of the whole Plant in Section II of the Works. The duration of Section II of the Works (Operation and Maintenance Period) will be 60 months. A Test on Completion for Section II has to be satisfactorily completed by the Contractor to demonstrate to the Employer that the whole Works is in good operative condition. The Engineer/Employer will issue a “minor outstanding works and defect list” that the Contractor has to accept to complete in the Defects Notification Period of Section II. Under such scenario, the Employer will take-over the whole Works and will allow the Contractor to access all the Plants to rectify the defects identified and completes all the outstanding works in the Defects Notification Period.

A14.2 Contractor's obligations during the first twelve months of Operation and Maintenance Period

During the first twelve months of Operation and Maintenance Period the Contractor shall be responsible for the following:-

Operation and routine maintenance for the whole of the Works, including the provision of all necessary skilled supervisory staff and unskilled workers necessary for full operation and maintenance of the works. The Contractor shall provide at least five persons per shift. In addition, the day shift shall include a supervisor for the whole of the plant, three pumping stations and water treatment plant, a process chemist, ICA system subcontractors, and a maintenance supervisor. The additional day shift staff shall be available on a "call out" basis to deal with any problems, which may arise outside the specified day shift period.

A14.3 Contractor's obligations after the first twelve months and before the last twelve months of Operation and Maintenance Period

(a) Same scope of work as A14.2(a) above, except that formal “hands-on” training is not required in this period. In this period, the Contractor shall provide advice to the operation and maintenance staff of the Employer at the Works for the queries they raise, based on the experience the Contractor obtained during the course of their operation and maintenance work;

(b) Same scope of work as A14.2(c) and (d) above.

(c) Provision of all materials including chemicals, fuel and lubricants excluding electricity power charges for the operation of the Works.

A14.4 Contractor's obligations during the last twelve months of Section II of the Works (Operation and Maintenance Period)

After satisfactory operation of the Works during the first four years of Section II, the Contractor shall be responsible for the following:

(a) Advising on operation of the whole of the Works to the Employer's personnel for the remainder of the Operation and Maintenance Period, who will be conducting operation and maintenance of the Works under the direction and supervision of the Contractor. The Contractor shall provide all necessary skilled advisory staff and providing necessary training. The staff shall be provided on a day shift basis on weekdays only and shall number at least three, including the overall plant supervisor, ICA sub-contractor's supervisor and a maintenance engineer. The staff shall also be available on a "call out" basis to deal with problems arising outside the specified day shift period. The Contractor shall be responsible for the work of the Employer's personnel during this period;

(b) During this twelve month period the Contractor shall provide `hands-on' training to the Employer's operating and maintenance personnel, who will be currently carrying out operation and maintenance of the Works under the direction and supervision of the Contractor. The Contractor shall supplement the "hands-on" training material being used in the training mentioned in Section A14.2(a) by those experience the Contractor gained in operation and maintenance of the Works in the first four years of Section II;

(c) Conducting studies as required by the Engineer on water treatment processes to optimise operations;

(d) The supply of all spare parts required for maintenance of plant as specified elsewhere in the Contract;

(e) Carrying out amendments to the operating and maintenance manuals based on experience gained in the Employer operating the plant.

(f) Provision of all materials including chemicals, fuel and lubricants excluding electricity power charges for the operation of the Works.

A14.5 Employer's responsibilities

During the Section II of the Works (Operation and Maintenance Period), the Employer will provide and be responsible for the following in respect of the operation of the Works:-

(a) All manpower to be trained to operate and maintain the Works under the direction of the Contractor;

(b) Electric power;

(c) All manpower to operate and maintain the Works in the last twelve months of Section II of the Works (Operation and Maintenance Period), under the direction and supervision of the Contractor.

A14.6 Periodic visits

The installation shall be visited during the eleventh month, twenty-third month, thirty-fifth month, forty-seventh month and fifty-ninth month of Section II of the Works (Operation and Maintenance Period) by a competent engineer or other specialist representative and training manager of the Contractor. He shall inspect all Plant provided under the Contract, ensure that servicing, adjustments and recalibrations as necessary are being carried out on all those items requiring attention and assess the competence of the Employer's personnel.

The Contractor shall obtain the Engineer's or the Employer's approval at 14 days prior to each visit and shall supply a full service report within 14 days after each visit.

A15.0 TEST ON COMPLETION FOR SECTION II OF THE WORKS

A15.1 General

Test on completion at the end of section II o the works shall be carried out to show that the works are in complete and satisfactory working order. The tests shall be agreed in detail with the employer and be carried out to an agreed programme which shall be submitted to the employer at least 28 days prior to the start of the tests.

The test will include functionality, leakage and any structural tests necessary to prove that the works are in full and compliant order, and are fit for purpose.

The test on Completion shall be similar to those set down or Trial Operation for Section I of the Works in Clause A 10.4. The continuous period the Works, to be tested on handover, shall be 7 days. The tests shall be designed to prove that the Works and treatment performance meets the Specifications and Performance Guarantees entered in the Schedule of Technical Particulars T9.12 to T9.15. Additionally, the following specifications and Performance Guarantee aspects shall also be included:

- Works Output
- Classified Water Quality
- Treated Water Quality
- Filter run duration
- Clarifier sludge discharge
- Filter Wash water Consumption
- Thickener supernatant turbidity
- Any other Parameters

The Procedures to be used for the Test on Completion during the specified period shall be as listed in items (a) to (f) inclusive of Cause A10.4.1.

All Mechanical Plant and Pumping equipment shall be inspected during operation, and tested for functionality and performance. The contractor shall prove to the Employer that plant as installed and operated complies fully with specified performance.

The complete SCADA system shall be tested for functionality, and all defects identified shall be rectified. Functions tests will include all level, flow and status indicators, together with all pump start/stop and valve open/close operations. This will include tests during power outage to test UPS adequacy. Any shortcomings shall be corrected and retested as necessary.

All rectifications works shall be carried out promptly and not later than 30 days after notifications.

APPENDIX A-1

A-1 Equipment for the Engineer and his staff

As a minimum the following equipment shall be provided:

Equipment for the Engineer and his staff

Item	**Quantity**
Safety helmets	10
Raincoats	10
Umbrellas	3
Leather boots with steel toe caps	10 pairs
Wellington boots with steel toe-caps	5 pairs
Fluorescent safety vests	10
Plastic safety glasses	3 pairs
Disposable earplugs(replaced as used)	10 pairs initially
Factor 10 sunscreen(replaced as used)	1 bottle initially
Digital cameras	1
Plastic coated tape 100m length	1
Plastic coated tapes 30m length	1
Steel tapes 5m length	3

VOLUME 2 OF 7 PART B

PARTICULAR SPECIFICATIONS – CAPACITY OF WATER TREATMENT WORKS

CONTENTS LIST

B 1.0 CAPACITY OF THE TREATMENT WORKS

B 1.1 Treatment works input

The mean annual permitted abstraction rate from the River Cauvery is 160.7 Ml/d and all the water abstracted will be pumped to the treatment works.

B 1.2 Treatment works capacity

The nominal capacity of the treatment works excluding such additional allowance of hydraulic capacity as is herein specified shall be 160.7 Ml/d.

The water produced in the washing of the filters (hereafter called used washwater) shall be discharged to washwater recovery tanks from which the supernatant shall be returned to the treatment works inlet. The returned supernatant shall be included in the throughput of the works. Sludge from the used washwater recovery tanks and sludge from the clarifiers shall be discharged to sludge thickeners from which the supernatant shall be discharged to a nallah and thickened sludge will be discharged to sludge drying beds. Therefore, the mean output to the treated water reservoir will be the treatment works input less the water discharged as sludge from the clarifiers and from the used washwater recovery tank and less service water used for flushing, irrigation or domestically. Mean losses from the works excluding service water used for flushing, irrigation or domestically shall not exceed 2.5% of the input.

The hydraulic capacity of the process units, the interconnections between units and to the treated water reservoir including overflows shall be designed for the relevant mean throughput of the works plus an allowance of 25%.

B 1.3 Variation in throughput

It is not possible to forecast accurately the extent or the frequency of variations in demand and therefore the throughput. In general the range of hourly variations in demand will be met by the storage in the treated water reservoir but there may also be short term variations in the input to the treatment works. Such variations shall be introduced slowly so as not to upset the performance of the treatment processes. Diurnal and seasonal variations in demand will be met by adjustments to the input to the treatment works.

B 1.4 Range of output

It is expected that the treatment works will be continuously operated at or near the nominal capacity. However for design purposes, the Contractor shall assume that the input will be in the range of 80 to 161 Ml/d.

B 1.5 Hydraulic capacity of the treatment works

In addition to the requirements of section B1.2 the hydraulic capacity of the process units and the relevant inter connections shall include provision for the maintenance of the works throughput with the following operational conditions present:

1 One clarifier taken out of service for maintenance;

2 Two filters out of service, one for washing and one for maintenance;

3 One compartment of the chlorine contact tank out of service for maintenance;

4 One compartment of the treated water reservoir out of service for maintenance;

5 One compartment or one unit, as appropriate, out of service for maintenance of all other units and inter connections that are necessary for the operation of the water treatment works at the required throughput.

Overflows shall be provided between all critical treatment process units for discharge to the site drainage system during emergencies or during commissioning of the treatment works without affecting the operation of process units upstream of the overflow.

B 1.6 Forwarding pumping plant

Forwarding pumping plant in the Contract includes the raw water pumps at the intake, the treated water high lift pumps at the water treatment works and the treated water pumps at the booster pumping station.

Treated water will be pumped to the master balancing reservoir at Madam.

B 1.7 Raw water quality

The raw water supply for the treatment works will be derived from the River Cauvery at Hogenakkal and will be conveyed to the treatment works via a pipeline of approximate length of 6250m. Preliminary raw water quality data for the River Cauvery at Hogenakkal is given in Appendix B1. The Contractor has to take his own samples of raw water that will be adequate for conducting a comprehensive treatability study. The result of this study shall be submitted to the Engineer.

B 1.8 Treated water quality

When operated in accordance with the Contractor's instruction at flows up to the required maximum throughput, the water treatment works treating raw water from the River Cauvery shall be capable of producing a reliable and continuous supply of potable water free of waterborne pathogenic organisms. The water quality from the works sampled after treatment at the treated water reservoir outlet or as otherwise stated shall comply with the following standards:

(a) 100% of the sample results shall have:

Turbidity	:	Not exceeding 1.0 NTU**
Taste and odour	:	Unobjectionable
Colour	:	Not exceeding 5° Hazen
Aluminium	:	Not exceeding 0.2 mg/l as Al
Iron	:	Not exceeding 0.3 mg/l as Fe
Manganese	:	Not exceeding 0.1 mg/l as Mn
Free chlorine	:	Not less than 0.5 mg/l*
pH	:	7.0 to 8.5
Total coliform bacteria	:	Nil in any 100 ml sample

*At the contact tank outlet **Before final pH correction

(b) 95% of the sample result shall have:

Aluminium		:Not exceeding 0.03 mg/l as Al
Iron		:Not exceeding 0.1 mg/l as Fe
Manganese		:Not exceeding 0.05 mg/l as Mn
pH	:	pH_s + 0.3; pH_s being the saturation pH value.

VOLUME 2 OF 7 PART B

PARTICULAR SPECIFICATIONS – MECHANICAL WORKS

CONTENTS LIST

B 2.0 PUMPING STATIONS

B 2.1 General

The process scheme under this Contract is to take raw water from the inlet works at upstream of river Cauvery, at site location 45 km west of Dharmapuri. Then the raw water will be delivered by the Raw Water Pumping Station via water pipeline of approximate length 6.25 km to the Water Treatment Works. The water supply handling capacity of the Water Treatment Works shall be 127.6 Ml/d upon completion of this Contract and be gradually increased to an ultimate volume of 160.7 Ml/d till 2036. The treated water will be pumped by the Treated Water Pumping Station via a length of 1.50 km to the Booster Pumping Station; and then subsequently pumped to a Master Balancing Reservoir (MBR – 24,000 m^3 capacity) at MADAM for a distance of 3.53 km.

Under the Contract, there will then be three pumping stations with their functionality being described in the above. These pumping stations are listed in the following:

(a) Raw Water Pumping Station;
(b) Treated Water Pumping Station; and
(c) Booster Water Pumping Station.

The Contractor is required to conduct detail design of the aforementioned pumping station based on the conceptual performance requirements as entered in the following sections and in other relevant parts of the Specification.

B 2.2 Scope of Mechanical Works

The Works to be undertaken by the Contractor include but not be limited to the following:

- Design, procurement, construction, testing and commissioning of raw water pumping station including water intake and transmission system,
- Design, procurement, construction, testing and commissioning of Water Treatment Works pumping station including water transmission system,
- Design, procurement, construction, testing and commissioning of booster pumping station including and transmission system,
- Undertake all necessary site investigations, surveys and testing related to the above works.

The overall, predicted pumping capacity of each of the above pumping stations shall be 6,956 m^3/h. Each of the above pumping stations shall include all necessary systems, plant, equipment, structures and protections allowing safe and undisrupted operation and maintenance. These systems and plant may not be expressively mentioned in the specifications but it shall be Contractor's responsibility to undertake relevant study and analyses and propose systems suitable for stipulated conditions and requirements.

B 2.3 Tender drawings

Tender drawings shall be deemed to have been issued for guidance to the Contractor and shall be referred to for the interpretation of the Contract only. The Contractor shall study and reconfirm available space and location and based on site survey, sizes of proposed plant and equipment, hydraulic calculations, etc., and shall carry out the design and prepare relevant drawings, procedures and method statements required for construction of the pumping station and all associated systems.

B 2.4 Works, systems and equipment common to all pumping stations

B 2.4.1 Valves and pipework – general requirements

Pump valves, pipework, and their supports shall be designed to withstand the maximum stresses imposed by any operating condition, including the shock resulting from pump starting when the advancing inrush of water strikes the closed non-return valve.

The design maximum velocity through the valves and pump branch pipework shall not exceed 2 m/s.

The design pressure rating of valves and pipework shall be 1.5 times the pump shut valve pressure or 16 bar, whichever is greater.

B 2.4.1.1 Valves

Each pump shall be provided with a delivery non-return valve, a delivery isolating valve, and an automatic air inlet/release valve. The air valve shall be fitted to the delivery pipework near to the discharge bend and upstream of the non-return valve.

A main suction isolating valves shall be provided as shown on the tender drawings. The valve shall be the same nominal size as the suction manifold. Valve shall be resilient-seated butterfly valves, fitted with electric actuators. Air valves shall be made of ductile iron and all other valves shall be made of cast steel. Valve operation when manual shall be by handwheel through integral reduction gearing. Valve operation when manual shall be by handwheel at the level of valve installation or from the platform/walkway at higher level (usually ground level) by headstock. The position to operate the valve manually shall provide the highest operation convenience to the future operators. The Contractor shall submit their proposal for the approval by the Engineer.

Pump suction isolating valve shall be resilient-seated butterfly valves, fitted with electric actuators. Valve operation when manual shall be by handwheel through integral reduction gearing.

Pump delivery isolating valves shall be resilient-seated butterfly valves, fitted with electric actuators. Valve operation when manual shall be by handwheel through integral reduction gearing.

Non-return valves shall be of the swing-check type, designed for rapid closing as soon as forward flow stops. If any closure-rate control is needed, full details shall be as provided in the Technical Schedules at the time of Tender.

A main isolating valve shall be provided as shown on the drawings. The valve shall be the same nominal size as the delivery manifold.

The valve shall be butterfly type with resilient seating, and manually operated by a handwheel through integral reduction gearing.

The valve shall be the same pressure rating as the delivery manifold.

All valves size DN250 and above, installed in the chambers within pumping station compound shall be fitted with electric actuator. Valve operation when manual shall be by handwheel through integral reduction gearing in the chamber and by T key from the chamber cover.

B 2.4.1.2 Pipework

Pump suction and delivery pipework shall be fabricated steel, with flanged connections.
Pressure ratings shall match those for valves as given above.

Dismantling joints shall be incorporated wherever needed to facilitate the removal of pumps and valves.

Pipework shall be protected from corrosion as detailed for exposed steel pipes elsewhere in the Specification.

B 2.4.1.3 Pump common delivery manifold

The pump deliveries shall be joined to a fabricated-steel delivery manifold, with flanged connections. The manifold shall be of nominal diameter as indicated on tender drawings.

The term pipework shall include all necessary supports, saddles, slings, fixing bolts and foundation bolts required to support the pipes and its associated equipment.

The pipework shall be laid out and designed so as to facilitate the erection, painting in-situ, dismantling of any section for maintenance and to give a constant and uniform flow of working fluid with a minimum head loss. Positions of flanges shall take in to account any necessary steel and concrete pipe supports or thrust blocks.

Flexible joints shall be provided where necessary to allow for differential settlement of building structure. Wherever practical, flexible joints shall be provided with tie bolts or other means to transfer longitudinal thrust along the pipework as a whole.

Wherever possible standard fittings shall be used in preference to fabricated or special fittings. Facilities shall be provided for draining the pipe system and releasing air. The drainage fluid shall be piped into the building drainage system and the period of time for drainage shall not exceed 30 minutes.

The pipework layout within pump stations shall have the approval of the pump manufacturer. Wherever the pipe enters and leaves the building through walls, a pipe sleeve should be used and proper sealing to be done to make it fully water tight.

Valves, strainers and other devices mounted in the pipework shall be supported independently of the pipes to which they are connected.

The manifold design pressure rating shall be 1.5 times the pump shut valve pressure or 16 bar, whichever is greater. Protection shall be as specified for pump delivery pipework.

The reducers on inlet and delivery branches shall suit the pump branch sizes and corresponding inlet and delivery pipe branch sizes shown. Inlet reducers shall be eccentric with flat tops.

B 2.4.2 Electric overhead travelling crane (EOTC)

An electric overhead travelling crane shall be provided in each of pumping stations and shall be designed to serve the pumps and all the plant installed in the motor hall, and for water intake pumping station, to lift and lower the skips provided for de-silting the pump wells. Enough hoisting cable shall be incorporated to lower skips to the bottom of the pump well.

The Contractor shall determine the Safe Working Load required for the crane.

The pendant control shall be designed for operation from the motor hall floor.

Crane operating speeds shall be as follows:

- Long travel: Not more than 40m/min
- Cross travel: Not more than 25m/min
- Hoisting and lowering: Not more than 10m/min

A fixed ladder with safety handrailing shall be provided for access to the crane for servicing, and to access the maintenance platform for use when servicing high-level lighting and ventilation units mounted in the roof.

B 2.4.3 Surge protection system for raw water main

B 2.4.3.1 Hydraulic and Surge analysis

The Contractor shall carry out comprehensive steady state hydraulic analysis and pressure (transient) surge analysis on the complete pumping system at the pumping stations and along the pipelines under all operating conditions. The surge analysis shall be undertaken by independent specialist SubContractor using a proven computer programme.

The surge analysis shall identify the most adverse transient operational conditions. The analyses shall include but not be limited to the following conditions:

- Complete power failure to the pumping station with all duty pumps running at maximum capacity.

- Start up of the pumps under the specified control system
- Shut down of the pumps under the specified control system

In addition to the delivery pipeline the surge analysis shall include consideration of the length of pipeline(s) between the pumping stations and the pressure vessel(s), and the suction condition(s).

The objective of the surge analysis is to recommend surge protection equipment which ensures maximum and minimum pressures under all conditions within the allowable surge rating of the pipelines as indicated below:

- Maximum pressures shall not exceed the capabilities of the pipes and fittings on the system.
- Minimum pressures in the system shall not fall below atmospheric pressure and subsequently rise above atmospheric pressures again during the same transient event. Pressures below atmospheric pressure will only be permitted as the systems drain down through supply connections during extended periods of pump shutdown.

The recommended solutions should include sensitivity checks to show that it is still valid with possible variations in system parameters such as wavespeed, friction factor and system demands.

The solution should include but not be limited to the following recommendations:

- Size and details for delivery air pressure vessel (Surge Vessel)
- Details for controlling the air volume in the above vessels
- Details and alarms for monitoring the air volume in the above vessel.
- Recommendations for controlling "slam" on the pump delivery non-return valve that may adversely affect the lifetime or operation of the valve and the system

Initial investigation indicates the surge vessel(s) of the following approximate total capacities will be needed:

- Raw water pumping station – 75 m^3;
- Treated water pumping station – 10 m^3;
- Booster pumping station – 70 m^3

The Contractor shall however determine the actual required capacity during detailed engineering, according to the transient surge analysis.

In addition to surge vessels of total capacity stipulated above, the Contractor shall install at least one standby surge vessel (for each pumping station) of the same type and size as the proposed ones. Such surge vessel shall provide stand by capacity in a case of releasing one of duty vessel for maintenance.

The Contractor should note the details of the pipe material as specified elsewhere in this document.

The Contractor shall furnish the surge analysis report to Engineer for approval. The report shall include computer printouts and graphs showing maximum and minimum pressure envelopes. The report shall also include time-flow and time pressure plots at critical points.

Surge protection may be by pressure vessel or feed tank, but flywheels to add to the pump rotating inertia shall not be used.

Surge Vessels shall be compressed air type, designed, constructed, installed and tested as detailed elsewhere in the Specification.

Surge vessel(s) shall be installed near, as practically possible, to the pumping station.

B 2.4.4 Provision of safe access

Steel access platforms and ladders shall be provided wherever needed. The arrangements shall ensure that all parts of the plant are made readily accessible in safety for operation and maintenance.

B 2.4.5 Ventilation system

Each of the pumping stations shall be provided with a ventilation system designed to limit the air temperature rise to not more than 5 deg. C, above the ambient, when the plant is operating. The system shall be designed to provide uniform ventilation throughout the pumping station to promote plant cooling and eliminate pockets of stagnant air.

The system shall be sized based on the maximum number of motors operating together, with all the lights switched on, and with three operating personnel present, but the design maximum air extraction rate shall be not less than five air changes hourly for the complete pump hall.

The system shall comprise a number of roof-mounted air extraction fans and manually operated air inlet louvers. The fans shall be fitted with non-corrodible protective cowls and all other protective measures needed to make them weatherproof in the climatic conditions at the Site, including monsoon winds combined with heavy rainfall. Louvers shall be manually operated and comprise as a minimum of removable anti-insects stainless steel mesh and sand trap.

The air extraction units shall be designed so that routine servicing can be from the maintenance platform on the crane and access from the roof is not needed.

Fans shall be controlled from wall-mounted contactors, accessible from pumping station floor level.

B 2.4.6 Sump Pump and Discharge Pipework

Each pumping station shall be equipped with a minimum two submersible sump pumps (one duty and one stand by) pumping water from the sump to the location approved by the Engineer. The sump pump shall have an integral vertical level switch and all principal components and shall be fabricated from Grade 304 stainless steel. Pump shall be capable of pumping solids up to 10 mm diameter.

The sump pump shall be supplied with all mechanical, electrical, I&C components, ancillaries and materials required for installation and normal operation.

Capacity of each of the sump pumps shall be minimum 100 l/min. For the purpose of this tender it has been assumed that the total head of the sump pump shall be 10m. This however has to be verified by the Contractor during design stage.

Sump pump control and electric systems shall be design in such a way that allows both pumps operation at the same time in a case of emergency.

Sump pump discharge pipework within the pumping station and above ground shall be of galvanised carbon steel and incorporate a check valve and isolation valve (as minimum) to prevent back syhonage. Below ground, pipework shall be made of HDPE.

B 2.5 RAW WATER PUMPING STATION

B 2.5.1 General

The Contractor shall design the plant to be installed in the raw water pumping station. The arrangement shall be generally as shown on the tender drawings.

The raw water pumping station shall draw water at upstream of river Cauvery through the screens and inlet openings and deliver it through the raw water pipeline to the treatment works. The length of the pipeline is about 6.25 km and the treatment works is located in the forest area with raw water discharge level of about +316m AMSL.

The exact total head for the raw water pumping plant will depend on head losses in the intake system and delivery pipework designed by the Contractor, and final levels chosen by the Contractor at the treatment works. This therefore cannot be given precisely in this Specification. Figures quoted herein are approximate only and shall be confirmed or amended by the Contractor in the detailed design.

The duty point at which the best efficiency is required is at the head when the river Cauvery is at the average water level of about +249.5m AMSL. Pump guaranteed performance required is chosen as applying at average reservoir water level.

The Contractor should also note the need for the flow pumped to match the treatment works capability, so that means may be required to limit the flow delivered at high reservoir levels.

B 2.5.2 Sump Model Study

To improve the performance of pumps, the Contractor shall perform sump model tests with various pumping combinations. The sump model study shall have to be taken up and completed before the finalisation of sump design. The tests shall be conducted considering the design parameters. The scale of the model sump shall be at least 1:20 and study shall be conducted based on established procedures.

B 2.5.3 Mechanical plant included

Mechanical plant to be installed at the intake structure and the raw water pumping station shall include but not be limited to the following:

- twelve intake screens/trash racks constructed in two levels;
- set of stop logs and lifting beams;
- manually operated overhead crane for intake screens and stoplogs;
- six penstocks, two for each pump well:
- six raw-water pumps;
- pump delivery valves and pipework, including delivery manifold with isolating valves;
- delivery pipework with isolation and throttling/control valve, flowmeter, and flowmeter bypass;
- electric overhead travelling crane for the pump hall;
- two submersible drainage pumps with flexible hose;
- two sump pumps;
- desilting plant and tools;
- pump well ventilation system;
- pump hall ventilation system;
- pump hall fire fighting system and other auxiliary systems,
- surge protection system including surge vessels, air compressors (duty and standby):
- provision for safe access

B 2.5.4 Intake screens/trash racks and stoplogs

Inclined bar screens shall be provided to protect each inlet. Screens shall be designed for easy cleaning by manual raking. The screen free area provided shall be not less than five times the area of the inlet which is protected.

Bars shall be spaced not more than 25 mm apart, and the screens shall be sized so that the maximum head loss shall not exceed 50 mm. Screen bars shall be provided with stiffeners for reinforcement, and the stiffeners shall be designed and installed to avoid impeding raking.

Six rakes shall be provided, each designed for use by one man. Rake handles shall be of non-corrodible lightweight tubular alloy. Rake tines shall fit the screen apertures and shall be of softer material than the screen bars to ensure bars are undamaged by raking.

Six rakings containers shall be provided, designed for ease of handling and lifting. They shall be free draining, with mesh apertures not larger than 25mm square. They shall be fitted with lifting handles designed for use by hand or with the hoist.

Stoplog slots to be provided in structures and shall be fitted with channel-section inserts, built-in to the structure during construction. Materials used for the inserts shall be corrosion resistant and designed for long life in installed conditions at site. The slot inserts shall be designed to ensure effective sealing with stoplogs.

Manually operated overhead travelling crane shall be provided to raise the containers to the structure top level for safe disposal as well as for lifting stoplogs. The hoist shall be fitted with a suitable hook, designed for quick attachment and release, and shall be designed for operation by one man.

B 2.5.5 Penstocks for isolating the inlets

Manually-operated penstocks shall be installed inside the pumping station pump well to shut off each of inlets. Each penstock shall be provided with a headstock, mounted at the floor level, complete with extension shaft and couplings.

Penstocks and their frames shall be cast iron, and the frames shall be provided with cast iron mounting spigots (thimbles), for building-in the frame to the structure.

Penstocks shall be the off-seating type, with rising spindles.

Apertures shall be rectangular, sized to provide a clear opening to match the inlet port size but not less than 1,500mm (W) x 1,500mm (H) Penstocks shall be designed for the maximum pressure to which they could be subjected in service.

B 2.5.6 Raw water pumps

B 2.5.6.1 General requirements

The Contractor shall review the pumping station design and the pump mounting proposals shown on the drawings, and shall ensure that the pumps he provides will operate satisfactorily as specified in all possible operating conditions, including any possible water level with any combination of pumps running. The drawings show one possible arrangement of six pumps of four duty and two standby but the Contractor may select a different arrangement which complies with the Specification.

The design of the pump wells shall be in collaboration between pump supplier and civil works designer to ensure the required hydraulic conditions are met in any possible operating condition.

Pumps shall be of the vertical turbine type, with water-lubricated bearings. Pumps shall be driven by directly-coupled, vertical-shaft induction motors, as described in the Electrical Specification.

The efficiency of the pump shall not be less than 80% at lowest suction head level unless specifically mentioned otherwise, and shall be designed for parallel operation of duty pumps.

A filtered-water supply system shall be provided to serve the pumps.

Unless otherwise approved, pump casings shall be of close-grained cast iron, and impellers and guide vanes of zinc-free bronze or stainless steel.

If the Contractor's design includes the need to streamline the flow into the pump inlet bellmouths, this may be by provision of conical concrete flow improvers. Alternatively the Contractor may provide shaped cast-iron conical pieces to be installed beneath the pump bell mouths at the time of pump installation. If required, flow straighteners shall be incorporated within the bell mouths using integrally-cast vanes.

B 2.5.6.2 Pump duty

The combined duty of the raw water pumps shall be 6,956 m^3/h against a provisional design duty head of 75m.

The pumps shall be arranged symmetrically, with equal numbers and sizes in each pump well. Not less than 50% standby pumping capacity shall be provided, and the arrangement shall include at least one standby pump for each size of pump installed.

For evaluation of pump operating costs, as detailed in Clause D1.2, the parameters to be used shall be:

A: 40%
B: 50%
C: 10%

A is the estimated % of time to be spent operating at the highest water level.

B is the estimated % of time to be spent operating at the average water level.

C is the estimated % of time spent operating at the lowest water level.

B 2.5.6.3 Varying the flow delivered by raw water pumps

The Contractor shall ensure that the flow delivered by the raw water pumping plant in any operating condition does not exceed the inlet capability of the treatment works.

Means used to achieve flow reduction if required may include installing pumps of different sizes, or if the flow reduction is expected to be of short duration, throttling the pump deliveries.

If throttling valves are required, they shall be separate extra valves, fitted in the common delivery manifold upstream of the main isolating valve. The pump delivery isolating valves shall not be used for throttling.

The throttling valve shall be a metal-seated butterfly valve, manually operated using a handwheel and reduction gearing to ensure slow operation. A clearly visible indication of the valve opening position shall be provided to the operator.

An identical valve shall be provided as a spare for each throttling valve installed.

The means used for flow variation shall not entail driving raw water pumps at variable speed.

B 2.5.6.4 Pump automatic air inlet/release valves

Each pump air inlet/release valve shall be designed and sized to ensure:

a) On pump stopping, the pump column pipe drains into the pump well so that negative pressures are not established which could be damaging when the pump is restarted.

b) On pump starting, air is expelled from the column pipe fast enough to prevent air being forced past the pump non-return valve and into the delivery main, and the air cushion in the column pipe prevents any damage from the advancing water column.

If draining the column pipe could result in reverse rotation of the pump, means shall be incorporated to ensure that the pump cannot be restarted during reverse rotation.

B 2.5.7 Submersible drainage pumps

Two submersible drainage pumps shall be provided to drain the pump well. Pumps shall be provided with flexible hose of sufficient length to connect to pumping station auxiliary pipework. Separate, dedicated stainless steel chain (two sets per pump) shall be supplied along with the pumps. Chain shall be of sufficient length for placing the pump on the bottom of the well using station crane.

Each pump shall be sized to empty the pump well in not more than twenty four hours when the pump well is initially drawn down to a low level by the main raw water pumps.

Drainage/sump pump discharge pipework shall be made of galvanised carbon steel and shall be equipped with isolation and non return valves as well as hose fast connection couplings. Drainage pipework shall discharge water to surface drains

B 2.5.8 Desilting plant and tools

The plant and tools to be provided for de-silting shall include:

- 4 No. long-handled shovels;
- 4 No. hand picks;
- 4 No. skips for loading with recovered silt.

Tools shall be of first-class commercial quality, designed for rough handling and frequent use.
Shovel blades and pick heads shall be steel, and handles of best quality ash or hickory wood.

Skips shall be robustly built of fabricated steel, designed for hard wear and protected from corrosion by painting. They shall be designed for emptying by tipping. They shall be provided with handles suitable for hand carrying and for safe lifting without tipping when using the station crane.

The total weight of each skip when fully loaded with silt shall not exceed 50kg.

B 2.5.9 Pump well ventilation system

B 2.5.9.1 General

A ventilation system shall be provided to supply fresh air to the bottom of the dewatered pump well during de-silting, to promote safe working. De-silting is expected to last for up to 24h, and to be needed not more often than once every 10 months. The design shall provide not less than five air changes hourly (ACH) for pump well.
The system shall include at least two (or more) wall-mounted electric fan units, designed to draw fresh air from outside the pumping station, and to deliver it to the pump wells through fixed and flexible ducts

B 2.5.9.2 Fans

Fans shall be sized to deliver not less than five ACH of fresh air through the duct system, discharging at the bottom of either pump well. Fan motors shall be rated for continuous operation.

Fan inlets shall be protected from ingress of harmful foreign matter by robust grilles at the inlets.

B 2.5.9.3 Ducts

Fixed ductwork shall lead the airflow from the fan to a suitable point near the top of pump well. Dampers shall be provided to direct airflow to the selected area. Fixed ducts shall end with a spigot and clipping arrangement, designed for connection to the flexible duct, which will be used only during de-silting.

Fixed ducts shall be of fabricated galvanized sheet steel or other approved material. Ducts shall be reinforced or protected where they could be damaged by the passage of personnel or goods in transit. Rectangular or circular sections may be used. Ducts shall be manufactured and installed to an approved code.

Flexible ducts shall be of tough, flexible, non-metallic construction, designed for hard wear in the conditions at Site. The length of flexible duct provided shall be not less than 30m. One end of the duct shall be arranged to connect to the fixed duct and the other to discharge safely at the bottom of pump well, with an outlet which can be secured and directed as required.

Fixed and flexible ducts shall be sized to limit air velocity to not more than 10m/s.

B 2.6 WATER TREATMENT WORKS PUMPING STATION

B 2.6.1 General

The Contractor shall design the plant to be installed in the Water Treatment Works pumping station. The arrangement shall be generally as shown on the tender drawings.

The Treated Water pumping station shall draw water from the two chambers of the treated water reservoir. From each chamber, a DN1200 inlet pipeline shall be installed to connect to one DN1500 suction manifold. Water will be pumped to the inlet sump of the Booster Pumping Station located about 1.2km away at the level of +457.00. Predicted water levels in WTW storage reservoir will be between +311.00 and +307.00m AMSL.

Individual pump discharge shall be of size DN500 and be connected to a DN1200 discharge manifold in pump hall. Main flow meter (and the by pass) shall be located in separate chambers outside the pump hall.

The exact total head for the pumping plant will depend on head losses in suction manifold and delivery pipework designed by the Contractor, and final levels chosen by the Contractor. This therefore cannot be given precisely in this Specification. Figures quoted herein are approximate only and shall be confirmed or amended by the Contractor in the detailed design.

The duty point at which the best efficiency is required is at the head when the reservoir is at the average water level of about +309.00m AMSL. Pump guaranteed performance required is chosen as applying at average reservoir water level.

B 2.6.2 Mechanical plant included

Mechanical plant to be installed at the pumping station shall include but not be limited to the following:

- suction incoming lines with motor operated isolation valves;
- suction manifold split into two halves which can be isolated with the motor operated butterfly valve;
- six treated water pumps;
- pump delivery valves and pipework, including delivery manifold with isolating valves;
- electric overhead travelling crane;
- submersible sump pumps;
- pump hall ventilation system;
- pump hall fire fighting system and other auxiliary systems,
- surge protection system including surge vessels, air compressors (duty and standby):
- provision for safe access:
- plant and equipment for the workshop.

B 2.6.3 Treated water pumps

B 2.6.3.1 General requirements

The Contractor shall review the pumping station design and the pump mounting proposals shown on the drawings, and shall ensure that the pumps he provides will operate satisfactorily as specified in all possible operating conditions, including any possible water level with any combination of pumps running. The drawings show one possible arrangement of pumps but the Contractor may select a different arrangement which complies with the Specification.

Pumps shall be vertical turbine type. All pumps shall be driven directly-coupled, vertical-shaft induction motors at a speed not greater than 1,500 rpm. Six pumps of equal size shall be installed, four duty and two standby.

All the pumps of the same duty shall be of similar characteristic and shall be selected for parallel operation.

B 2.6.3.2 Pump duty

The combined duty of the treated water pumps shall be 6,956 m^3/h against a provisional design duty head of 162m.

The pumps shall be arranged symmetrically, with equal numbers and sizes in the pump hall. Not less than 50% standby pumping capacity shall be provided, and the arrangement shall include at least one standby pump for each size of pump installed.

The efficiency of the pump shall not be less than 80% at lowest suction head level unless specifically mentioned otherwise, and shall be designed for parallel operation of duty pumps.

B 2.6.3.3 Varying the flow delivered by treated water pumps

The Contractor shall ensure that the flow delivered by the treated water pumping plant in any operating condition matches with operating conditions of connected transmission system.

Means used to achieve flow reduction if required may include installing pumps of different sizes, or if the flow reduction is expected to be of short duration, throttling the pump deliveries.

If throttling valves are required, they shall be separate extra valves, fitted in the common delivery manifold upstream of the main isolating valve. The pump delivery isolating valves shall not be used for throttling.

The throttling valve shall be a metal-seated butterfly valve, manually operated using a handwheel and reduction gearing to ensure slow operation. A clearly visible indication of the valve opening position shall be provided to the operator.

An identical valve shall be provided as a spare for each throttling valve installed.

B 2.6.4 Pumping Station Workshop

Mechanical works shop shall be arranged in the pump hall as shown generally on the tender drawings. Workshop shall be equipped with the following plant:

- Overhead lifting beam with manually operated hoist of minimum 1 tonne capacity;
- Forklift trolley of minimum capacity 1 tonne;
- Two sets of spanners, hammers, etc on the trolleys. Spanners to cover range of bolts up to M64;
- Two sets of measuring instruments including but not limited to vernier callipers and micrometers size up to 300mm;
- Two welding machines. TIG/MIG/Arc welding, input 440V, current range 0-400A,
- Column drilling machine. Drilling capacity up to 50mm;
- Double ended motorized bench grinder – size of dia of grinding disc 200mm;
- Two portable grinding machines. Dia of grinding disc 250mm;
- Three metal work tables with drawers. Size of table (W)2m x (L)0.8m;
- Medium duty metal shelves size app (L)5 m x (H)3m x (W)1m;
- Three metal wardrobes size (H)1.8m x (W)1m x (L)0.8m;
- Three universal workshop stools

B 2.7 BOOSTER PUMPING STATION

B 2.7.1 General

The Contractor shall design the plant to be installed in the Booster pumping station. The arrangement shall be generally as shown on the tender drawings. The Contractor shall review the pumping station design and the pump mounting proposals shown on the drawings, and shall ensure that the pumps he provides will operate satisfactorily as specified in all possible operating conditions, including any possible water level with any combination of pumps running. The drawings and the requirements entered hereafter show four duty and two standby pumps arrangement but the Contractor may select a different arrangement which complies with the Specification.

The Booster pumping station shall draw water from the inlet sump to Booster pumping station through DN1500 suction manifold. Water shall be pumped to Master Balancing Reservoir located about 3.5km away at the level of +527.00.

Individual pump discharge of size DN500 shall be connected to a DN1200 discharge manifold.

The exact total head for the pumping plant will depend on head losses in suction manifold and delivery pipework designed by the Contractor, and final levels chosen by the Contractor. This therefore cannot be given precisely in this Specification. Figures quoted herein are approximate only and shall be confirmed or amended by the Contractor in the detailed design.

B 2.7.2 Mechanical plant included

Mechanical plant to be installed at the pumping station shall include but not be limited to the following:

- inlet pipework connected to the inlet pipeline;
- six booster pumpsets as detailed below;
- pump inlet and delivery valves, including delivery non-return valves;
- delivery pipework connected to the delivery pipeline;
- main inlet and outlet isolating valves;
- submersible sump pumps;
- electric overhead travelling crane;
- pump hall ventilation system;
- pump hall fire fighting system and other auxiliary systems;
- surge protection system including surge vessels, air compressors (duty and standby);
- provision for safe access.

B 2.7.3 Booster pumps

B 2.7.3.1 General requirements

The Contractor shall review the pumping station design and the pump mounting proposals shown on the drawings, and shall ensure that the pumps he provides will operate satisfactorily as specified in all possible operating conditions, including any possible water level with any combination of pumps running. The drawings show one possible arrangement of pumps but the Contractor may select a different arrangement which complies with the Specification.

Pumps shall be of vertical turbine type. Pumps shall be driven by directly-coupled, vertical-shaft induction motors, as described in the Electrical Specification.

All the pumps of the same duty shall be of similar characteristic and shall be selected for parallel operation.

B 2.7.3.2 Pump duty

The combined duty of the raw water pumps shall be 6,956 m^3/h against a provisional design duty head of 102m.

The pumps shall be arranged symmetrically, with equal numbers and sizes in each half of the pump well. Not less than 50% standby pumping capacity shall be provided, and the arrangement shall include at least one standby pump for each size of pump installed.

The efficiency of the pump shall not be less than 80% at lowest suction head level unless specifically mentioned otherwise, and shall be designed for parallel operation of duty pumps.

B 2.7.3.3 Valves and pipe work

Pipework shall be fabricated steel, and the pump inlets and deliveries shall be joined to fabricated steel manifolds which shall be joined to the respective inlet and delivery mains through flanged connections. Dismantling joints shall be incorporated where shown to facilitate removal of pumps and valves.

The design pressure of valves and pipework shall be 16 bar for both inlets and deliveries.

B2.7.3.4 Varying the flow delivered by booster pumps

The Contractor shall ensure that the flow delivered by booster water pumping plant in any operating condition matches with operating conditions of connected storage/transmission system.

Means used to achieve flow reduction if required may include installing pumps of different sizes, or if the flow reduction is expected to be of short duration, throttling the pump deliveries.

If throttling valves are required, they shall be separate extra valves, fitted in the common delivery manifold upstream of the main isolating valve. The pump delivery isolating valves shall not be used for throttling.

The throttling valve shall be a metal-seated butterfly valve, manually operated using a handwheel and reduction gearing to ensure slow operation. A clearly visible indication of the valve opening position shall be provided to the operator.

An identical valve shall be provided as a spare for each throttling valve installed.

VOLUME 2 OF 7 PART B

PARTICULAR SPECIFICATIONS – WATER TREATMENT WORKS

CONTENTS LIST

B 3.0 WATER TREATMENT WORKS

B 3.1 Treatment processes

The sequence of treatment processes proposed for the treatment works is summarised below. Where aluminium sulphate is mentioned as a coagulant the Contractor may use polyaluminium chloride (PAC) instead at his sole responsibility subject to the approval of the Engineer.

Location / Process	Function
Works Inlet	
Parshall flume	Flow measurement
Hydraulic mixing with the addition of aluminium sulphate.	Coagulation.
Hydraulic mixing with the intermittent addition of chlorine.	Biological control.
Flocculation	
Mechanical flocculation or hydraulic and contact flocculation depending on the type of clarifier.	Agglomeration of coagulated particles.
Clarifiers	
Sedimentation.	Removal of flocculated particulate matter.
Rapid gravity filtration	
Filtration through sand media.	Removal of flocculated particulate matter carried over from clarifiers.
Contact tank	
Mechanical mixing with the addition of chlorine.	Chlorination.
Retention in contact tank to maintain a pre-set residual for an effective contact time.	Disinfection.
Treated water storage	
Hydraulic mixing with the addition of lime.	Final pH correction to give a positive Langelier Index
Storage in treated water reservoir.	Balancing treated water inflow to treated water pumped outflow to master balancing reservoir.
Used washwater recovery	
Sedimentation of used filter washwater.	Separation of supernatant for return to inlet works from sludge discharged for further treatment.

Sludge thickeners	
Thickening of clarifier sludge and sludge from used filter washwater.	Reduction of volume of sludge for further treatment
Sludge drying beds	
Removal of excess water.	Increase in dried solids concentration to facilitate handling for removal from site.

B 3.2 Treatment works

The complete water treatment works comprising the specified processes and such other additional or alternative processes as the Contractor may consider appropriate, together with the associated plant shall comply with the following clauses of the Particular Specification.

B 3.3 Control of the treatment works

B 3.3.1 Control

Overall control and monitoring of the raw water pumping station, booster pumping station and the water treatment works will be directed from the control room in the filter building. Operation of plant and treatment processes will normally be from local control centres in various buildings associated with the process units and chemical and chlorine buildings.

Facilities in the form of instruments shall be provided to monitor critical plant states and alarm plant faults, failures and abnormal operations on local panels as specified. Information essential to the overall running of the treatment works shall be presented in the control room in the filter building.

B 3.3.2 Operation

The treatment works shall be arranged for manual operation with the following exceptions:

(a) Automatic desludging of clarifiers;

(b) Automatic filter flow control;

(c) Automatic filter washing following manual initiation;

(d) Automatic changeover of chlorine drums;

(e) Automatic operation of chlorine building ventilation system;

(e) Automatic operation of, washwater supply pumps, used washwater transfer pumps and thickener feed pumps;

(f) Automatic desludging of sludge thickeners;

(g) Automatic operation of some drain pumps as specified.

All automatic operations shall be provided with manual override facilities as specified.

B 3.3.3 Ability of processes to meet variations

The treatment processes shall be capable of dealing effectively and efficiently with the variations in raw water quality and in the throughput which are likely to occur, due both to seasonal changes in the water quality and consumer demands.

B 3.4 Hydraulics

B3.4.1 Head loss through the treatment works

The hydraulic head loss through the treatment works for the maximum output, from the normal TWL at the inlet to the Parshall flume to the TWL in the treated water reservoir shall not exceed 5.0 m.

The hydraulic head loss calculations for the system downstream of the filters shall take into account of increase in flowrate over the maximum works flow when a filter is in draindown mode.

B 3.4.2 Overflows

The Contractor shall design and install all overflow systems complete with necessary pipework and channels from the point of overflow to a point of safe discharge.

All overflows shall be designed for the safe evacuation of the maximum flow at the point of discharge resulting from the following conditions:

(a) Restriction to water flow, e.g. excessively clogged filters.

(b) Total obstruction to water flow, e.g. inadvertent closure of filter inlet penstocks.

(c) Commissioning and testing of the water treatment works,

and shall be provided at the following locations:-

- Inlet to the clarifiers;
- Inlet to the filters;
- Treated water reservoir;
- Used washwater holding tank;
- Clarifier sludge balance tank.

At the maximum overflow rate, the head over any overflow weir shall not be greater than 250 mm and at the maximum design treatment flow, taking into account conditions when the specified number of process units are not in service, the upstream overflow level shall be at least 100 mm below the crests of the overflow weirs. Each overflow shall be served by a level probe arranged to initiate an alarm state when the water level rises to within 20mm of the overflow weir level.

The hydraulic profile of the works shall be such that overflow occurs at the point in the process stream immediately upstream of the condition causing the overflow, so that water does not back up to other upstream overflow locations and so that no more than one overflow occurs in the water treatment process at any time. The tanks, chambers and channels shall be designed to accommodate the head necessary to evacuate the maximum flow at overflows with a freeboard of at least 200 mm.

The sludge balance tank overflow shall be discharged to the sludge drying beds. All other overflows shall be discharged to the site drain.

B 3.4.3 Drainage

All water retaining structures and interconnecting channels and pipes shall be provided with facilities for complete dewatering.

Where practicable, provisions shall be made to allow draining of individual process units, compartments, sections of channels and lengths of pipes without interrupting the operation of the treatment works.

Dewatering shall be either by gravity (direct or via a sump) or using pumps or by both. Where pumped drainage is proposed adequately sized pump sumps with portable pumps of the submersible type shall be provided as specified

A site drainage system discharging to an approved nallah off the site of the water treatment works shall be provided. All drainage not discharging to a specified location shall be directed to the site drainage systems.

B 3.5 Inlet works

B 3.5.1 General

Raw water shall be delivered by pipeline from the intake pumping station on the Cauvery River through a steel pipe to the treatment works, terminating at an upturned bellmouth at the inlet works.

The inlet works shall consist of an inlet chamber, a Parshall flume and a clarifier flow division chamber unless flow division is incorporated in the clarifier block.

B 3.5.2 Mixer M1

The downstream section of the inlet flume shall provide for the dosing of aluminium sulphate or polyaluminium chloride and chlorine at the point of maximum turbulence.

B 3.5.3 Clarifier flow division chamber

A clarifier flow distribution chamber shall be provided unless provision for the uniform distribution of flow from the clarifier inlet channel to individual clarifiers is incorporated in the clarifier block.

The clarifier flow distribution chamber shall distribute flow to the clarifiers using a system of free-fall weirs. The design of the system shall ensure that equal division of flow is effected between the clarifiers in service at all flows up to the hydraulic capacity of the clarifiers.

Weir penstocks (also called weir gates) on the flow division weirs shall be provided for isolating the individual clarifiers at the flow division chamber or other equivalent arrangements shall be incorporated in the clarifier inlet channel. The flow division weirs could be provided in sections to enable weir penstocks to be accommodated. The arrangements for isolation shall be provided with access.

B 3.5.4 Access and drainage

All structures of the inlet works including the flume and clarifier flow division chamber shall be provided with stair access and platforms complete with handrailing for operation and maintenance of the plant. Where structures are connected by channel a walkway complete with handrailing shall be provided along the side of the channel.

The clarifier flow division chamber shall also be provided with access from the top of the clarifier.

At least one hydrant point and a high pressure hose of 20 m length complete with hose reel, hose connector and nozzle shall be provided central to the clarifier flow division chamber for washing and cleaning purposes.

The inlet works shall be provided with facilities for completely dewatering the pipelines, conduits, chambers and where applicable individual compartments independently.

B 3.6 Mixing of chemicals

B 3.6.1 Location of dosing points

The points of application of chemicals to each stream shall be as follows:-

Dosing point	Location	Chemical
M1	Inlet flume	Aluminium sulphate Chlorine
M2A/B	Mixer chamber in the chlorine contact tank	Chlorine
M3A/B	Treated water reservoir inlet weirs	Hydrated lime

B 3.6.2 Mixing - general

Mixing of chemicals at all dosing points shall be by hydraulic means or by immersed high speed impellor.

Hydraulic energy for mixing at the relevant points of chemical application shall be derived from a device which produces a headloss adequate for mixing.

Mixing of chemicals at each point shall produce the most uniform dispersion of the chemical into the body of the water as quickly as possible. Chemical solutions shall be diluted with an adequate amount of carrier water before dosing into the point of greatest turbulence at the mixer.

B 3.6.3 Design criteria

Design requirement for each mixing point shall be as follows:-

M1A/B Head loss across the flume at the mean annual throughput shall be not less than 300 mm.

M2A/B The mechanical energy of each mixer shall produce a G value of not less than 600/s and the product of the G value and the retention time in the mixer chamber expressed in seconds shall not be less than 18000 at the mean annual throughput.

M3A/B Head loss across each weir at the mean annual throughput shall be not less than 300mm.

All free-fall weirs shall be ventilated below the nappe to prevent a depressed or clinging nappe and shall have a downstream freeboard of not less than 50 mm under the maximum flow condition.

B 3.6.4 Mixing chambers

Mixing chambers at the contact tank and treated water reservoir inlets shall be fully covered and ventilated and access to dosing facilities shall be sealed with removable water-tight covers.

All mixing chambers shall be provided with facilities for completely draining of all water and sludge. Drainage shall be by either gravity or pumped to the site drainage system and for gravity drainage each chamber shall be supplied with a 150 mm diameter outlet valve and pipework. Valves shall be provided with extension spindles and supporting brackets and shall be operated by handwheel.

Where gravity drainage is not feasible, facilities shall be provided for pumped drainage and shall consist of pump sumps within the chamber.

B 3.6.5 Chemical dosing at mixers

Aluminium sulphate shall be dosed at M1 by a perforated pipe distributor located above the water surface just upstream of the hydraulic jump. Chlorine shall be dosed at M1 by a submerged pipe distributor at the inlet to the flume.

Dosing of chlorine at M2A/B shall be by an injection pipe terminating close below the eye of the impellor.

Dosing of lime at M3A/B shall be by perforated distributor channel.

All distributors shall be designed to minimise clogging and provide uniform distribution. The coagulant distributor shall be provided with removable end caps to give access for cleaning. Two flexible wire brushes shall be supplied to serve the pipe distributors.

A hydrant and a hose complete with hose reel, hose connector and nozzle shall be provided at mixing points for cleaning and washing down purposes.

Means of access shall be provided at the mixing points for operation of valves, flushing and cleaning of distributors and for maintenance purposes.

All chemical injection devices at each point of application shall be provided in duplicate (1 duty, 1 standby) to allow one to be taken out of service for cleaning, without interrupting chemical dosing.

B 3.6.6 Protection against chemical attack at dosing points

At M1 where aluminium sulphate and chlorine are distributed the concrete surfaces within 0.5 m upstream and 2.5 m downstream of the dosing point, both above and below the water surface shall be protected against chemical attack by a suitable protective coating.

B 3.7 Clarification

B 3.7.1 General

Clarifiers shall be of the vertical flow flat bottomed sludge blanket or counter-current lamella plate-sedimentation type or pulsators or any other design suitable for the Project and shall be designed for operation in concrete tanks.

The clarifiers shall be of a single type and size. A minimum of six nos. of clarifiers shall be provided. If the clarifier is of the lamella plate sedimentation type, a dedicated flocculation chamber shall be provided.

A conceptual process and instrumentation diagram is given in the drawings.

The aggregated quantity of water discharged as sludge from the clarifiers and from the wash water recovery tank averaged over 24 hours shall not exceed 2.5% of the works input averaged over the same 24 hours.

B 3.7.2 Sludge blanket clarifier

(a) Design rating

The general design of the clarifiers shall place importance on simplicity of operation and the ease with which routine work and maintenance can be carried out.

Each clarifier shall treat the same proportion of the throughput and shall be hydraulically capable of taking the same higher rate of flow to enable the throughput to be maintained when one clarifier is out of service for maintenance.

The maximum surface loading rate or rise rate computed in the clear water section of the clarifier at a depth of approximately 1.25 m below the water surface shall not exceed 2 $m^3/h.m^2$ when all tanks are operating at the rated throughput.

The depth of 1.25 m is assumed to be the straight side depth within the clear water section which is below any inlet and draw-off channels or pipes and above any sludge extraction devices to give an uninterrupted horizontal plane for measurement of area for calculation of the rising velocity. If the design of the tank requires structures or devices to be located at this depth, the area provided by the Contractor shall be increased to give a nett area equivalent to a surface loading rate or rise rate of 2 $m^3/h.m^2$.

There shall be a delay time of about five minutes between the mixing of coagulant and the entry of the dosed water to the clarifier to allow initial flocculation to occur. The residence time in the inlet channel before the entrance to the first clarifier may be included in the delay time.

(b) Layout and design consideration

The layout and the design of the clarifier shall comply with the following:-

(i) Flocculation shall be hydraulic and shall be within the clarifier;

(ii) Distribution of dosed water between clarifiers shall be equal;

(iii) Distribution of dosed water throughout the clarifier shall be uniform;

(iv) Concentration of floc in the sludge blanket shall be uniform over the area of the clarifier;

(v) Collection of clarified water throughout the clarifier shall be uniform;

(vi) Withdrawal of clarified water shall be by submerged orifices in decanting launders constructed of concrete discharging to a common clarified water channel;

(vii) Horizontal velocity through orifices in decanting launders shall not exceed 0.5 m/s and the diameter of orifices shall not be less than 25 mm;

(viii) Any mechanical plant with motor drives except valve actuators provided as part of each clarifier shall be supplied with 100 percent standby;

(ix) Scum removal system shall be provided for removing floating debris in the clarifier;

(x) Sludge shall be extracted from suspended concentration hoppers to which sludge shall be transported uniformly from the entire area of the clarifier;

(xi) Periodic evacuation of sludge as a fluid under hydrostatic pressure from the concentration hoppers shall be provided;

(xii) The minimum vertical side water depth of the clarifiers shall be not less than 4.5 m;

(xii) Two sample points shall be provided at different levels in each clarifier to enable samples to be collected for determination of floc blanket concentration;

(xiv) Hydraulic isolation of individual clarifiers by penstocks (or gates) shall be provided;

(xv) Facilities shall be provided for clearing blockages in all sections of sludge lines by flushing and rodding;

(xvi) Pumps or fans proposed to enhance the characteristics of the blanket or improve distribution of dosed water in each clarifier or effect other improvements shall be provided in duplicate (one duty, one standby).

The clarifier design shall have been proved in service in at least two existing installations in the tropics, treating river waters of similar turbidity values for a minimum period of three years.

(c) Flocculation

Flocculation shall be hydraulically induced in the clarifier and completed within the sludge blanket. The Contractor shall provide all necessary devices, for inducing flocculation including all pipework, distributors, injectors and baffle systems.

(d) Sludge removal

In sludge blanket clarifiers sludge from the blanket shall overflow into concentrating hoppers so arranged that excessive sludge extraction has minimal effect on sludge blanket concentration and sludge collection is uniform from the area of the clarifier.

Sludge collected in hoppers of each clarifier shall be evacuated individually or in groups by hydrostatic pressure from the bottom of the hoppers through a discharge pipe into a sludge collection channel common to all the clarifiers located between a pair of clarifiers or external to the clarifiers. A gallery shall be provided to accommodate the sludge channel which shall be of sufficient size to provide walkways along the side of the channel and to give access to all sludge and drain valves and to house controls and associated equipment. Enclosed sludge galleries shall be force-ventilated.

All sludge valves shall be of the eccentric plug or ball type and shall be arranged for pneumatic power operation with manual override. Each power operated valve shall be of the spring loaded type arranged to close on air supply failure and shall be provided with a manually operated guard valve.

The Contractor shall install floor scrapers or piped pressure water sparge system or any other proven device if he considers necessary for the removal of settled material from the clarifier floor.

(e) Drainage and cleaning of clarifiers

Facilities shall be provided for complete draining of all water and sludge both from the main body of the clarifier and from the sludge concentrators. The time to drain a clarifier from full to empty shall be less than four hours. Once the sludge in hoppers has been evacuated the clear water above the sludge blanket may be drained to the site drainage system. All sumps, pumps, pipework and fittings required to dispose the drainage shall be provided.

It is envisaged that the clarifiers will be drained during periods of good water quality and normal demand.

Washdown points and hoses complete with hose reels, hose connectors and nozzles shall be provided on the clarifiers and sludge gallery for cleaning and maintenance. The spacing of the washdown points shall be determined on the basis of a hose length of 20 m. Equipment provided on the clarifiers shall be housed in cabinets suitably mounted.

(f) Access

Access shall be provided between the clarifier flow division chamber (where provided) and the clarifiers. Access shall also be provided on top of the clarifiers for cleaning of launders and channels and maintenance of any plant.

Access shall be provided to the sludge galleries from the clarifier and in the sludge galleries for cleaning of channels, draining of hoppers and clarifiers and for maintenance of sludge valves.

All access ways shall be provided with handrailing.

Each clarifier shall be provided with at least one life buoy complete with line and shall be shielded from sun light.

B 3.7.3 Lamella plate sedimentation clarifier

(a) Design rating

The general design of the clarifiers shall place importance on simplicity of operation and the ease with which routine work and maintenance can be carried out.

Each clarifier shall treat the same proportion of the throughput and shall be hydraulically capable of taking the same higher rate of flow to enable the throughput to be maintained when one clarifier is out of service for maintenance.

The maximum sedimentation rate for the clarifier shall not exceed 0.75 m/h (based on the total horizontal projection of the lamella plates) when all clarifiers are operating at the rated throughput.

(b) Layout and design consideration

The layout and the design of the clarifier shall comply with the following :

(i) Flocculation shall be mechanical and shall be external to the clarifier;

(ii) Distribution of dosed water flow between flocculator streams shall be equal;

(iii) Distribution of flocculated water throughout the clarifier between lamella plates shall be equal;

(iv) Collection of settled water throughout the clarifier between the lamella plates shall be equal;

(v) Withdrawal of clarified water shall be by v-notches or submerged orifices in decanting launders constructed of stainless steel or concrete;

(vi) Horizontal velocity through orifices or v-notches in decanting launders shall not exceed 0.5 m/s and the diameter of the orifices shall not be less than 25 mm;

(vii) Removal of the sludge collected on the floor of the clarifier shall be by periodic evacuation of sludge as a fluid under hydrostatic pressure and shall be uniform over the entire area of the clarifier floor;

(viii) The minimum side water depth of the clarifier shall not be less than 4.5 m;

(ix) Hydraulic isolation of individual clarifiers by penstocks shall be provided;

(x) Facilities shall be provided for clearing blockages in all sections of sludge lines by flushing and rodding;

(xi) Clarifiers shall be enclosed in a building to prevent growth of algae on the lamella plates; pre chlorination is therefore not necessary.

The clarifier design shall have been proved in service in at least two existing installations in the tropics treating river water of similar turbidity values for a minimum period of three years.

(c) Flocculation

The flocculation stage of each clarifier shall be provided with a minimum of two equal and parallel flocculator streams, each stream comprising at least two equal size compartments connected in series.

Flocculation shall be by mechanical means and each flocculation compartment shall be provided with a top entry mechanical paddle stirrer with motor and reduction gear unit.

The total retention time of the flocculation chamber of each clarifier shall be not less than 15 minutes at the maximum works throughput. The maximum energy input for flocculation in the two compartments in series, expressed as velocity gradient (G) shall not be less than 50 sec^{-1} (at 27°C). The stirrer tip speed shall not exceed 0.5 m/s.

The flocculation compartments in series shall be separated from each other by baffle walls and shall be designed to direct the flow across each compartment from bottom to top in a diagonal path or in any other flow arrangement to ensure short circuiting is minimised. At peak flow rate the velocity of water between compartments shall not exceed 0.5 m/s.

(d) Lamella plates

Lamella plates shall be of stainless steel construction and shall have a working depth (vertical) of 2.75 m and shall be partly submerged with plates laid to extend above the normal water surface in order to isolate the area between the plates. The arrangement of lamella plates shall not allow the formation of dead areas of flow within the clarifier.

(e) Clarifier channels

Flocculated water shall be distributed evenly to all the plates. The method of distribution shall be by slotted openings in the side walls of channels running on either side of the plates along the length of the tanks which shall introduce the flocculated water between each pair of plates near the bottom. The channels and the openings shall be hydraulically designed to equally distribute the influent to all of the plates.

The clarified water shall be collected by submerged orifices, one between each pair of plates, in decanting launders.

The flocculated water distribution and clarified water collection channels and channel components shall be of stainless steel or concrete construction.

Alternative flocculated water distribution systems and clarified water collection systems will be acceptable provided good operation can be demonstrated with references to operating plants.

(f) Sludge removal

In lamella plate sedimentation clarifiers the floor of the clarifier below the area occupied by the plates shall be formed into rectangular or square concentrating hoppers into which sludge will fall.

Sludge collected in hoppers of each clarifier shall be evacuated individually or in groups by hydrostatic pressure from the bottom of the hoppers through a discharge pipe into a sludge collection channel common to all the clarifiers located between a pair of clarifiers or external to the clarifiers. A gallery shall be provided to accommodate the sludge channel which shall be of sufficient size to provide walkways along the side of the channel and to give access to all sludge and drain valves and to house controls and associated equipment. Enclosed sludge galleries shall be force-ventilated.

All sludge valves shall be of the eccentric plug or ball type and shall be arranged for pneumatic power operation with manual override. Each power operated valve shall be spring loaded and arranged to close on air supply failure and shall be provided with a manually operated guard valve.

The Contractor shall install floor scrapers or piped pressure water sparge system or any other proven device if he considers necessary for the removal of settled material from the clarifier floor.

(g) Drainage and cleaning of clarifiers

Facilities shall be provided for complete draining of all water and sludge from both the flocculators and clarifiers. The time to drain a clarifier and its flocculators from full to empty shall be less than four hours. Once the sludge in the clarifier floor and hoppers has been evacuated, the clear water shall be drained to the site drainage system. All sumps, pumps, pipework and fittings required to dispose the drainage shall be provided.

It is envisaged that the clarifiers will be drained during periods of good water quality and normal demand.

Washdown points and hoses complete with hose reels, hose connectors and nozzles shall be provided on the clarifiers for cleaning and maintenance. The spacing of the washdown points shall be determined on the basis of a hose length of 20 m. Equipment provided on the clarifiers shall be housed in cabinets suitably mounted.

(h) Access

Access shall be provided between the clarifier flow division chamber and the clarifiers. Access shall also be provided on top of the clarifiers for cleaning of launders and channels and maintenance of any plant.

Access shall be provided to the sludge galleries from the clarifier and in the sludge galleries for cleaning of channels, draining of hoppers and clarifiers and for maintenance of sludge valves.

Each clarifier shall be provided with at least one life buoy complete with a line, which shall be located on top of the clarifier.

B 3.7.4 Clarified water quality

The clarified water from either type of clarifier when operating at the rated throughput shall be better than the following quality:

Turbidity:	5 NTU (90% ile value)
Turbidity:	10 NTU (100% ile value)
Colour:	5^{o}Hazen
Aluminium:	0.5 mg/l as Al

B 3.7.5 Dosed and clarified water pipes and conduits outside the clarifiers

Concrete channels shall be used for all dosed water and clarified water conduits where practicable, but pipes shall be used at road crossings and other locations where channels are impractical.

Where pipes are used to convey clarified water, velocity of flow shall be selected to minimise settlement of suspended matter in the pipe but without damaging the floc. Pipes shall be provided with facilities for flushing to clear deposits.

Conduits and pipes shall be provided with drain valves complete with pipework draining to the site drainage system either direct or via pump sumps. In this case, a power socket outlet shall be provided local to the sump for connecting a portable drain pump.

The clarified water pipe between the clarifiers and the filters shall be provided with a flowmeter of the magnetic type.

B 3.8 Filtration

B 3.8.1 General

The treatment works shall be provided with a minimum of ten filters. Each filter shall be designed and equipped for a maximum filtration rate of 7.5 m/h at the throughput corresponding to the nominal capacity of the treatment works with two filters out of service, one for washing and one for maintenance.

The filters shall be of the duplex type comprising two equal size beds separated by a central used washwater collection channel and operating at constant rate on the principle of influent flow division and constant water level. The underdrain system shall comprise nozzles set in a plenum concrete floor.

The filters shall be arranged in two banks located on either side of a covered central gallery containing a walkway and filter wash consoles at high level and filter pipe gallery and filtered water channel complete with walkway at low level.

The banks of filters shall be served by an adjoining filter building which shall house the air scour blowers, compressors and any other equipment required for the operation of the filters. The filter building shall also accommodate administration facilities for the works, which shall include offices, the control room, laboratory, toilets and mess facilities. Air blower and compressor rooms shall be sound proofed to reduce the sound level in offices on the floor above to less than 65 dB(A).

B 3.8.2 Layout and design considerations

Layout and design of the filters shall comply with the following:-

(a) All filters shall be identical in dimensions and designed for combined air and water washing using filtered and chlorinated water.

(b) Filtration shall be through sand media of the depth not less than 900 mm. The effective size of the sand shall not be larger than the depth of the filter media divided by 1000 and the uniformity coefficient of the sand shall not be less than 1.4.

(c) Filter media shall be supported by a layer of gravel of depth not less than 350 mm and which shall be placed in graded layers so as to be stable under the simultaneous application of air and water wash unless the filter nozzle system is specifically designed to operate with a lesser depth of gravel under the simultaneous application of air and water wash.

(d) The depth of water in the filter above the top of the media shall be not less than 1.8 m.

(e) The 'clogging head' (i.e. the available head for suspended solids retention), which is equal to the geometric head between the inlet and outlet of the filter less the head loss across the filter having clean filter media shall not be less than 1.5 m at the filtration rate with all filters in operation.

(f) The design shall minimise any tendency to develop negative head in the filters; filter outlet shall be arranged to discharge filtered water over a weir into the filtered water channel with weir crest set at about the top level of the sand layer.

(g) Filter run length shall be not less than 24 hours.

(i) The design shall minimise any tendency to scour the media, particularly during filling or surface flush and to carry-over of media particularly at the start of the air scour.

(j) Filters shall be arranged for slow start by opening the outlet in a step wise manner over 30 minute period.

The filter works shall be designed to facilitate sections being taken out of service for inspection, cleaning of filters and channels and maintenance, without total loss of supply. Stoplogs shall be provided at the inlet channel to each bank of filters for isolation.

The filter design shall have been proved in service in existing installations in the tropics for a minimum period of five years in at least three drinking water treatment works.

B 3.8.3 Filter media

The loss of media in the first year of operation shall be not greater than 1% of the total media in the filters.

Spare media shall be provided to replace that lost in the first 5 years of operation following issue of the Performance Certificate.

The minimum quantity supplied shall be 50 m^3 and shall be packed in bags and stored on 2-way entry close boarded pallets in a location to be advised by the Engineer. Pallets shall be shrink wrapped and shall be stacked two high.

B 3.8.4 Filter flow control

The filter control shall be of the equal inlet flow division, constant water level type.

The inflow to the filters shall be divided equally between filters using the pre-set overflow weirs in the inlet to each filter. The control system shall be arranged to maintain the level of water in each filter constant irrespective of the inflow and the headloss by modulating the filter outlet flow control valve as necessary.

The filtration rate shall be as uniform as possible between filters any variation shall be limited to plus or minus 5%. The water level variation in the filter shall be limited to 50 mm during the complete filtration cycle.

B 3.8.5 Filter inlet and flow division

The inlet flow division weir to each filter shall be provided with a stainless steel weir plate set in stainless steel frame with an adjustable height of at least 150 mm and an pneumatically actuated penstock / valve for filter isolation and shall be arranged to feed the filter by way of a central washout channel. A flow stabilising baffle shall be provided at the inlet to each weir.

B 3.8.6 Filter outlet valve

The outlet pipe of each filter shall be provided with a flow control valve of the butterfly type with a pneumatic actuator and shall be arranged to discharge into the filtered water channel via a chamber containing an outlet weir.

B 3.8.7 Filter level

Each filter shall be provided with a level electrode system for terminating the drain down of a filter and for the execution of any other operations during the wash and for initiating any level alarms.

B 3.8.8 Loss of head indicators

Each filter shall be provided with a loss of head transmitter and local indicator. The unit shall be designed and installed to eliminate air entrainment and sand ingress. The transmitter signal shall be utilised to initiate remote indication and alarm annunciation.

In addition, each filter shall be provided with piezometer tappings to monitor head loss across the media and outlet valve. The system shall be provided complete with all necessary puddle pipes, strainers, manometer tubes (diameter 50 mm) and floats, mounting boards, scales calibrated in 0.10 m minor divisions and 1m major divisions to show water levels, interconnecting pipes, valves and fittings.

B 3.8.9 Filter washing

The method of cleaning filters shall be by simultaneous application of air and water followed by a water rinse.

Filter washing shall be automatic following manual initiation. Filter valves and penstocks which require to be operated as part of the wash sequence shall be fitted with pneumatic actuators of the double acting type. Except where specified the time to open/close penstocks/valves shall be less than one minute.

It is an essential requirement of the Contract that only proven wash systems, materials and procedures be used. Particular care shall be exercised in ensuring equality of pressure and flow to the nozzle floor system bearing in mind the high velocities of air and water. The design shall incorporate such devices as may be necessary for converting velocity head to pressure head.

Wash rates proposed shall be those of the Contractor's own proven design, but in any case shall meet the following minimum requirements:

(a) Distributed air at a rate of not less than 55 m^3 free air/h.m^2;

(b) Distributed water at a rate of not less than 14.5 m^3/h.m^2.

Air supply for air scour shall be provided by Rootes type rotary air blowers. One or two duty blowers and at least one standby blower of equal capacity to one duty blower shall be provided. Air blowers shall be provided with acoustic enclosures.

Each filter shall be provided with an air release if the Contractor considers it is necessary to remove any residual air from the plenum floor.

Disinfected water shall be used for washing filters and shall be drawn under gravity from an elevated storage tank.

The scour air and washwater pipes shall be laid in a ring main.

The washwater supply to the filters shall be provided with a flowmeter of the magnetic type. The rate of washwater flow shall be controlled by a butterfly valve located downstream of the flow measuring element. Operation of the valve shall be manual by handwheel unless the Contractor requires it to be automated for applying two different rates for combined air-water wash and the water only rinse. The valve shall be provided with a position indicator and a locking device where applicable. The maximum velocity through the control valve shall not exceed 5 m/s. The valve shall be provided with access for operation and maintenance.

The rate of flow shall be indicated local to the control valve.

Washwater shall be removed from above the media by a side weir arrangement. The system shall be designed to:

- Remove washwater evenly from the filter and as rapidly out of the filter as possible.
- Prevent the loss of filter media, particularly at the start of the air scour.
- Incorporate means for removal of residual solids at the end of the rinse phase.
- Be free draining on completion of the backwash.

Suspended troughs over the media surface for washwater removal will not be accepted.

A surface flush (also known as cross-wash) using clarified water may be provided and the manner in which it is introduced onto the filter shall be such that scouring of the filter media at the points of entry is avoided. The quantity of surface flush water used shall be included in the computation of the washwater consumption.

It shall be possible to drain a filter, in emergencies, to waste via the washwater outlet valve instead of draining it to supply. This is defined as a `dump' and will amount to the volume of water formed by the full depth of water over the sand media down to the washout weir sill. Used washwater including `dump' water shall gravitate to the used washwater holding tanks. Dump water is not required to be included in the computation of the wash water consumption.

B 3.8.10 Filter sampling

Each filter shall be provided with facilities for taking a filtrate sample, which shall be brought to an accessible point in the lower walkway gallery. Each sampling point shall be provided with a sink complete with a drain.

B 3.8.11 Filter performance

When operated in accordance with the Contractor's instructions at the rated throughput using all filters less one out of service for maintenance and one washing individual filters working together with clarifiers shall perform to the following standards:-

(a) Filtered water samples shall be tested for 100% compliance with the following:
Turbidity : Not exceeding 1.0 NTU

(b) Filtered water samples shall be tested for 95% compliance with the following:-
Turbidity : Not exceeding 0.4 NTU

(c) Filters shall achieve the filtrate quality specified with a minimum length of filter run of 24 hours.

(d) Water used in washing filters (i.e. washwater and surface flush water) averaged over a 24 hour period shall not exceed 2.5% of the works input averaged over the same 24 hour period.

B 3.8.12 Drainage

The filter building shall be provided with a drain sump to collect and evacuate drainage in the filter pipe gallery.

If drainage by gravity is not practicable the sump shall be provided with two drain pumps arranged to operate on automatic level control as duty and `duty assist'.

Pumps shall be fitted with quick release couplings and lifting chain and shall be supplied complete with delivery and non-return valves and pipework.

All filter plant drainage shall be discharged to the used washwater channel or to the site drainage system.

B 3.8.13 Access

Access shall be provided on top of the filters as follows:

- Along filter inlet channels
- Between pairs of filters leading to the upper filter gallery
- Covered walkway between the two banks of filters.

Access shall also be provided from the filter building to the lower and upper filter galleries and also to the opposite end of the upper filter gallery. Lower filter gallery shall be provided with stair access from the upper filter gallery from the opposite ends. Filter wash control panels shall be located opposite each filter in the upper filter gallery. Upper filter gallery shall be provided with glass panels to observe the filters from the central walkway.

All access ways where necessary shall be provided with handrailing.

B 3.9 Used washwater disposal plant

B 3.9.1 General

Filter washwater after use shall be discharged to a filter wash water recovery tank from which supernatant will be returned to the treatment works inlet at a rate not greater than 5% of the rated throughput.

B 3.9.2 Used washwater recovery tank

One used washwater holding tank shall be provided. The tank shall be provided with two equal sized compartments interconnected by a penstock, to allow one to be taken out of service for settling of the used washwater or for maintenance, whilst the other remains available to receive used washwater. Each compartment shall be rectangular in plan with the floor laid to a fall and terminating in a pump sump. The capacity of each compartment of the tank shall be adequate to store as a minimum, the washwater from two consecutive filter washes. In sizing the tank and the draw-off systems the Contractor shall assume that all filters will be washed consecutively spaced at 30 minutes apart.

The used washwater shall flow into an inlet channel and then through penstocks into the compartment in use.

The inlet channel to the tank shall be provided with an overflow discharging to the site drainage system.

Each compartment shall have a floating draw-off arm which shall be design to remove settled water from the upper part of the tank. The floating arm shall be connected to the draw-off connection by an articulated pipe. A restraint system shall be provided to prevent excess movement of the floating draw-off arm and articulated pipe during filling and when the compartment is fully emptied.

Each compartment shall have a sludge draw-off connection with a downward facing bellmouth in the sump.

Each compartment of the used washwater recovery tank shall be provided with level monitoring equipment for filter wash inhibit and pump control.

The Contractor shall include sufficient pedestrian access-ways in reinforced concrete, which shall be fitted with handrailing and kick-plates on both sides of the tank and on the common wall throughout their full length, to enable the operational staff to have ready access around each compartment and to the inlet channel.

Means of access shall be provided into each compartment of the washwater recovery tank.

B 3.9.3 Used washwater return

After a period of settling the supernatant shall be returned to the works inlet from the used washwater recovery tank at a rate not exceeding 5% of the raw water inflow to the treatment plant. The water remaining shall be pumped to the sludge balancing tank.

The supernatant discharge pipe at the works inlet water tank shall terminate in a nozzle to give an exit velocity of not less than 2.5 m/s to promote mixing of the water with the raw water. The flow in the pipe shall be measured.

The washwater recovery pump house shall be arranged as a dry basement having a common wall with the wash water recovery tank.

Separate pumps (one duty, one standby) shall be provided for supernatant and for sludge. Pumps shall be located below the minimum sludge level in the wet wells to ensure that they are fully primed and operate under positive suction head at all times. Drive from the motor to pump shall be direct and motors shall be mounted at a suitable level to avoid the risk of flooding.

Pumps shall be of the vertical spindle, volute type arranged to draw supernatant or sludge directly from the tank. Pump volute casing shall have integral suction and delivery branches and shall be constructed to permit the removal of the rotating assembly without disturbing the branch connections.

The suction connections form each compartment shall be interconnected so that the duty and standby pumps can draw from either compartment. The pump delivery connections shall be manifolded to a single delivery main in each case.

Operation of the pumps shall be controlled by level probes in each compartment of the used washwater recovery tank. Pumps shall be arranged for automatic changeover from duty to standby on the failure of the duty pump.

The sludge pumps shall be installed to minimise ingress of sand originating from the filters. Pump design and materials shall be selected to minimise damage to the pump due to sand in the sludge.

The installation shall be provided with all pipework, valves, fittings, level detectors and penstocks. Sludge pipework shall be arranged with easily detachable joints and isolating valves to allow any blockages to be easily cleaned.

B 3.9.4 Tank cleaning

At least two hydrant points shall be provided near the used washwater recovery tank for washing down purposes. The Contractor shall provide a high pressure hose of length 20m complete with hose reel, connector and nozzle to serve the two hydrant points.

B 3.10 Contact tank and treated water reservoir

B 3.10.1 Contact tank

The contact tank shall be designed to provide a minimum effective contact time t of 30 minutes, between the time of entry into the tank and the time of discharge of disinfected water from the tank into the treated water reservoir, at the rated throughput. The effective contact time is defined as the detention time at which 90% of the water passing through the contact tank is retained within the tank. The `C.t' value (= free chlorine residual concentration C mg/l at the end of the effective contact time t x t minutes) shall not be less than 15 mg.min/l.

The tank shall be covered and shall be constructed with a central division wall, so that either compartment may be drained down for maintenance, the other compartment remaining operational. The hydraulic design of the contact tank shall allow the full throughput to pass through one compartment.

Each compartment of the contact tank shall be provided with valved drainage facilities for completely draining down a compartment, and access manholes and ventilators raised to a level above the free water surface.

Each compartment shall be provided with an overflow.

The minimum freeboard of the contact tank shall be 500mm and 150mm during normal operation and during overflow at the maximum rate respectively.

Baffle walls of `around the end' type shall be provided in each compartment of the contact tank to minimise short-circuiting and to ensure maximum effective contact time.

Chlorine solution shall be mixed into the filtered water at the inlet to the contact tank by hydraulic or mechanical means. The inlet jet shall be baffled if the inlet pipe discharges directly into the contact section of the tank.

Free fall weirs shall be provided on the outlet of the contact tank, or at the inlet to the treated water reservoir where this is adjacent to the contact tank to ensure the effective contact time is maintained under all draw-down conditions in the treated water reservoir and to provide for mixing of lime at the exit of the contact tank if this is required.

The contact tank shall be provided with all process pipework, inlet isolating valves, ventilators and washouts required, access arrangements, ladders and all necessary fixtures and fittings.

B 3.10.2 Treated water reservoir

The treated water reservoir shall be covered. The effective storage capacity of the reservoir shall be sized to provide 1.0 hours storage at a flow of 161 Ml/d. The reservoir shall be provided with a division wall to provide two equal capacity compartments, so that a compartment may be drained down for maintenance, whilst the other compartment remaining operational. Each compartment of the reservoir shall be designed to ensure through circulation of water in the reservoir.

The minimum freeboard of the treated water reservoir shall be 500mm and 150mm during normal operation and during overflow at the maximum rate respectively.

The floor of the reservoir shall be sloped for drainage at a minimum fall of 1 in 200, either directly to the drainage sump or indirectly via drainage channels in the floor.

Each compartment shall be provided with inlet and outlet isolating valves, drainage and overflow to the site drainage system and water level transmitters. Each compartment of the treated water reservoir shall be provided with an overflow unless the hydraulic design of the reservoir provides for the use of the overflow system of one compartment of the contact tank.

A monitoring and sample house shall be located in a suitable position on the roof of the reservoir. This shall house reservoir level monitoring equipment, sampling pumps and associated equipment.

The reservoir shall be provided with all pipework, valves, penstocks, ventilators and washout and overflow pipework together with access covers, ladders, level measuring equipment and all necessary fittings and fixings. Ventilators shall be designed to promote cross flow of air through the reservoir.

Access covers shall be sealed and lockable and shall be installed on concrete upstands 150mm above the roof slab.

Ventilation shall be provided of capacity equivalent to the maximum rate of outflow from the reservoir. Openings shall be screened with insect-proof mesh which shall be easily inspected and replaceable.

B 3.10.3 Treated water reservoir outlet system

The outlet pipes from each compartment of the treated water reservoir shall be at low level from floor sumps located at the lowest point of the reservoir floor so that all storage can be utilised. Inverted bellmouths shall be used for the outlets. The outlet pipework shall be fitted with isolating valves and shall be connected to the pipework of the treated water pump station, which shall be adjacent to the treated water reservoir.

B 3.10.4 Drainage

It shall be assumed that a compartment of the treated water reservoir will be pumped out by the treated water pumps to about 300 mm water depth at the outlet end before draining down to waste.

The drainage system of the contact tank shall provided for emptying of a full compartment.

Drainage shall be by gravity to the site drainage system or by gravity to a sump for pumping to the site drainage system. If pumping is necessary two submersible pumps each of capacity 50 l/s shall be provided and located in a drainage chamber of suitable capacity outside the reservoir.

The operation of the pumps shall be automatic and the two pumps shall be arranged to operate as 'duty' and 'duty assist'. The sump shall be provided with level monitoring system for pump control.

B 3.11 Sludge treatment

B 3.11.1 General

Sludge from the clarifiers and from the used washwater recovery tank shall be thickened before disposal to the drying beds.

Sludge works shall include the following treatment stages and plant:-

(a) Sludge balance tanks.

(b) Thickener feed pumps.

(c) Sludge thickeners.

(d) Thickened sludge tank.

(e) Supernatant and thickened sludge discharge system.

(f) Sludge drying beds.

B 3.11.2 Sludge balance tanks

The function of the balance tanks is to balance the intermittent sludge discharges from the clarifiers and from the used washwater recovery tank, to provide a well mixed uniform sludge to the thickeners and to act as a sump for the thickener feed pumps. The tanks shall be sized to balance the intermittent flow while it is withdrawn at a steady rate and concentration to the thickeners. The minimum criteria for sizing shall be all clarifiers desludging consecutively for a predetermined period every hour plus emptying of sludge from the used washwater recovery tank.

One tank with two equal compartments of combined capacity adequate to balance sludge discharges shall be provided.

At least one submersible mixer shall be provided in each tank and shall be designed to maintain solids in suspension and keep the sludge fully mixed. The mixers shall comprise a drive unit and propeller integrated into a compact installation with guide rails, lifting chains and davits.

Each balance tank shall be provided with level measuring equipment for pump control, to ensure a minimum submergence required for the mixer is maintained, to prevent dry running of the pumps and for clarifier and washwater recover tank desludge inhibit and alarm initiation.

Balance tank compartments shall be provided with an overflow discharging to the sludge drying beds.

A hydrant shall be provided on the tanks for washing down purposes. The Contractor shall provide a high pressure hose of length 20 m complete with the hose reel, connector and nozzle to serve the hydrant point. Facilities shall be provided for completely draining the balance tank.

B 3.11.3 Thickener feed pumps

The sludge thickener feed pump house shall be arranged as a dry basement having a common wall with the sludge balance tanks.

The pumps shall be located below the minimum sludge level in the wet wells to ensure that they are fully primed and operate under positive suction head at all times. Drive from the motor to pump shall be direct and motors shall be mounted at a suitable level to avoid the risk of flooding.

Pumps shall be of the vertical spindle, volute type arranged to draw sludge directly from the tank. Pump volute casing shall have integral suction and delivery branches and shall be constructed to permit the removal of the rotating assembly without disturbing the branch connections.

Each thickener shall be provided with two pumps (one duty, one standby). The duty pump of each pair of pumps shall be arranged to draw sludge from the two balance tanks separately and pump to the respective thickener.

However the outlets of all the pumps shall be manifolded to allow two duty pumps feed one thickener when the other thickener is out of service for maintenance. Each feed pump shall have an output equivalent to at least the thickener scraper capacity.

Operation of the pumps shall be controlled by level probes in each sludge balance tank compartment. Pumps shall be arranged for automatic changeover from duty to standby on the failure of the duty pump.

The sludge thickener pump basement shall be provided with a drain sump and pumps to collect and evacuate drainage in the pump area. There shall be two pumps arranged to operate on automatic level control as duty and `duty assist'.

All drainage form the pump basement shall be discharged to the sludge balance tanks.

B 3.11.4 Sludge thickeners

Two thickeners of the continuous flow type suitable to thicken the sludge feed to a concentration greater than 1.5% w/v (15 g/l) without the aid of polyelectrolyte shall be provided. The thickener shall be designed to accept polyelectrolyte conditioned sludge in the future and thicken it to 3% w/v (30 g/l).

The thickeners shall be sized for a nominal design surface loading rate of 0.75 $m^3/h.m^2$ at the maximum feed rate with both thickeners in service. Each thickener shall be hydraulically designed to a surface loading rate of 1.5 $m^3/h.m^2$ to permit the maximum feed rate to be passed through one thickener.

The process design of the thickener shall be based on a proven method for continuous thickening of coagulant sludges with and without polyelectrolyte conditioning.

Thickeners shall comprise a feed channel or pipe discharging to a central feed well, a scraper mechanism driven by a fixed speed motor for moving sludge to a central hopper and a peripheral launder for collecting the supernatant. The floor of the thickener shall be laid to a minimum fall of 7.5%.

Hydrant points and a high pressure hose of length 20m complete with hose reel, hose connector and nozzle shall be provided for washing down and cleaning purposes.

Each thickener shall be provided with facilities for complete draining.

Thickeners shall be provided with bypass facilities to allow part or all of the clarifier sludge to be discharged directly to drying beds.

Thickeners shall be provided with access to the top of the thickener to enable cleaning of supernatant launders and operation and maintenance of scraper drive unit to be carried out.

B 3.11.5 Thickened sludge collection and disposal

Sludge from the thickeners shall be discharged to the sludge drying beds by gravity. Each thickener sludge outlet pipe shall be provided with a pneumatically operated valve arranged to operate on timer control. Each power operated valve shall be provided with a guard valve. Valves shall be provided with access for maintenance. Where chambers are provided access shall be by stairs.

The thickener bypass and the overflow from the site septic tank shall also be discharged to the sludge drying beds.

B 3.11.6 Sludge valves

All sludge valves shall be of the eccentric plug or ball type and where specified shall be arranged for pneumatic power operation with manual override. Each power operated valve shall be spring loaded and arranged to fail close and shall be provided with a manually operated guard valve.

B 3.11.7 Flushing system

Flushing points complete with isolating valves and terminating in hose connectors shall be provided on sludge pipework and on both sides of all isolating valves on thickener feed and thickened sludge withdrawal systems.

A pressure water supply complete with high pressure hoses, hose reels, nozzles and hose connectors shall be provided.

B 3.11.8 Thickener supernatant

Supernatant from the sludge thickeners shall be discharged by gravity to a nallah as shown on the drawings.

B 3.11.9 Sludge drying beds

Reusable type sludge drying beds shall be provided to accept sludge from the thickeners of concentration up to 1.5% w/v (15 g/l) without polyelectrolyte and up to 3% w/v (30 g/l) with polyelectrolyte and dewater to a concentration greater than 15% w/w dry solids. Dewatering shall be by settling and supernatant decanting followed by evaporation drying and under floor drainage.

The capacity of the drying beds shall be based on the time to settle sludge, time to decant supernatant and rainfall and time to evaporate or drain water from the sludge and rainfall in the wettest month of the year. The capacity of the drying beds shall be adequate at least to accommodate sludge produced over the longest cycle time of all the sludge drying beds at the maximum rate of production of sludge. Drying beds shall be of equal or similar capacity. Where the space available does not lend itself to drying beds of equal capacity, the capacities shall be proportioned accordingly. A minimum of eight drying beds shall be provided and shall be used in rotation each being in various stages of filling, dewatering and emptying. Drying beds may be set at different levels.

The floor of the drying beds shall be comprise a graded filter and collector pipe system to remove water from the area of the drying beds with minimum loss of efficiency. The decanting and under-drainage systems shall discharge by gravity to a nullah at a location to be approved by the Engineer. Sludge will be removed by mechanical or manual scraping. Concrete strips shall be incorporated in the floor to permit the passage of plant and to provide a bed reference level which will facilitate the removal of the sludge without damage to the drainage layer.

Individual beds shall be separated by reinforced concrete walls which shall provide a minimum of 300mm freeboard when the higher of adjacent drying beds is overflowing. The decanting system shall include manual weir penstocks which shall be accessible at all times and which shall also serve as overflows. The weir penstocks shall be located on the side opposite to that on which the inlets are located and shall discharge to a common collection channel.

The inlet pipes shall discharge onto splash slabs so that there is no damage to the beds.

The under-drainage of each drying bed shall discharge to a manhole on the drainage collection system so that the flow from individual drying beds can be inspected.

Concrete access ramps into the drying beds shall be provided. Ramps shall be at least 3m wide and set at a maximum gradient of 20%. Slope transitions shall be provided at the top of the ramps. Road access shall be provided around the area of the drying beds for transportation of the sludge by tipper trucks to remote landfill sites.

B 3.12 Chemical treatment

B 3.12.1 List of chemicals and estimated dosages

The following list of chemicals and estimated dosages shall be used as guidance in the design of chemical storage facilities, slurry/solution preparation and handling plant and dosing equipment used to apply the chemicals to various dosing points scheduled below:-

Dosing point and chemical	Function	Estimated dose (mg/l)	
		Average	Maximum
Clarifier inlet			
Chlorine*	Biological control (intermittent)	1.0	2.0
Aluminium sulphate or polyaluminium chloride (as 15.2%w/w Al_2O_3)	Coagulation.	15	25
Contact tank inlet			
Chlorine	Disinfection.	1.5	3.0
Contact tank outlet			
Hydrated lime (as 92%w/w $Ca(OH)_2$)	pH correction for positive Langelier Index	7	10

** Pre chlorination is not required for the treatment process incorporating lamella clarifiers.*

B 3.12.2 Chemical building - layout

The facilities comprising storage, handling, slurry/solution preparation and dosing for chemicals (except chlorine) shall be housed in the chemical building or buildings as shown on the drawings. The flowing description applies to the provision of one building, which shall be a separate self-contained building comprising the following:-

(a) A segregated areas on the ground floor for aluminium sulphate and hydrated lime storage.

(b) An area in the basement for aluminium sulphate solution and hydrated lime slurry preparation and transfer area.

(c) An area on the first floor for lime saturators and aluminium sulphate constant head tank and metering equipment.

(d) An electrical switch room.

(e) Toilet, wash room and shower room.

If separate buildings are to be provided then the requirements shall be the same except that the buildings shall be specifically for aluminium sulphate or hydrated lime.

A separate building shall be provided for chlorine.

B 3.12.3 Chemical building - storage and reception

Hydrated lime will be delivered in 50 kg bags of approximate dimensions 550 mm x 750mm and a depth of 250 mm. Aluminium sulphate will be delivered loose in blocks of approximate weight 17 to 20 kg.

Aluminium sulphate and lime will be manually unloaded from delivery vehicles on to pallets for conveying to storage.

The basis for sizing storage space for bags of lime shall be that they will be stacked on pallets to a height not more than 1.5 m. Aluminium sulphate shall be stored loose on the floor in bunkers of width about 3 m to an average height of about 1 m. Transfer of bags and blocks from delivery vehicle to storage area shall be by pallet truck. Movement of bags and blocks in the storage area and to slurry/solution preparation area shall be by pallet truck.

The storage space for aluminium sulphate and lime shall be estimated on the basis of average dose x maximum throughput x 28 days.

The aluminium sulphate storage area floor and the walls up to the storage height shall be protected by a 5 mm thick trowel applied epoxy mortar.

B 3.12.4 Chemical building - drainage

Slurry/solution preparation and stock tanks shall be located in the basement of the chemical building. Floor drains shall be provided to collect overflow, spillage leakage and drainage from the tanks and discharge by gravity to a chemical waste holding tank in the basement of the chemical building. The drains shall be provided with open mesh flooring of GRP construction.

The contents of the chemical waste holding tank shall be pumped to the clarifier sludge balance tanks. There shall be two pumps arranged to operate on level control as duty and duty `assist'. The pumps shall be arranged for control on level in the tank using a system of level electrodes.

The basement floor, plinths, drains and waste holding tank and the walls up to 300 mm shall be protected by a 5 mm thick trowel applied epoxy mortar.

B 3.12.5 Chemical handling

Equipment provided for handling chemicals shall include the following:-

(a) Five hand powered hydraulic pallet trucks each with a lifting capacity of not less than 1500 kg and 10 Nos 4-way entry open deck reversible pallets of approximate size 1200 x 1200 mm for transfer of lime and aluminium sulphate.

(b) 75 Nos. 2-way entry closed deck non-reversible type pallets for lime bag storage, each of timber construction and approximate size 1200 x 1200 mm.

B 3.12.6 Chemical plant safety

The following safety equipment shall be provided to serve the chemical building:-

(a) Two safety showers (complete with eye bath), one local to the aluminium sulphate bulk storage tanks and one local to the lime slurry tanks in the chemical building.

(b) 20 Nos. boxes of face masks each containing 40 disposable dust masks for lime handling area.

(c) Four sets of protective clothing as specified in Volume 3.

(d) Four sets of goggles.

(e) Three first aid boxes.

B 3.13 Aluminium sulphate

B 3.13.1 General

Aluminium sulphate will be delivered in approximately 17 to 20 kg blocks containing 15.2% w/w Al_2O_3. Aluminium sulphate shall be stored in the chemical building, transferred to saturator tanks and drawn by pumps as a saturated solution which shall then be diluted to a 10% w/v (100 g/l) solution in stock tanks, transferred to constant head tank for metering under gravity to the point of application.

The plant for storage, solution preparation, solution transfer and dosing shall be provided.

A process flow and instrumentation diagram is given in the drawings.

B 3.13.2 Saturators

A total of two saturators constructed in concrete each of aluminium sulphate storage capacity of not less than 16 t shall be provided. The effective volume of a tank (excluding the gravel layer and free board) shall be not less than 38,000 litres. The tanks shall be lined with fibre reinforced plastic.

The water shall be introduced along the length of the saturator by a spray bar and the inlet shall be provided with a float operated isolating valve and a guard valve. The time to fill a saturator with water from empty to full shall be not more than one hour. Each saturator shall be provided with piped saturated solution collection system placed in a layer of gravel. The outlet shall be provided with a manual isolating valve and a strainer and the recirculation return pipes shall be provided with a manual isolating valve.

Saturators shall be provided with a drain discharging to the waste holding tank in the chemical building. The outlet pipe shall be provided with a flushing connection to back flush the gravel bed in the saturator via the overflow to waste.

The float valve and any other fittings shall be located within stainless steel compartments inside the saturators to protect them against damage from blocks of aluminium sulphate.

B 3.13.3 Saturated solution recirculation and transfer

Two pumps (one duty, one standby) shall be provided for recirculation and transfer of a saturated solution and the pumps shall be of the centrifugal type.

The pumps shall be arranged to draw a saturated solution of aluminium sulphate from any selected saturator downstream of the strainer and return to the same saturator. Each pump shall be sized to turnover the solution in a saturator (making an allowance for the solid present) in less than 2.5 hours. The pumps shall also be arranged to transfer the solution from one saturator to another. The capacity of each pump shall be not less than 11 m^3/h.

The same pumps shall be used to transfer aluminium sulphate from the saturators to the stock tanks.

The transfer pumps shall be provided with all necessary isolating and non return valves, pressure gauges and facilities for flushing the pumps.

B 3.13.4 Stock tanks

The saturated solution containing approximately 70% w/v (700 g/l) of solid as 15.2% $^{w}/_{w}$ Al_2O_3 shall be diluted in the stock tanks to a concentration of 10% w/v (100 g/l).

The dilution process shall comprise transfer of a known volume of saturated solution to the stock tank followed by the addition of water to the maximum level in the tank and mixing of the contents.

Two GRP lined concrete tanks each of working capacity not less than 19,000 litres shall be provided. Each tank shall be equipped with a mixer. The tanks shall be arranged to operate on a rotational batch basis. The estimated holding period for a single tank at the maximum demand is about eight hours.

The stock tanks shall be provided with a water supply for in-tank dilution.

The water inlets, solution inlets and solution outlets shall be provided with manually operated isolating valves. Tanks shall be provided with a valved drain. A strainer shall be provided on each outlet.

Each solution tank shall be provided with level probes for monitoring the level in the tanks, level sensors for measuring the volume of contents in the tank and sight glass type contents monitoring device calibrated in litres.

B 3.13.5 Diluted solution feed to constant head tanks

Two feed pumps (one duty, one standby) of the centrifugal type arranged to draw the chemical from any one of the selected stock tanks and feed a constant head tank shall be provided. The pumps shall be rated at least 15% in excess of the maximum aluminium dosing flow rate and shall be not less than 2740 l/h.

The feed pumps shall be provided with all necessary isolating and non return valves, pressure gauges and facilities for flushing the pumps.

B 3.13.6 Constant head tank

One constant head tank of fibre reinforced plastic construction and of capacity 1000 litres shall be provided. The tank shall be arranged to operate as a constant head tank by providing a supply of aluminium sulphate solution in excess of the maximum outflow from the tank for the coagulation process and discharging the excess as overflow to the stock tanks.

The tank shall be provided with a high level return pipe arranged to return the excess flow (the difference between the inflow and the outflow) to the duty stock tank and thereby maintaining a constant head in the tank. The return pipe shall be provided with a manual isolating valve on each branch to the stock tanks. In addition, the tank shall be provided with an overflow discharging to the chemical house drainage sump.

The tank shall be located at such a level to ensure gravity dosing of aluminium sulphate to the point of application.

The tank shall be also provided with an outlet complete with a strainer and an isolating valve and a valved drain.

The tank shall be provided with level probes for monitoring the level in the tank.

B 3.13.7 Aluminium sulphate dosing

Aluminium sulphate solution from the constant head tank shall be conveyed to the point of application by gravity. The point of application shall be provided with a minimum of one duty variable area flowmeter. The capacity of the flowmeters shall not be less than 2380 l/h, and shall be graduated in 50 l/h major divisions and 5 l/h minor divisions. An equal number of standby flowmeters of equal capacity to the duty flowmeters shall be provided.

Flowmeters shall be provided with inlet isolating valves and outlet flow regulating valves.

The flowmeters shall be manifolded on the upstream side. The manifold shall be provided with flushing facilities. One dosing line shall be provided and shall be terminated in two perforated distributor pipes provided complete with isolating valves and flushing connection at the point of application.

B 3.14 Hydrated lime

B 3.14.1 General

Lime will be of the hydrated type consisting 92% $^{w}/_{w}$ $Ca(OH)_2$ and will be delivered to the works in 50 kg bags. Lime shall be stored in the chemical building, manually emptied into tanks for preparing a 5% w/v (50 g/l) slurry and then transferred by pumps to lime saturators for metering to the points of application.

The plant for lime storage, handling, slurry and solution preparation, metering, and transfer shall be provided.

A conceptual process and instrumentation diagram is given in the drawings.

The components of the lime plant shall comply with the requirements of the General Specification Volume 3.

B 3.14.2 Slurry preparation tanks

Two vertical concrete tanks shall be provided. The concentration of lime slurry prepared in the tanks shall be 5% w/v (50 g/l) and the working capacity of a tank shall be 31,000 litres. The estimated holding period of a single tank at maximum demand, (combined maximum dose x maximum flow) is about eight hours.

Each tank shall be provided with a cover complete with a dust filter sock and a hinged access hatch. A bag loader sized for taking bags up to 50 kg capacity shall be provided on each tank. Tanks shall be equipped with slow speed paddle type or similar mixers for mixing lime and keeping lime in suspension.

The tanks shall be provided with a water supply. Water inlet and slurry outlet shall be provided with isolating valves. A valved drain shall also be provided on each tank.

Each slurry tank shall be provided with level electrodes for level monitoring.

B 3.14.3 Slurry transfer pumps

Lime slurry transfer pumps shall be of the open impeller centrifugal type. Two pumps (one duty, one standby) each of capacity not less than 20 m^3/h shall be provided. Each pump shall be arranged to draw lime from any selected slurry tank and pump separately to a selected saturator. Each delivery pipe shall be provided with a magnetic flowmeter with local and remote indication.

Pumps shall be provided with pressure gauges Flushing connections shall be provided on pumps, pump suction manifold, pump delivery saturator manifolds and the manifolds at each saturators.

B 3.14.4 Saturators

Saturators shall be designed to prepare a saturated solution of lime. The concentration of a saturated solution is about 1.53 g/l at 30^{o}C. In practice, the concentration of lime that can be expected from a saturator is estimated to be about 85% of the theoretical value. The Contractor shall use his previous experience in similar applications to arrive at a design value for the lime concentration from a saturator.

A total of four vertical steel saturators shall be provided for meeting the pre and post lime dosing requirements. Two saturators shall be assigned for pre-lime dosing and one saturator each shall be assigned for the two post lime dosing points. The use of inclined plates in the saturator to increase the surface loading rate of the saturators will not be acceptable.

The saturators shall be located on the first floor of the chemical building.

All pipework conveying lime solution Desludging of the saturators shall be manual. Sludge shall be conveyed by open channel to a pit outside the chemical building for manual removal and off site disposal. The overflow from the pit shall be discharged to the drying beds via the site drainage system.

The proposed saturator design shall have been proved in service in existing installations operating on similar quality of lime at the specified or higher rates for a minimum period of five years.

B 3.14.5 Lime dosing

Lime solution from the saturators serving each dosing point shall be combined as applicable and shall be metered to the points of application by gravity. Each point of application shall be provided with a minimum of one duty variable area flowmeter. The capacity of the flowmeters for pre-lime dosing shall not be less than 34 m^3/h and the capacity of post lime flowmeters shall be not less than 37 m^3/h, and shall be graduated in 10 m^3/h major divisions and 1 m^3/h minor divisions. An equal number of standby flowmeters of equal capacity to the duty flowmeters shall be provided for each application.

Flowmeters shall be provided with inlet isolating valves and outlet flow regulating valves.

The flowmeters serving each point of application shall be separately manifolded on the upstream side. The manifolds shall be provided with flushing facilities. Each dosing point shall be provided with a dosing lines which shall be terminated in two perforated distributor channels provided complete with isolating valves and hosing down connection at the point of application.

The Contractor is at liberty to propose proven alternative methods for manual lime dose control.

B 3.15 Chlorine

B 3.15.1 General

Chlorine shall be drawn as a gas from drums and metered under vacuum, mixed with water in ejectors and transferred to the points of application.

Plant for storage, metering and dosing of chlorine shall be provided and shall be contained in a fully segregated self-contained building.

For treatment process incorporating lamella clarifiers pre chlorination is not necessary and the chlorine plant shall therefore be designed for post chlorine dosing only.

A process and instrumentation diagram is given in the drawings.

B 3.15.2 Chlorine Building

Chlorine storage and dosing facilities and ancillary plant shall be provided in a fully self-contained building as shown on the drawings and shall comprise the following:

(a) Drum store with an unloading bay to accommodate duty and standby drums and storage and empty drums.
(b) Chlorinator room.
(c) Ejector room.
(d) Motive water pump room.
(e) Switch room.

B 3.15.3 Safety equipment

The chlorine plant shall be provided with the following safety facilities:

(a) Two safety showers complete with eye baths located at the two entrances to the chlorine drum store.
(b) Three sets of self contained air breathing apparatus and wall-mounted cabinets in the switch room.
(c) Three sets of protective clothing including overalls, boots, goggles and helmets and storage lockers in the switch room.
(d) One eye irrigator located in the switch room.
(e) One first aid box located in the switch room.

B 3.15.4 Equipment manufacture

The Contractor shall provide the following items of plant and shall ensure that these items are the products of a single manufacturer.

(a) Drum changeover device.
(b) Vacuum regulators and pressure relief valves.
(c) Chlorinators.
(d) Ejectors.

B 3.15.5 Chlorine drums

Chlorine will be delivered as a liquid in cylindrical drums with heads convex inwards. At each end, the sides are crimped inwards over the ends to form chimes that provide suitable grips for hooks used in handling drums.

The approximate dimensions and weights of chlorine drums currently used by the Employer are as follows:

(a)	Net weight of chlorine	1000 kg
(b)	Maximum gross weight (chlorine and drum)	1750 kg
(c)	Length	2080 mm
(d)	Diameter	890 mm

B 3.15.6 Chlorine storage

Chlorine drum room shall contain duty and standby drums connected to a gas chlorine manifold, storage drums to provide 28 days storage at the average combined dose x maximum flow and empty drums. The total number of spaces to be provided in the drum room / store shall be as follows:

(a) 8 spaces for duty and standby drums connected to the manifold.
(b) 16 spaces for storage of drums.
(c) 2 empty spaces for unloading of new drums.

Drums shall be arranged in two parallel lines. Drums connected to gas headers shall be placed on drum rollers bolted to a plinth on the floor. V-shaped cradles of concrete construction shall be provided to place empty and storage drums.

B 3.15.7 Chlorine drum handling and weighing

One overhead monorail arranged as a U-beam complete with an electrically operated wire rope hoist and trolley shall be provided and shall extend over the entire drum store including the unloading bay.

The hoist shall be provided with a suspended weighing device.

B 3.15.8 Chlorine draw-off system

Chlorine shall be drawn off as gas; adequate connections and drum isolating valves shall be provided to enable eight drums to be connected in two banks of four drums, each to an automatic cylinder changeover device so that four drums are on duty and four drums are on standby.

One automatic cylinder changeover unit shall be provided. Automatic changeover of cylinders from duty to standby banks shall be initiated by low pressure measured by a pressure switch on the common gas header. A pressure gauge shall be provided on the gas header. A motorised valves shall be provided on each header downstream of the catchpot to effect changeover from duty to standby banks of drums. It shall be possible to manually bypass the automatic changeover system.

Two vacuum regulating/pressure relief valves (one duty, one standby) shall be provided.

The system shall be provided complete with all necessary gas chlorine pipework, including fixings and supports, electrically operated changeover valves, vacuum regulating/pressure relief valves, manual isolating valves, catchpots and pressure and vacuum gauges.

B 3.15.9 Chlorinators

Not less than four vacuum operated chlorinators each complete with a remote mounted ejector to give aqueous solution output shall be provided.

One chlorinator, shall be designated for pre-chlorination duty and shall have a capacity not less than 15.7 kg/h and two chlorinators (one duty, one standby) shall be designated for post-chlorination duty and shall have a capacity not less than 23.5 kg/h each.

Chlorinators shall be supplied complete with remote wall mounted ejectors, located in the adjacent ejector room and vent pipes discharging separately to a point outside.

B 3.15.10 Ejector motive water supply

Ejector motive water supply shall be drawn from the works water supply system. Motive water pumps shall be used to boost the pressure of the works water supply system.

Pre chlorine ejector shall be provided with a motive water pump. The post chlorine ejectors shall be provided with two pumps (one duty, one standby). The pumps shall be of the vertical multistage centrifugal type. All pumps shall be provided with a common suction manifold. The pumps serving the post chlorinators shall be manifolded on the delivery side.

The pumps shall be provided with isolating and non-return valves and pressure gauges.

B 3.15.11 Chlorine solution transfer system

The pre chlorine dosing point shall be provided with a solution transfer line terminating in a distributor. The post chlorine ejectors shall be manifolded on the outlet and shall be provided with a dosing line terminating in two distributors.

B 3.15.12 Chlorine leak detection

Chlorine leak detectors complete with leak sensors shall be provided in the chlorine drum store and chlorinator room to monitor abnormal concentrations of chlorine in air such as would occur on a leakage of chlorine cylinders and equipment.

The minimum requirements for the detectors shall be as follows:

(a) Drum store - two detectors each with two sensors.

(b) Chlorinator room - one detector with two sensors.

B 3.15.13 Ventilation

The chlorine drum store and the chlorinator room shall be made reasonably gas tight and provided with forced ventilation facilities.

The chlorine drum store shall be provided with gravity operated louvers at high level at least in one end of the store. The extraction system shall consist of at least eight extraction points (four per side) with low level extraction and high level discharge. The vertical extraction ducts on each side of the store shall be manifolded to a single duct running along the wall at high level terminating in a fan at the drum unloading bay of the building. The discharge points shall be located remote from the fresh air intakes. The system shall be provided with vermin screens.

B 3.16 Sampling and monitoring

Facilities shall be provided for taking and conveying continuous samples from the following locations on the plant to the laboratory:

(a) Raw water (inlet to the inlet flume).
(b) Dosed water (inlet to the clarifier).
(c) Clarified water (clarified water pipe to the filters).
(d) Filtered water (filtered water pipe to the contact tank).
(e) Treated water (inlet to the treated water reservoir after lime addition)
(f) Final water to supply (treated water reservoir outlet).

Each sample point shall be provided with means of extracting the sample at a rate not less than 2.5 l/minute, a sample pump (where necessary) of the centrifugal type and pipeline of nylon or flexible reinforced PVC construction for conveying the sample to the laboratory. All sample lines shall be laid in trenches provided with covers and protected from the sun light.

Pumps shall where possible be located under cover in the nearest building. Where this is not possible the pumps shall be located in a weather-proofed kiosk. A standby sample pumps are not required. One spare pump common to all installed pumps shall be provided and kept in store.

A sink shall be provided in the laboratory dedicated for receiving the samples. Each sample tap shall be appropriately labelled.

Treated water quality at (e) above shall be continuously monitored for pH, turbidity and free chlorine residual. The instruments shall be mounted on a backboard and shall be located in the laboratory. Each instrument shall be provided with local indicators. The Contractor is at liberty to derive the sample to the instruments from the sample delivered to the laboratory, provided the sample flow to the instruments is not influenced by the sample flow to the laboratory.

B 3.17 Treatment works water supply system

B 3.17.1 General

A treated water supply shall be provided to serve the treatment works service water supply requirements include the following:

(a) Process water for the preparation of chemical solutions / slurries.

(b) Motive water for chlorine.

(c) Safety showers.

(d) Water for flushing chemical and sludge pipelines.

(e) Water for washing down purposes.

(f) Domestic potable water for all buildings and the laboratory.

(g) Irrigation water.

Sufficient pressure shall be maintained in the system at all times for all service conditions by means of an elevated storage tank, but if necessary also by pumps or hydropneumatic booster system. The elevated storage tank specified for storage of filter washwater shall be used to store the site service water requirements specified above.

B 3.17.2 Elevated water storage tank

A fully covered storage tank of concrete construction shall be provided. The tank shall have two interconnected compartments of equal capacity with isolating facilities to enable one compartment to be taken out of service for cleaning and maintenance.

The capacity of the tank shall be adequate to provide water for two consecutive filter washes, all continuous water requirements and the simultaneous use of one flushing point, two washing down points, two safety showers and shall be not less than 1000 m^3.

The supply to each compartment shall be provided with an isolating valve. Each compartment shall be provided with a level transmitter and level switches for monitoring / measurement. The two compartments shall be provided with overflows and valved drains. Each compartment shall be provided with separate outlets for filter washing and site water supply.

The tank shall be located either on top of the filter building or independently supported on any other part of the Site at an elevation adequate for the requirements of backwashing.

Access shall be provided to the tank, around the tank in particular to the level monitoring equipment, drains and isolating valves.

B 3.17.3 Works water supply pumps

Two pumps of the horizontal radial flow type (one duty, one standby) shall be installed in the treated water pump station, arranged to draw treated water from the treated water reservoir. The capacity of each pump shall be sized on the assumption that all the filters will be washed consecutively spaced at 30 minutes apart and shall not be less than 5% of the maximum works input.

The operation of the pumps shall be automatic, controlled on level using a system of level probes in the storage tank.

The pumps shall be provided with all necessary suction and delivery pipework, isolating and non return valves, pressure gauges and instrumentation and control system.

B 3.17.4 Works water supply boosting system

Water for flushing and hosing down duties shall if necessary be boosted by using either booster pumps (one duty, one standby) or a hydro-pneumatic type boosting system.

The hydro-pneumatic system shall consist of two booster pumps (one duty, one standby) drawing water from the works water supply system and operating in conjunction with a precharged diaphragm pressured air/water vessel of suitable capability.

The boosting system shall be designed to satisfy conditions of maximum water demand as would occur in the event of simultaneous flushing of all duty dosing/feeder/transfer pumps and the operation of at least four hosing down points. The start/stop operation of the booster pumps shall be on pressure in the air/water vessel, controlled by a pressure switch in the supply water line.

The system shall be supplied as a package unit, complete with all necessary valves, pressure gauges, control switches, starters, fuses and other associated electrical equipment, all contained in a composite control panel; volt free contacts shall be provided to indicate unit in operation and unit failure alarm on a remote panel.

The high pressure system if provided, shall be separated from the low pressure process water system.

B 3.17.5 Loop system

The main supply system shall be in the form of a loop or loops, with arrangements made to ensure continuity of supply in case of a break or interruption at any point. Pipe diameters shall be amply sized to permit maximum flows under service conditions.

B 3.17.6 Pipe work

All pipes shall be laid underground with 1 m minimum cover. Valves and air valves shall be provided in drained chambers where required. Valved washwater branches with effluent drain systems shall be provided at low points in the main system to permit sections of the loop to be emptied when necessary.

Service connections shall be provided from the main system to all buildings and points of individual demand or likely demand, and where required for washing down, e.g. chemical building, clarifiers and filters, and for general purposes. Branch lines shall be connected to points of demand by properly designed assemblies, with backflow and excess pressure protection and by-pass draining. The number of washing-down points to serve a particular area shall be determined on the basis of a maximum hose length of 20 m. Washing-down points for each area shall be provided with the required number of hoses complete with hose reels, connectors and nozzles all suitably mounted and shaded from sunlight.

B 3.18 Laboratory equipment

B 3.18.1 General

The works shall be provided with a laboratory equipped for routine monitoring of parameters necessary for process control including setting of chemical doses as follows:

(a) pH value;
(b) Turbidity (NTU);
(c) Colour (true);
(d) Residual chlorine (free and total);
(e) Total alkalinity
(f) Aluminium concentration
(g) Jar testing.
(h) Specific gravity of chemical solutions

B 3.18.2 Laboratory equipment

The following equipment shall be provided:

- 1 No. Laboratory pH meter with combination electrode and temperature compensation;
- 1 No. Spare combination electrode for the pH meter above;
- 1 No. Laboratory turbidimeter to cover the range 0.1 to 1000 NTU including six sample cells and standards (Hach 2100N or equivalent);

- 1 No. Laboratory Spectrophotometer to cover wavelength range of at least 330 to 900 nm, with facility to accept cells from 10 to 100 mm. Single beam instrument with microprocessor control. To include spare tungsten-halogen lamp, cell holders as appropriate for 10 and 40 mm cells and 2 pairs of each of 10 mm and 40 mm cells. (Hach DR/4000 or similar)
- 1 No. Lovibond type Nessleriser with integral comparator including six sample tubes (50 ml) and disc for colour (0 to 70 Hazen units);
- 2 Nos. Comparator (Lovibond type) with twenty sample cells for analysis by DPD method, discs for the range 0.1 to 1.0 mg/l and 0.1 to 4.0 mg/l residual chlorine;
- 3 Nos. Hydrometers calibrated in specific gravity units with the range 1.000 to 1.200 for measuring lime slurry of concentration at 50 g/l;
- 1No conductivity meter complete with a graph of conductivity against concentration at 30^{o}C to measure saturated limewater concentration;
- 3 Nos Hydrometers calibrated in specific gravity units with the range 1.000 to 1.400 for measuring saturated aluminium sulphate concentration;
- 3 Nos Hydrometers calibrated in specific gravity units with the range 1.000 to 1.200 for measuring diluted aluminium sulphate of concentration 100 g/l;
- 1 No. Jar tests apparatus of the 4 jar unit type with adjustable speed control, illumination and timer including 10 No. 1 litre jars;
- 1 No. Water deionisation unit of capacity 10 litres/hour;
- 1 No. Aspirator, heavy duty high density polyethylene (HDPE) construction, with screw in tap; 50 litre capacity;
- 1No. Aspirator, heavy duty HDPE construction, with screw in tap; 10 litre capacity;
- 10 Nos. Plastic sample bottles with screw caps of capacity 500 m;
- 10 Nos. Plastic sample bottles with screw caps of capacity 1000 ml;
- 4 Nos. Plastic buckets of capacity 10 litres;
- Beakers, Pyrex, low form with spout (10 Nos. capacity 100 ml., 5 Nos. capacity 250 ml. and 5 Nos. capacity 1000 ml);
- 5 Nos. Wash bottles capacity 600 ml;
- Filter Papers (Whatmann) 15 cm diameter (10 Nos. boxes No. 1 Grade and 10 No. boxes No. 42 Grade);
- 10 Nos. Funnels, plain glass, conical, 75 mm diameter;
- Beakers, low form with spout; (5 Nos. 100 ml; 5 No. 250 ml; 5 Nos. 600 ml; 4 Nos. 1000 ml; 2 Nos. 2000 ml)
- Burette, schellbach, Class B, with interchangeable PTFE key (2 Nos. 50 ml)
- Retort stand base, stainless steel, 210 x 130 x 8 mm; with threaded retort rod, 750 x 12.5 mm. (2 Nos of each).
- Retort stand boss and clamp (5 Nos. of each)
- Measuring cylinders, polypropylene with spout (5 Nos. 25 ml., 5 Nos. 50 ml., 5 Nos. 100 ml. and 2 Nos. 1000 ml.);
- Volumetric flasks BS 1792 Class B type, with polystop (5 Nos. 100 ml., 5 Nos. 250 ml., 5 Nos. 500 ml. and 5 Nos. 1000 ml.);
- Erlenmeyer flask, DIN 12387 (5 Nos 200 ml)
- Pipettes, straight sided BS 700, Class B, graduated to deliver fast flow (10 Nos. 1 ml., 10 Nos. 2 ml., 10 Nos. 5 ml. and 10 Nos. 10 ml.);
- Pipettes, bulb, Class B, BS 1583 (2 Nos. 10 ml; 2 Nos. 25 ml.)
- 2 Nos. pipette fillers;
- Nessler tubes (20 pairs 50 ml. and 5 pairs 100 ml.);
- Racks for Nessler tubes (5 Nos. 50 ml. and 2 Nos. 100 ml.);

Chemical Reagents

Aluminium standard solution; 1000 mg/l	2 x 500 ml
Ammonia 35% solution	4 x 1000 ml
DPD tablets No 1 (comparator)	2000 No.
DPD tablets No.3 (comparator)	2000 No.

□	Hexamine	4 x 500 g
□	Hydrochloric acid (2N)	6 x 1000 ml
□	Hydroxylammonium chloride	2 x 500 g
□	Indicator solution, BDH 4.5	2 x 500 ml
□	1, 10 Phenanthroline hydrochloride	6 x 5 g
□	Pyrocatechol violet	2 x 5 g
□	Sulphuric acid, 0.02 N (0.01 M), CONVOL	3 carton x 6 ampoules

All chemicals to be of Analytical Reagent (AR) or equivalent grade.

The Contractor shall provide step by step procedures for carrying out the determinations for pH, turbidity, aluminium, alkalinity, residual chlorine and jar tests. Hydrometers shall be provided with graphs for specific gravity against concentration in g/l and %w/v.

B 3.18.3 Room Specifications

The laboratory shall be a single room of approximate dimensions 8 x 8 m including a chemist room of dimensions 3 x 4 m. It shall be provided with the appropriate benching and furniture suitable for use in the laboratory environment. Cupboards shall be provided for storage of glassware, equipment and other items.

There shall be two sinks each provided with a water supply terminating in swan neck taps and draining board. A further sink shall be provided to receive water samples pumped from the process as specified. The deionisation unit shall be provided with a separate water supply. There shall be at least four twin power points located at bench top level distributed around the laboratory.

Drainage from the laboratory shall be discharged to the site drainage system.

B 3.19 Miscellaneous requirements

B 3.19.1 Compressed air plant

A plant to supply compressed air for actuation of filter valves, clarifier desludging valves and thickener desludging valves shall be provided and located in the filter building. The plant shall comprise one duty and one standby compressor and one duty and one standby receiver. The plant shall be supplied as necessary with air dryers, filters and lubricators.

B 3.19.2 Lifting equipment

The Contractor shall supply lifting equipment such as gantries, hoists, cranes, shear legs, davits etc for the operation and maintenance of all mechanical and electrical plant and equipment, pipework, stoplogs etc. provided both in buildings and outside in the open. The lifting equipment such as monorail/hoists in pumping stations and chemical building shall be permanently installed. The lifting equipment for external plant shall only be permanently installed if the equipment is not portable.

Storage facilities shall be provided for portable/mobile lifting equipment and stoplogs. Trolleys, trucks, containers etc shall be provided for transporting plant/equipment which are heavier than 50kg or bulky to be man handled between user points or workshop and storage facilities.

B 3.19.3 Access equipment

The Contractor shall provide all necessary mobile/portable access equipment for operation and maintenance of plant where permanent access is not provided. The equipment shall include but not be limited to safety steps, safety ladders and access platforms.

B 3.19.4 Spacer pieces for flowmeters

The magnetic flowmeters of each size shall be provided with a spacer piece of pipe of the same length to enable works to be operated when flowmeters have to be removed for maintenance.

B 3.19.5 Portable submersible pumps

A minimum of six portable submersible pumps of several capacities shall be provided for dewatering chambers and sumps which cannot be drained by gravity.

B 3.19.6 Plant identification

All plant, equipment, instruments, panels, pipework and valves and manholes shall be identified and safety signs shall be provided where appropriate.

B 3.20 Starch plant

The process for the preparation and dosing of the modified starch is as follows:

One of the tanks for the preparation of modified starch will be filled with service water until the 20% of its capacity. The concentration usually used in this type of uses is 1.5%. The quantity of modified starch required for 5 m3 (volume of the deposit) is 75 kg. The mixer will be put in operation.

After obtaining an homogeneous mixture, NaOH (50%, 1.0386 kg/l) will be added. The added amount shall be the 20% of the modified starch required. Thus, it will be necessary 14.5 l.

After observing that the new mixture is homogeneous, it will be proceeded to fill with water the deposit. After of one hour of mixing, the solution will be prepared for its dosing.

According to the instructions submitted by Process Chemist, the valves of the starch modified pumps and the water service will be adjusted to dosage of the modified starch that is necessary, taking into consideration the Jar-test results obtained in the laboratory.

DESCRIPTION OF THE FACILITIES:

2 tanks of 5 m3 of capacity for the preparation of modified starch (including 2 mixers of 1.5 HP).
1 tank for the storage of NaOH of 1 m3 of capacity.
2 pumps for the dosing of modified starch. Flow rate: 700 l/h.
1 pump for the delivery of NaOH. Flow rate: 100 l/h.
2 rota meters. The first one installed in the starch modified dosing pipeline and the second one installed in the service water line to procure a possible dilution of the prepared solution in line.
3 water meters. Two of them installed to quantify the water used in the preparation of starch and a third one for quantifying the volume of NaOH used.
Pipes and valves made in PVC.

VOLUME 2 OF 7 PART B

PARTICULAR SPECIFICATIONS – ELECTRICAL WORKS

CONTENTS LIST

ELECTRICAL WORKS

B 4.1 Scope of Works

This section covers the particular requirements for the provision of electrical site works for the raw water intake works, raw water pumping station, treatment plant, treated water pumping station, booster pumping station and master balancing reservoir.

The Contract shall include the design, manufacture, testing at manufacturers' works, delivery to Site, off-loading, storage, erection, testing, commissioning and setting to work the complete electrical works for all sites including but not limited to:-

(e) TNEB electricity supplies;
(f) High voltage switchboards, motor control centres and motor starters;
(g) Low voltage switchboards, motor control centres and motor starters;
(h) Battery units for switchgear operation;
(i) Power factor correction equipment;
(j) Local control units including emergency stop and start/stop or open/close push-buttons, local control panels, cable marshalling boxes and cable termination boxes;
(k) Uninterruptible power supply units;
(l) Power, control, instrumentation, network and telephone cabling installations;
(m) Earthing system and lightning protection installations including soil resistivity survey;
(n) Harmonic filtering equipment if necessary for complying with local Codes, Regulations and TNEB's requirements;
(o) All cabling, termination and cable containment works;

The electrical plant, cabling and earthing installations shall comply with Standard Specifications and the following clauses herein. Where the Drawings, Standard Specification and Particular Specification differ, the latter shall take precedence.

B 4.2 General electrical requirements

B 4.2.1 Design considerations

The Contractor shall design the electrical installation taking into consideration the following:-

(f) Location and power demand of all loads;
(g) Availability and reliability of supply;
(h) Prospective short-circuit current;
(i) Environment in which electrical plant is located;
(j) Ambient temperature, humidity and its effect on the rating of switchgear, transformers, cables and generating plant;
(k) Method of cable installation;
(l) Cable transient and steady state volt-drop on motor starting;
(m) Transient volt-drop on motor starting at point of supply;
(n) Electrical protection discrimination;
(o) Ground earth resistivity;
(p) Overall system power factor shall be minimum 0.95;
(q) Total harmonic distortion;
(r) Effective operation, control and monitoring of plants;
(s) Easiness and effectiveness of maintenance.

B 4.2.2 Environmental conditions

All Plant shall be designed and manufactured for continuous operation under the specified climatic and environmental conditions as detailed elsewhere within the Specification.

B 4.2.3 Estimated power requirements

The Tenderer shall submit estimated installed and running loads and distribution schematic diagram with rating of major equipment for each site and calculate the estimated available load required as part of his Tender submission.

Load estimates for sizing all equipment/cables shall consider present load, future expansion and 20% design margin on the total value.

The Contractor shall update the preliminary load schedule during the detailed design stage, finalise plant ratings and submit all calculations to the Engineer for approval.

B 4.2.4 Electrical distribution system

The electrical distribution systems shall be designed to provide:-

(g) Redundant transformer shall be provided for supplying switchboards and MCCs for each site. Each transformer of a transformer pair shall have the capacity to support the maximum connected duty load. The connected loads shall be shared evenly by the transformer pair during normal operation.
(h) Switchboards and MCCs shall be provided with a bus coupler to enable change over in case any one of the transformer failed.
(i) Operational flexibility.
(j) Ease of maintenance with minimum operational disruption to the operation of the works.

A conceptual electrical distribution system is shown on the Drawings. The Contractor shall determine the equipment quantity, equipment rating, equipment location, suitable distribution network and protection scheme.

Unless otherwise consent by the Engineer, the Contractor shall retain the basic system concept although it may be amended in detail to suit the Plant provided under the Contract. Any change shall be at no extra cost to the Contract.

The configuration of the sub-distribution system shall be determined by the Contractor.

B 4.2.5 Electricity supply

The high voltage electricity supply to each pumping station and water treatment works will be provided by dual feeders from Tamil Nadu Electricity Board (TNEB) via 33 kV or 11kV overhead lines as shown on the drawings and detailed herein.

The TNEB contract interface shall be the 11kV or 33kV metering panels incoming cable boxes or termination chambers at the switchgear of TNEB. The cables connecting to the switchgear of TNEB from the incomer switchgear of the Electrical Works of this Contract shall be provided under this Contract.

The cost for the provision of the TNEB power supplies to each site including any registration fees/charges shall be paid by the Employer. All liaison works for the procurement of the TNEB supplies shall be included within the Contract Price.

B 4.2.6 TNEB supply system data

(a) Voltage :33kV
(b) Frequency :50Hz
(c) Voltage tolerance :plus and minus 10%
(d) Frequency tolerance :plus and minus 5%
(e) Neutral earthing :direct
(b) Three phase symmetrical short-circuit current:-
- maximum : 20 kA
- minimum : 20 kA

B 4.2.7 Liaison with TNEB

The Contractor shall be responsible for:-

(c) Confirming short-circuit and earth fault current data.
(d) Finalising supply capacity and supply scheme.
(e) Establishing any special TNEB requirements.
(f) Finalising protection relay characteristics, settings and co-ordination.
(g) Agreeing procedures and responsibility for connection of incoming feeder cables to the metering panel and pre-commissioning testing.
(h) Responsibility of co-ordination with TNEB for overhead line work.

Liaison with the TNEB shall be by the Contractor through the Engineer.

B 4.2.8 Liaison with Electrical Inspectorate

The Contractor shall be responsible for all the works required for obtaining all design approvals necessary from the local Electrical Inspectorates Chief Officer as well as obtaining a sanction for energising the new supplies. All liaison with the Electrical Inspectorate shall be by the Contractor through the Engineer.

B 4.2.9 TNEB Metering Requirements

The Contractor shall be responsible for co-ordinating all designs with TNEB. The Contractor shall provide metering CTs, electricity maximum demand watt meter and testing terminals in accordance with the requirements of TNEB as detailed below. Meter shall conform to standards IEC 1107, IEC 1000-4, IEC 255, IEC 60687 in concurrence with IS 13779 and IS 14697. All metering equipment including VTs and CTs shall be housed in HV metering panels which shall be fully sealed and self-contained to ensure TNEB metering seals can be installed. Prior to procurement of any equipment, the Contractor shall submit full technical details of the proposed plant to TNEB.

(vi) Metering Voltage Transformer(VTs)

VTs shall be provided for the main switchboard. Tappings from each VT compartment shall be used to provide a supply to the separate TNEB metering compartment.

(xii) Metering Current Transformer(CTs)

Separate metering summation CTs shall be provided. The CTs shall have an accuracy class of better than 0.5. In any case total metering error shall be less than 1%.

(xiii) Electricity Maximum Demand Watt Meter

The Contractor shall provide electricity maximum demand watt meter located within the metering panel. The meter shall be programmed in accordance with TNEB requirements. Prior to procurement of the meter the Contractor shall confirm latest requirements of TNEB.

B 4.2.10 Utilisation voltages

(a) High voltage	:33kV, 11kV, 6.6kV or 3.3kV three phase to suit plant rating. 33kV incomer for capacity demand above 5MVA in accordance with the Distribution Code of TNEB.
(b) Low voltage	:415V three phase
(c) Control	:a.c. - 240V single phase for anti-condensation heater, instrumentation and LV motor starter control. d.c - 110V for high voltage switchboard control, protection, motor starter control, circuit breaker motor charging and indication lamps. d.c - 24V for SCADA and instrumentation. d.c.- 48V for low voltage switchboard incomer and bus section circuit breaker control and indication lamps.

B 4.2.11 Neutral earthing

The 415V transformer winding neutral shall be solidly earthed.

The 6.6kV and 3.3kV main transformer winding neutral shall be earthed through resistance. The selected value of resistance should restrict the earth fault current below the full load current of the largest drive/motor in the system. Time rating of neutral earthing resistor shall be 10sec. Necessary provisions in the protection systems shall be made to avoid adverse impact on sensitivity of protection relays.

B 4.2.12 System voltage drop

(d) Steady state

Under normal service conditions the volt-drop at the terminals of the fixed current-using equipment shall not be greater than 4% of the nominal voltage of the supply except where a lower value is necessary for the:-

- satisfactory operation of the equipment;
- compliance with the volt-drop criteria for motors during the starting period.

(e) Transient

During motor starting periods the following criteria shall apply:-

- Under minimum supply voltage conditions specified earlier, the voltage at the motor terminals shall not be lower than 85% of the motor rated voltage;
- the voltage drop at the point of supply shall not be greater than 10% of the rated voltage.

B 4.2.13 Protection co-ordination and protection relays

The TNEB and protection devices provided as part of this Contract shall be capable of co-ordination so that on the occurrence of a fault only the affected section is disconnected from the system.

The Contractor shall carry out a protection co-ordination design study for the different types of faults occurring at different points in the system under maximum and minimum fault conditions. The proposed relay characteristics shall be submitted to the Engineer for approval.

Unless otherwise approved by the Engineer, all relays shall be of the microprocessor based numerical type and shall have a front of panel test facility. Relays shall be tropicalised.

Relays shall have hand reset operation indication for each element.

Front of panel mounted relays shall have a clear polycarbonate cover providing a degree of protection not less than that of the switchboard or motor control centre on which they are mounted. The Contractor shall provide all necessary computer connections and software including actual relay settings for the re-programming of these devices including a hard-copy of the protection setting for each device.

B 4.2.14 Electrical Safety

The Contractor shall provide adequate safety labels for the safe operation and maintenance of all electrical equipment.

An A1 framed single line diagram shall be provided on each switchroom wall.

Each electrical switchboard shall be provided with all necessary safety equipment including operating gloves, full length rubber safety mat, a minimum of 2 No CO_2 portable fire extinguishers, fire bucket and any other equipment required by the Authorities.

An emergency first aid kit and safety procedure shall be provided in each switchroom.

B 4.3 High voltage switchboard and motor control centre

The Contractor shall design the high voltage power distribution to meet the requirements of the proposed plant.

The high voltage switchboard/motor control centres shall be of the floor mounting metal-clad cubicle type equipped with VCBs, vacuum contactors and motor starters as appropriate. All compartments shall be provided with and designed for withdrawable type switchgear. The switchboard shall be provided with the protection and metering as shown on the single line diagram.

Cable entry shall be located at the bottom with suitable gland plates. Cable openings in the base of switchboards and motor control centres shall be fitted with plates to prevent the entry of vermin.

Switchboards and motor control centres shall be extensible to cater for the future designed development. The Contractor shall take this requirement into account when designing switch rooms and control rooms.

Rubber insulation floor mat of 9mm thickness shall be provided at the front of each switchboard and motor control centre. The mat shall extend over the full depth of switchboards and motor control centre plus 800mm minimum at each end.

Test plugs and tools shall be provided to facilitate switchboard testing.

(f) Technical requirements

• Rated voltage:	36/12/7.2/3.6kV
• Rated short circuit: breaking current	Shall be coordinated with supply fault level subject to a minimum 380MVA for 11kV system
• Rated short-circuit: current withstand time	Not less than 1 second.

- Incoming circuit breakers and bus-couplers shall be motorised to allow automatic operation of the circuit breakers on loss of power on any incomer;

- Switch-disconnector, earth switch and circuit-breaker operating mechanisms shall be of the independent manual type and shall have positively driven position indicators;

- Operating mechanisms shall be padlockable in all positions;

- Control functions shall be centralised on the module front;

- Busbars shall be insulated;

(h) Incomer units

All incomer units shall be 3 pole.

Circuit-breaker type incomer units shall be equipped with the following minimum facilities:-

- Voltage transformer and voltmeter with phase to phase selector switch.

- Indicator lights shall be provided to indicate voltage presence;

- Power meter/load manager shall be provided to monitor kVA, kW, kWh, power factor, voltage and current with provisions for RS485 communication port. The outputs shall be wired to the ICA system;

- Overcurrent and earth fault protection relay/release as indicated in single line diagram. The relay characteristics shall be selected to co-ordinate with upstream and downstream protection devices.

- Auxiliary relay with hand reset operation indicators for transformer winding temperature high alarm,transformer oil temperature high alarm and circuit-breaker trip initiation (for incomers derived from transformers only)

- Phase failure and undervoltage relay/release for circuit-breaker trip initiation, alarm annunciation and remote indication. The relay shall be connected on the busbar side of the circuit-breaker.

- High voltage inter-trip receive relay (for incomers derived from transformers only).

- Trip circuit supervision relay.

- Current transformers of appropriate accuracy class and limit factor and output for instrumentation and protection.

- Status Indicator lights for:-
  Circuit-breaker open
  Circuit-breaker closed
  Circuit-breaker trip supply healthy

- Push-buttons for:-
  Circuit-breaker open
  Circuit-breaker close
  Circuit-breaker trip supply test
  Lamp test

(k) Motor starters

Motor starters shall be provided for all plant specified in the Specification, any additional plant recommended by the Contractor and as generally shown on the Drawings.

Motor starter types shall be direct-on-line, star-delta, solid state soft starter, variable speed drives, auto-transformers or other equivalent reduced voltage type as required to suit the plant operation and to comply with the specified transient voltage drop criteria. For the raw water pumps, treated water pumps and booster pumps at Package I of the Project, the starters for these pumps shall be able to ramp up and down the speed of these pumps gradually, in order to minimize any water pressure surge to induce to the pipelines and other equipments.

Motor starter control and protection facilities shall include but not be limited to:

- Staggered start circuits shall be provided to prevent more than one motor starting at the same time;
- All necessary interlocks/safety devices as described in the mechanical specification to prevent the pumpsets being re-started until the pump pipe column has stopped draining;
- All necessary interlocks/safety devices for the proper operation and effective protection of the pumpset;
- Motor thermal overload and single phase protection;
- Start and Stop push buttons;
- Available, running, fault tripped lamps; Fault reset push-button;
- Hours Run meter; Indicating ammeter;
- Individual power factor correction capacitor;
- Microprocessor based comprehensive numerical type motor protection relay. The relay shall have thermal overload, phase unbalance/single phasing, reverse phase sequence and earth fault protection functions. The earth fault trip function shall be co-ordinated with the short-circuit protection device and contactor current breaking current;
- Control selector switch - Local/Off/Remote;
- Auxiliary relays and indicating lamps for direct pump/motor mounted protection facilities, covering no flow, winding temperature, bearing temperature, motor exhaust air temperature, gland seal monitoring, oil leakage, motor water ingress, motor vibration detection, coolant failure detection and lubricant failure detection.

Motors provided with variable speed drive or soft starter shall be provided with the following additional facilities:
- Drive Fault Indicator;
- Motor Speed Indicator;
- Variable Speed Controller (door-mounted).

Cooling facility shall be provided for dissipating heat generated by the variable speed drive or soft starter in accordance with the manufacturer's recommendations.

(c) Control and operation

A local control panel shall be provided adjacent to each pumpset for accommodating pumpset instrument transmitters and pump status indicators for effective monitoring of the pumpset.

(e) Interlocking

The switchboards/motor control centres with incomers derived from two separate sources shall have circuit braekers for the two incomers and bus-coupler. The switchboard shall be provided with an electrical and mechanical interlocking scheme to allow only two out of

three circuit breakers to be closed at any one time. The normal operation of the switchboard will have the two incomers closed and the bus-coupler open, with the load equally distributed between the two incomers. On power failure of one incomer, the bus-coupler will be closed automatically and the complete plant operating from one supply as shown in SLD.

Interlock shall be provided to prevent access to cable termination enclosure unless the associated earth switch is closed. Alternative interlocking arrangements, which are standard to a particular switchgear manufacturer, shall be submitted to the Engineer for approval

- **Feeder units**

Feeder units shall be provided as required on each switchboard and motor control centre.

(g) Lamp test

Each switchboard and motor control centre compartment shall be provided with a lamp test facility when fitted with indicating lamps.

* **Anti-condensation heaters**

Anti-condensation heaters shall be provided for each panel.

(f) Auxiliary contacts

Voltage-free changeover type contacts shall be provided for remote status and alarm indications as follows:-

- Each incomer (mains/generator)
  Circuit-breaker/switch open;
  Circuit-breaker/switch closed;
  Circuit-breaker tripped on fault;
  Transformer winding temperature high;
  Transformer oil temperature high;
  Supply healthy;

- Each bus-coupler
  Circuit-breaker/switch open;
  Circuit-breaker/switch closed;

- Each motor starter
  Motor available
  Motor running
  Motor fault (common)

The contacts shall be wired to a common marshalling terminal in the associated LCP.

(c) Switchroom design considerations

Switchroom floor flatness and concrete insert shall be provided to the requirements of switchboard manufacturer. Space shall be provided within the switchroom to permit two circuit-breaker panels to be added to one end of the switchboard. Front clearance shall be not less than 1500mm.

For switchboards and motor control centres designed for rear access, a clear space of not less than 800mm shall be provided at the rear of the panel. For front access switchboards a nominal 150mm clear space shall be provided at the rear of the panel.

Where floor trenches for cabling is provided it shall extend over the full depth of switchboards and motor control centres plus 800mm minimum at each end. Trench depth shall be not less than 1000mm. A galvanized steel supporting framework shall be provided for switchboards and motor control centres.

Galvanised steel or aluminium chequer plate cable trench covers shall be provided.

Doorways shall be dimensioned to permit the entry of the largest section of switchboards and motor control centres in its upright position.

An identification label shall be fitted to the outside of the building adjacent to the access door. The label shall identify voltage and substation location. The label material shall be plastic laminate or other material approved by the Engineer and the size of characters and numerals shall be not less than 50mm. The label description shall be subject to the approval of the Engineer. The label shall be fixed to the building using non-ferrous screws.

Mechanical ventilation shall be provided for the switchroom. Ventilation fan sizing calculation taking into account of equipment heat dissipation rate shall be provided for Engineer's approval. The minimum air change rate for switchroom shall be 10 air change per hour.

B 4.4 Transformer

B 4.4.1 Service Transformer

Main transformers shall be oil filled and naturally air cooled outdoor type with winding temperature indicator incorporating alarm and trip contacts for remote indications, pressure relief device with trip contacts and primary/secondary cable boxes.

Dry type cast resin indoor transformers shall be provided for the auxiliary loads below 630kVA.

The transformers shall be sized for total duty loads of the Works plus the following additional capacities:

(ϕ) 3% for system losses
(γ) 10% for design margins
(η) 10% for future expansion works

Main transformers shall be provided with an on-load tap changing (OLTC) facility as shown on single line diagram. All other auxiliary transformers shall be provided with off-load tap changing facilities. On load tap changer panels shall provide automatic adjustment of voltage level with facility of manual operation.

The transformers shall be fitted with a removable link to connect the low voltage winding neutral point to earth. The link shall be accommodated in the low voltage cable box and shall be fitted with a label inscribed LV WINDING NEUTRAL EARTH LINK.

Transformers using open type bushings shall not be accepted.

Each transformer shall be provided with an emergency trip push button in the secondary voltage switchroom or as agreed with the Engineer.

Provisional transformer ratings for tender purposes are indicated on the drawings. The Contractor shall review and amend as necessary these ratings during the detailed design stage to suit the requirements of the plant supplied.

B 4.4.2 Remote control unit for OLTC

The OLTC control equipment shall be housed in an indoor sheet steel cubicle located in the adjacent HV switchroom. It shall conform to degree of enclosure protection IP 54 or better and shall comprise the following but not be limited to:

(ϕ) Control switch : Raise / Off / Lower (spring return to normal type)/automatic or independent push buttons.
(γ) Tap position indicator.
(η) Facia type alarm annunciators with "accept","lamp test" facilities and hooter / buzzer for alarms.
(ι) Necessary auxiliary relays.

(φ) Lamp indications for tap change in progress, lower limit reached, upper limit reached etc.
(κ) 240 V rated panel space heater with thermostat.
(λ) Fluorescent type interior lighting fixture with lamp and door switch.
(μ) Voltage sensing and voltage regulating devices
(ν) Line drop compensator with adjustable R and X elements.
(ο) Timer 5-25 seconds for delaying the operation of the tap changer in the first step for every tap change operation.
(π) Adjustable dead band for voltage variation.
(θ) Volt free contacts for alarms for a. c. supply failure, drive motor auto tripped and other protective purpose considered essential by the Contractor shall be wired to a common terminal rail. The Contractor shall cable the outputs to the ICA compartment of the adjacent switchboard/motor control centre.

B 4.4.3 Transformer Compounds

The transformers shall be housed in a compound surrounded by 2.4m high chain link fencing or similar approved. Each transformer shall be provided with a double leaf gate not less than 2.4m wide. The transformers shall be shaded from direct sunlight.

A minimum clearance of 1500mm shall be provided to all sides of the transformer.

Transformers shall stand on reinforced concrete plinths surrounded by an oil retaining sump. The sump shall be filled with suitable single size (nominally 40mm) rounded stones. The capacity of the sump when filled with stones shall be suitable to hold the total oil content of the transformer plus 15%. The sumps shall be connected to a separate chamber to permit the removal of standing water and oil.

Trenches and ducts entering the oil-retention area shall be sealed after the cable installation.

The compound shall be provided with a name plate identifying the transformer number and rating. The name plate shall be plastic laminate or other material approved by the Engineer and the size of characters and numerals shall be not less than 50mm. The name plate shall be fixed to the access gate using stainless steel fixings.

Each transformer compound shall be provided with adequate portable fire fighting equipment accordingly to Statutory Requirements.

B 4.5 415V switchboard and motor control centre

The Contractor shall design the low voltage power distribution to meet the requirements of the proposed plant. The Contractor shall generally provide motor control centres at each process area including the chemical house, clarifier works, individual pumping station, the filter building, the sludge treatment plant and the chlorine plant. The motor control centres shall be supplied from the main works switchboard which shall then feed the sub-distribution switchboards/ motor control centres. The Contractors design should not derive feeders from one sub-distribution switchboard to another sub-distribution switchboard.

The 415V switchboard/motor control centres shall be of Form 4 construction, floor mounting metal-clad cubicle type equipped with ACBs, MCCBs, fuse-switches and motor starters as appropriate. Cable entry may be top or bottom with panel access to the front to suit the requirements of the site layout drawings.

Cable openings in the base of switchboards and motor control centres shall be fitted with plates to prevent the entry of vermin.

Provision shall be made on switchboards and motor control centres for supplying building and external electrical & mechanical services.

Supplies to process plant and instrumentation shall be derived from a separate process/ instrumentation services distribution board and not derived from building services distribution boards.

Switchboards and motor control centres shall be extensible to cater for the future designed development. The Contractor shall take this requirement into account when designing switch and control rooms.

Rubber insulation floor mat of 9mm thickness shall be provided at the front of each switchboard and motor control centre. The mat shall extend over the full depth of switchboards and motor control centre plus 800mm minimum at each end.

Test plugs and tools shall be provided to facilitate switchboard testing.

(f) Technical requirements

• Rated voltage:	460V
• Three phase symmetrical: short-circuit current	The maximum let-through current of the supply transformer or feeder protective device but not less than 50kA for 1600A busbar
• Rated short-circuit: current withstand time	Not less than 1 second.

(e) Incomer units

Incoming supplies and associated bus-couplers rated at 800Amps and above derived from transformer secondary circuit shall be controlled by withdrawable air-break circuit breakers. All other incoming supplies of similar case shall be controlled by withdrawable type MCCBs.

All other supplies derived from other switchboards shall be terminated on switch-disconnectors. In a distribution system ACB/MCCB of upstream side shall either be followed by switch disconnector or with-drawable type MCCB

All incomer units shall be 4 pole.

Circuit-breaker type incomer units shall be equipped with the following minimum facilities:-

- Voltmeter with phase to phase and phase to neutral selector switch.
- Ammeter with phase selector switch.
- Power meter/load manager shall be provided to monitor kVA, kW, kWh, power factor, voltage and current with provisions for RS485 communication port and selectable pulsed outputs. The outputs shall be wired to the ICA compartment of the switchboard/motor control centre (for incomers derived from main transformers only);
- Overcurrent and earth fault protection relay/release as indicated in single line diagram. The relay characteristics shall be selected to co-ordinate with upstream and downstream protection devices.
- Phase failure and undervoltage relay/release for circuit-breaker trip initiation, alarm annunciation and remote indication. The relay shall be connected on the busbar side of the circuit-breaker.
- High voltage inter-trip receive relay (for incomers derived from transformers only).
- Trip circuit supervision relay for incomer circuit breakers.

- Current transformers of appropriate accuracy class and limit factor and output for instrumentation and protection.

- Status Indicator lights for:-
  Circuit-breaker open
  Circuit-breaker closed
  Circuit-breaker trip supply healthy

- Push-buttons for:-
  Circuit-breaker open
  Circuit-breaker close
  Circuit-breaker trip supply test
  Lamp test

Switch-disconnector type incomer units shall be equipped with the following minimum facilities:-

- Voltmeter with phase to phase and phase to neutral selector switch.

- Ammeter with phase selector switch.

- Phase failure and undervoltage relay for alarm annunciation and remote indication. The relay shall be connected on the busbar side of the switch-disconnector.

- Current transformers of appropriate accuracy class and limit factor and output for instrumentation.

(g) Motor starters

Motor starters shall be provided for all plant specified in the Process and Mechanical Specification, any additional plant recommended by the Contractor and as generally shown on the Drawings.

Motor starter types shall be direct-on-line, star-delta, solid state soft starter, variable speed drives, auto-transformers or other reduced voltage type as required to suit the plant operation and to comply with the specified transient voltage drop criteria.

Motor starter control and protection facilities shall include but not be limited to:

- Motor thermal overload and single phase protection; Start and Stop push buttons;
- Available, running, fault tripped lamps; Fault reset push-button;
- Hours Run meter;
- Indicating ammeter for motor above 5kW;
- Individual power factor correction capacitors above 15kW;

- Motor starters above 22kW shall be fitted with a microprocessor based comprehensive numerical type motor protection relay. The relay shall have thermal overload, phase unbalance/single phasing, reverse phase sequence and earth fault protection functions. The earth fault trip function shall be co-ordinated with the short-circuit protection device and contactor current breaking current;
- Control selector switch – Starters shall be provided with a Hand/Off/LCP selector to determine the control location. Starters with field start/stop push-buttons shall be provided with an additional selector for Field/MCC;
- Auxiliary relays and indicating lamps for direct pump/motor mounted protection facilities, covering no flow, winding temperature, bearing temperature, motor exhaust air temperature, gland seal monitoring, oil leakage, motor water ingress, motor vibration detection, coolant failure detection and lubricant failure detection.

Motors provided with variable speed drive units shall be provided with the following additional facilities:

- Drive Fault Indicator;
- Motor Speed Indicator;
- Variable Speed Controller (door-mounted).

Cooling facility shall be provided for dissipating heat generated by the variable speed drive or soft starter in accordance with the manufacturer's recommendations.

- **Control and operation**

Control and operational requirements for motor starters shall be as specified herein. All control and instrumentation equipment shall be located within the ICA section of each switchboard/motor control centre.

- **Interlocking**

The main switchboards/motor control centres with incomers derived from two transformers shall have ACBs for the two incomers and bus-coupler. The switchboard shall be provided with an electrical interlocking scheme to allow only two out of three circuit breakers to be

closed at any one time. The normal operation of the switchboard will have the two incomers closed and the bus-coupler open, with the load equally distributed between the two incomers. On power failure of one incomer, the bus-coupler will be closed automatically and the complete plant operating from one supply as shown in SLD.

Main switchboards/motor control centers with incomers derived from a generator and transformer shall be provided with two incomers electrically interlocked to prevent the paralleling of the incoming supplies or an automatic (with manual over-ride) changeover switch.

(f) Feeder units

Feeder units shall be provided as required on each switchboard and motor control centre.

(g) Lamp test

Each switchboard and motor control centre compartment shall be provided with a lamp test facility when fitted with indicating lamps.

(h) Anticondensation heaters

Anticondensation heaters shall be provided for each panel.

(i) Auxiliary contacts

Voltage-free changeover type contacts shall be provided for remote status and alarm indications as follows:-

- Each incomer (mains/generator)
  - Circuit-breaker/switch open;
  - Circuit-breaker/switch closed;
  - Circuit-breaker tripped on fault;
  - Supply healthy;

- Each bus-coupler
  - Circuit-breaker/switch open;
  - Circuit-breaker/switch closed;

- Each motor starter
  - Motor available
  - Motor running
  - Motor fault (common)
  - Individual fault signal

The contacts shall be wired to a common marshalling terminal in the associated ICA section of the switchboard/motor control centre.

(j) Socket outlet

A 240V 5A single phase socket outlet shall be provided within the ICA compartment of each switchboard and motor control centre.

(k) Location

The switchboards and motor control centres shall be located generally as shown on the Drawings.

(l) Switchroom design considerations

Switchroom floor flatness shall be finished to the requirements of switchboard manufacturer. Switchboards and motor control centres shall be extensible to cater for the future designed development. The Contractor shall take this requirement into account when designing switch and control rooms. Front clearance shall be not less than 1500mm.

For switchboards and motor control centres designed for rear access, a clear space of not less than 800mm shall be provided at the rear of the panel. For front access switchboards a nominal 150mm clear space shall be provided at the rear of the panel.

Where floor trenches for cabling is provided it shall extend over the full depth of switchboards and motor control centres plus 800mm minimum at each end. Trench depth shall be not less than 1000mm. For switchboards and motor control centres designed for front cable access the trench shall extend not less than 600mm from the front face. A galvanized steel supporting framework shall be provided for switchboards and motor control centres.

Galvanised steel or aluminium chequer plate cable trench covers shall be provided.

Doorways shall be dimensioned to permit the entry of the largest section of switchboards and motor control centres in its upright position.

An identification label shall be fitted to the outside of the building adjacent to the access door. The label shall identify voltage and substation location. The label material shall be plastic laminate or other material approved by the Engineer and the size of characters and numerals shall be not less than 50mm. The label description shall be subject to the approval of the Engineer. The label shall be fixed to the building using non-ferrous screws.

Mechanical ventilation shall be provided for the switchroom. Ventilation fan sizing calculation taking into account of equipment heat dissipation rate shall be provided for Engineer’s approval. The minimum air change rate for switchroom shall be 10 air change per hour.

B 4.6 Electrical ancillary equipment

B 4.6.1 Power factor correction

The power factor at each load centre shall be corrected to no less than 0.95 lagging. The correction may be by means of capacitors connected to individual items of plant or by automatically controlled multistage capacitors connected to each busbar section.

For multistage power factor correction, capacitor ratings shall be selected to ensure that motors are not subjected to leading power factor conditions or abnormal operating conditions due to the effect of self-excitation when switched off.

Multistage capacitors shall be controlled by contactors via an automatic capacitor controller with target power factor setting adjustment and manual override facilities. The contactors shall be de-rated to compensate for zero power factor switching duty, the permitted capacitor positive tolerance and the presence of harmonic currents.

Capacitors shall incorporate a discharge circuit and shall not contain polychlorinated biphenols.

Each of the HV main pump motors shall be provided with an individual power factor correction unit to the highest value obtainable without the self-excitation of the motor. Power factor correction units shall comprise one or more three phase capacitor banks and a set of three fuses, housed in an enclosure and connected through fusegear and an isolating link by cable to the motor starter such that it is permanently connected across the motor windings. A manually operated mechanical key interlock system shall be provided to ensure that the enclosure cannot be opened until the associated motor starter breaker is open and in the "earthed" position.

Calculations corroborating capacitor kVAr ratings shall be submitted to the Engineer for approval.

B 4.6.2 Switchgear battery units

(a) 110V Battery and battery charger

The Contractor shall provide battery charger units with adequately sized batteries and battery chargers for the HV switchboard and motor control centre with eight (8) hour battery back up. Each battery supply unit shall incorporate two float and boost chargers with auto changeover facility in case of failure of one.

The batteries shall have adequate capacity to operate HV switchboard control and relay system, monitoring devices, circuit breaker charging, OLTC etc. The sizing calculations shall be submitted to the Engineer for approval.

(b) Battery and battery charger for 415V switchboard

Battery units of the appropriate voltage and capacity shall be provided for 415V switchboard circuit-breaker tripping, control, indication and alarm supplies.

Battery capacity calculations shall be submitted to the Engineer for approval.

B 4.6.3 Uninterruptible power supplies

An uninterruptible power supply (UPS) unit or units shall be provided where it is necessary to maintain a no-break supply to instrumentation, control, PLCs, servers, computer workstations, telecommunication systems, network systems and alarm systems as detailed in the ICA section of the site works specifications.

The UPS system with fully charged batteries shall, on loss of mains supply, be capable of supplying the connected loads for a minimum period of 3 hours.

Battery capacity calculations shall be submitted to the Engineer for approval.

B 4.6.4 Emergency stop push-buttons

An emergency stop push-button shall be installed adjacent to all motors.

B 4.6.5 Local Control Units (LCU)

Each motor shall be capable of being manually operated from a local operating position. Where motor starters are provided at remote locations, the Contractor shall provide a local control unit (LCU) in a safe and accessible operating position adjacent to the motor. Each LCU shall be of robust construction suitable for the environmental conditions. The LCU shall be provided with a start/stop or open/close pushbutton.

Local control units installed externally shall be protected from the sun with sun covers and constructed with an IP rating of IP65.

The Contractor shall submit drawings identifying the locations of the LCUs for the Engineer's approval.

B 4.7 Cabling

(a) General

The Contractor shall provide a complete cabling installation comprising power, control, instrumentation, communications and telephone cables and all accessories including cable glands, terminations, cable markers, support systems, clips, fittings and fixtures to:-

- Interconnect all Plant provided under the Contract;
- Interconnect Plant provided under the Contract to the TNEB point of supply;
- Interconnect ICA signals to the regional telemetry outstation; and
- Interconnect existing plant with the Plant provided under the Contract.

All calculations to corroborate current carrying capacity and compliance with the volt-drop criteria specified herein shall be submitted to the Engineer for approval.

The power, control and instrumentation cabling shall interconnect the entire Plant including but not limited to:

- Valves actuators, pumpsets, etc;
- Switchgear and distribution boards;
- Motor control centers;
- Local control panels, PLCs, intelligent outstations;
- Regional telemetry outstation;
- Local control units; and
- Measuring instruments and sensors.

(b) Cable grouping

The cables shall be grouped as follows:

- power cables - 240 Vac;
- control cables - 24 Vdc;
- Signal cables - process signals (e.g. 4-20 mA, 24 Vdc to 48 Vdc status signals);
- data cables - modulated signals (e.g. serial data communication signals); and
- fibre optic cables - if required.

(c) Cable types

High voltage power cables shall be of the XLPE/SWA/PVC type with a conductor size appropriate to the short-circuit current and short-time requirements. The cable shall be suitable for prolonged operation at plus 10% rated voltage.

415V power cables and control cables shall be 600/1000V grade PVC or XLPE/SWA/PVC unless otherwise approved to by the Engineer.

(d) Installation

- External below ground

  Unless otherwise approved by the Engineer all cables shall be installed in ducts and concrete trenches.

  Duct systems shall be provided with draw chambers at the point of entry into buildings, at changes in direction and at suitable intervals in straight runs to permit the installation of cables without exceeding the manufacturers' recommended maximum tensile stress. Draw chambers shall be generously dimensioned to enable cables to be pulled without damage or excessive stress due to bending.

  Where high voltage and low voltage cables are installed in a common trench, they shall be on opposite faces. Cables in trenches shall be installed on tray and/or ladder systems.

- External above ground

  Cables on structural surfaces shall be installed on tray and ladder systems or in trunking and conduit as appropriate. Cable tray on structural surfaces shall be fitted with covers.

- Internal

  Cables on structural surfaces shall be installed on tray and ladder systems or in trunking and conduit as appropriate. Cables in trenches shall be installed on tray and/or ladder systems.

- Cable tray, ladder and trunking systems

  Cable tray, ladder and trunking systems shall be heavy duty galvanised steel. Cable tray on external structural surfaces shall be fitted with covers.

  Installations in the chemical and chlorine buildings shall be heavy duty PVC or GRP systems.

- Conduit systems

  Conduit shall be heavy duty galvanised steel. Installations in the chemical and chlorine buildings shall be heavy duty PVC or GRP systems.

B 4.8 Earthing

(a) General

A complete and fully interconnected earthing installation comprising earth electrodes, earthing terminals and all earthing, protective and equipotential bonding conductors shall be designed and provided by the Contractor.

The Contractor shall co-ordinate the earthing design with the TNEB earthing requirements.

As a minimum, material for buried earthing conductors shall be of Mild Steel (MS) and for earthing conductors laid above ground/open to air shall be of Galvanised Steel (GS) tape or insulated copper cable. Connection between MS conductor buried in ground and GS conductor above ground shall be welded type made by bringing the MS conductor above ground. Connection between earth leads and equipments shall be of bolted type.

(b) Earth electrode system

The Contractor shall carry out a ground resistivity survey for each site and design and install the earth electrode systems to provide an overall resistance to earth not greater than 1 ohm and subject to a maximum hand-to-hand touch voltage of 116V for 1 s. The earthing system shall ensure effective operation of protective devices for timely isolation of fault.

The earth electrode system shall comprise at least two separate groups of rods located at agreed locations to allow for testing of one earth electrode system whilst the other is connected to the system. The main earth bar shall be provided with test links to enable independent testing of each group of earth electrodes.

Design calculations for the earth electrode system shall be submitted to the Engineer for approval.

(c) 415V system neutral earthing

The low voltage winding star point of the transformer shall be connected to earth via a removable link located in the associated transformer low voltage cable box.

(d) Earthing terminals

Earthing terminals shall be located adjacent to the associated switchboard or motor control centre. The earth terminals shall be interconnected.

(e) Bonding to structural steelwork

Structural steelwork including concrete reinforcement bars shall be bonded to the earthing system. The method of connection to reinforcement bars shall be subject to the approval of the Engineer.

All metallic pipework and other extraneous conductive parts shall be provided with positive earthing terminals and provided with equi-potential bonding.

(f) Instrumentation earthing

The Contractor shall provide insulated earth cables to connect the instrumentation earth bars in each LCP to the station earth system. The instrumentation signal earth cables shall have different outside insulation colour to the power earth cables in order to make them easily identified. Earthing system design shall comply with local regulations.

B 4.9 Lightning Protection

A lightning protection system shall be provided on all main structures. Air terminations and down conductors shall be copper.

The Contractor shall also provide all terminating equipment for all I/O and communications signals transmitted between buildings on a copper cable with lightning protection barriers. The barrier shall be installed in a barrier panel which shall be located adjacent to the main cable entry point into the building or in a small enclosure adjacent to the transmitter. The barriers shall be earth bonded in accordance with manufacturers' recommendations and the Standard Specification.

The lightning protection installation shall comply with Standard Specifications.

VOLUME 2 OF 7 PART B

PARTICULAR SPECIFICATIONS – BUILDING SERVICES WORKS

CONTENTS LIST

B 6.0 BUILDING SERVICES

B 6.1 Scope

The Contractor shall design, supply, delivery to Site, off-loading, storage, erection, testing and commissioning the complete building services installations at raw water intake works, raw water pumping station, treatment plant, treated water pumping station, booster pumping station and mass balancing reservoir and associated ancillary facilities including but not limited to:-

(a) Internal main and emergency lighting;
(b) External lighting and floodlighting;
(c) Roadway lighting;
(d) Small power;
(e) Air conditioning;
(f) Ventilation and ceiling fans;
(g) Telephone lines and handsets;
(h) Fire Detection System;
(i) Plumbing and drainage.

The building services installation shall comply with Standard Specification and the following clauses herein and local Codes and Regulations. Where the drawings, standard specification and particular specification differ, the latter shall take precedence.

B 6.2 Lighting

B 6.2.1 Internal main lighting

Internal lighting shall be designed to provide the following minimum service illuminance, measured at floor level:-

(a)	Process plant/pump hall areas	:200 lux
(b)	Chemical and chlorine areas	:300 lux
(c)	Switchrooms	:300 lux
(d)	Control room	:350 lux
(e)	Workshop areas	:300 lux
(f)	Laboratory	:500 lux
(g)	Offices	:350 lux
(h)	Staff rooms and reception areas	:150 lux
(i)	Toilets, washrooms, mess rooms, corridors and staircases	:100 lux

Luminaries shall be fixed directly to, or suspended from, the underside of roof slabs, ceilings or fixed to walls as appropriate.

Pump halls and other high bay areas shall be provided with high or low bay energy efficient lighting. The Contractor shall provide all necessary equipment to ensure lighting maintenance can be performed in a safe and efficient manner. Where special provision would have to be made for accessing luminaries supported from the underside of the roof slab for maintenance, luminaries shall be wall mounted.

Luminaries for the control room and offices shall be designed to minimise glare and shall be suitable for VDUs.

Light switches shall be located adjacent to doorways. Multi-way switching shall be provided for rooms and areas with more than one point of access. For large area light switching or high/low bay lighting, contactors shall be provided to switch lighting in blocks from each entry point.

Luminaires and associated electrical accessories installed in chlorine or chemical plant rooms shall be protected to IP 65 minimum.

B 6.2.2 Internal emergency lighting

Emergency lighting shall be provided and shall comprise exit and escape route luminaries to facilitate safe movement of personnel in or from any building or major dry structure in the event of a mains supply failure. Exit luminaries shall be provided above all doors leading to or accessible to an outdoor area.

Emergency lighting shall be provided in areas where essential operations may be required during a mains supply failure, for example, switchroom and control rooms. Exit luminaires of emergency lighting shall be powered by integral battery units

B 6.2.3 External walkway areas

Luminaries shall be provided to illuminate all external personnel walkway areas around buildings and structures. The lighting shall be designed to provide an even minimum service illuminance measured at ground level of 15 lux.

Lighting shall be switched at personnel access doors. Multi-way switching shall be provided where there is more than one point of access.

Luminaires and associated electrical accessories installed in outdoors shall be protected to IP 65 minimum.

B 6.2.4 Floodlighting

Floodlighting shall be provided for the entrance to the site, raw water intake, chlorine cylinder store, clarifiers, all site pumping stations and wetwells, sludge thickening areas, loading/unloading areas, the contact/treated water tank and the ground level balancing reservoir. Floodlighting shall also be provided at all locations requiring inspection.

Floodlights shall be mounted on galvanised steel poles or on structure walls as appropriate.

Floodlighting shall provide a minimum service illuminance of 50 lux measured at the working plane.

Floodlighting shall be locally switched. Luminaires and associated electrical accessories installed in outdoors shall be protected to IP 65 minimum.

B 6.2.5 Lighting for master balancing reservoir at MADAM and general roadway lighting

Lighting for master balancing reservoir at MADAM and general roadway lighting at all plants in this Contract shall comprise tubular steel columns with semi cut-off high pressure sodium type luminaires complete with control gear, which shall in general conform to the Standard Drawing STD/E/005/TA. The lighting shall provide a minimum illuminance at ground level of 25 lux.

Concrete mass base and skirting, in conceptual design as that shown in the Standard Drawing STD/E/005/TA shall be installed. Each lamp pole shall be structurally sound to withstand, as a minimum, 160 knots without causing any damage. The height of the lamp pole for general roadway lighting shall be not less than 4.5m and that for MADAM master balancing reservoir shall be not less than 8m. Lamp poles of mild steel construction shall be hot dip galvanized to BS 729. The poles shall be finished overall with at least two coats of primer and two coats of finishing paint after erection. The colour of the finishing paint shall be as directed by the Engineer.

Minimum of 4c x 6sq mm, 1.1 kV, Cu., PVC, Armoured cables shall be used for power supply from distribution board up to the individual junction boxes of each street light pole. From the junction boxes up to the luminaries 2.5sq mm Cu flexible wire shall be used.

Roadway lighting shall be solar time switch controlled. The time switch shall be located adjacent to the point of supply. An over-ride switch shall be provided to manually over-ride the solar time switch controller. This shall be located at the control room for the water treatment works and at the low voltage switchroom for the raw water pumping station.

Luminaires and associated electrical accessories installed in outdoors shall be protected to IP 65 minimum.

B 6.3 Small power

Industrial switched type 240Vac socket outlets with residual cuurent devices for the connection of electric tools shall be installed in convenient places in all plant and workshop areas.

Suitable rated 415Vac/240Vac socket outlets with residual current device shall be provided for all water retaining structures for the water treatment works, intake structure and raw water pumping station. The socket outlets shall be located in an IP65 weatherproof enclosure fixed to the structure wall.

For process plant areas, industrial type socket outlets shall be so spaced so that any location within the area is no greater than 20m from an outlet. A minimum of two socket outlets shall be provided in each area.

Commercial type 240V 15A and 5A socket outlets shall be installed throughout all administrative office areas including the associated corridor areas. A minimum of two socket outlets shall be provided in each room to allow each desk to be serviced with a power supply without the need for extension leads. Additional socket outlets to suit the particular requirements of the main control room and the laboratory shall be provided.

B 6.4 Local area network

The Contractor shall provide a local area network for all offices including control room and laboratory within the filter building in accordance with the standard specification. As a minimum two RJ45 connections shall be provided in each office, laboratory and control room. The Contractor shall submit details of the proposed network for the Engineer's approval.

B 6.5 Ventilation

Mechanical ventilation shall be provided as follows:-

Location:	Air changes/hour (ACH):
Chlorine building:-	
- Cylinder store	12
- Chlorinator room	10
- Monitoring room	6
- Pump room	6
Miscellaneous:-	
-Toilets and washrooms	6
-Mess rooms and kitchen	6
-Sludge galleries	10
-Electrical switchrooms	10

For further details of ventilation requirements refer to the mechanical specification.

B 6.6 Ceiling fans

All administrative areas such as the control room, all offices and building entrance areas at the water treatment works and each water pumping station shall be provided with ceiling fans to provide 4 ACH. The fans shall be provided with local speed controllers and switches adjacent to each individual unit.

B 6.7 Air conditioning

As a minimum, the control room and the laboratory shall be air conditioned. The Contractor shall also provide additional air conditioning units to meet the requirements of his design.

The air conditioning shall be designed to maintain a dry bulb temperature of 22 ^{0}C and relative humidity of 50% under the outside mean monthly maximum shade temperature and humidity specified elsewhere. Split type air conditioning units shall be used and the air conditioning system shall be designed to provide 100% standby functional capacity.

B 6.8 Fire detection system

A fire detection system shall be provided in accordance with BS 5839: Fire detection and alarm systems for buildings, the local fire regulations and the following requirements:-

(a) Fire detectors

Optical smoke type detectors shall be installed in switchrooms, stores containing flammable materials and the control rooms.

The Detectors shall be locally-resettable and shall be detachable from their installation position to facilitate maintenance and replacement. Detectors shall have light-emitting type operation indication and shall be suitable for fixing direct to circular conduit boxes.

(b) Manual call points

Manual call points shall be located strategically throughout the plant. A call point shall be located adjacent to each external door and at personnel doors to switchrooms, chemical areas and stores of flammable materials. For multi-storey buildings, call points shall additionally be located at stairwell landings on each floor.

(c) Control panel

Wall mounted addressable type control panels shall be located in the control room of the administration building for the water treatment works and in the low voltage switchroom at the raw water pumping station.

A system-test facility and a power supply failure indication shall be provided.

Each control panel shall be provided with voltage-free changeover contacts to be monitored by the SCADA system for the following conditions:

(i) system fault;
(ii) normal supply failed;
(iii) system operated.

The contacts shall be wired to cable terminations.

A correctly-oriented plan of the premises showing the locations of the fire zones and exits, and instructions for the actions to be taken in the event of fire or fault indication, shall be positioned adjacent to the control and indicating equipment. They shall be in an approved durable form.

(d) Fire alarm devices

Sounder and visual fire alarm devices shall be installed in switchroom and on each floor of multi-storey buildings. The fire alarm sounder/strobe device locations shall be audible or easily observed from all parts of the water treatment works and pumping station.

(e) Power supplies

The normal supply for each control panel shall be derived from the normal site power supplies. A standby supply shall be provided by an integral sealed-type battery complete with an automatic charger. The battery shall be of the nickel-alkaline or lead-acid type and shall have a life of not less than 4 years and shall be capable of automatically maintaining the system operational for a minimum period of 24 hours.

The battery charger shall be fitted with a milli-amp meter to indicate the rate of charge.

The normal site power supply for each control panel shall be from a dedicated outgoing MCB. The outgoing unit shall be coloured red and shall be fitted with a label inscribed 'Fire alarm - do not switch off'.

(d) Wiring

Wiring shall be carried out using the red covered fire resistant cabling in accordance with the local fire regulations.

B 6.9 Telephone facilities

A complete telephone system shall be provided for the water treatment works, each pumping station, the telemetry and power house at master balancing reservoir at MADAM and the Central Control Room at Dharmapuri. The system at water treatment works shall comprise a site EPABX located in the Central Control Room. The site telephone system shall be connected to the telephone company network to provide off-site communications. The Contractor shall make all necessary arrangements with the telephone company for provision of the lines into the works. The EPABX shall also be capable of future connection to IP telephony system.

The quantity of telephone lines, fax lines, telephone sets and fax machines to be provided shall conform to Clause B7.12 of the Instrumentation, Control and Automation Particular Specification.

A provisional sum item is included within the Contract for the provision of any telephone line additional to that described in Clause B7.12 of the Instrumentation, Control and Automation Particular Specification.

The EPABX shall be sized to provide 50% spare capacity for additional telephone handsets and external telephone lines.

The treatment works telephone cable network shall be used for telephones only and not instrumentation signals.

B 6.10 Site Intercom

The Contractor shall provide a site intercom system comprising of an externally mounted call-point at the site entrance gates at each site of the Contract, including the water treatment works, the intake work/booster pumping station, the raw water pumping station and the master balancing reservoir at MADAM, which shall be linked to the Central Control Room in the filter house.

The external call-point shall be provided with in-built call button, a microphone and speak push-button, and a speaker all located in a weather proof enclosure adjacent to each site entrance.

The Central Control Room shall be provided with a desk mounted microphone and speak push-button. An audible call alarm shall be provided which is audible in all parts of the administration area of the filter building.

B 6.11 Distribution boards

Each individual building or facility shall be provided with suitably sized distribution board dedicated for building services. The distribution board shall provide distribution to lighting, socket outlets, heating, ventilation and air conditioning. Circuits shall be arranged to provide a balanced load on each phase of the supply. Each distribution bord shall be provided with 20% spare ways.

The fire detection system shall be supplied from a dedicated feeder unit on the appropriate 415V switchboard.

B 6.12 Wiring

Internal wiring on concrete and blockwork surfaces shall be carried out using single core PVC insulated non-sheathed cables installed in surface mounted heavy duty galvanised steel conduit and/or trunking. Wiring in plastered and tiled areas shall be installed in concealed steel conduit.

External wiring shall be carried out using single core PVC insulated non-sheathed cables installed in heavy duty galvanised steel conduit or PVC covered mineral insulated copper sheathed cables.

Wiring associated with lighting and ventilation fans in the chlorine and chemical buildings shall be carried out using heavy duty PVC or GRP conduits/trunking and/or cable tray/ ladder as necessary.

Within the Central Control Rooms at the filter building and at Dharmapuri, the Contractor shall provide a computer raised floor. All communications, control, small power services and telecommunications cabling shall be contained within a three compartment cable management system to allow adequate segregation of cabling. The cable management system shall be designed to allow flexibility and future expansion as well as providing mechanical protection for all cabling.

VOLUME 2 OF 7 PART B

PARTICULAR SPECIFICATIONS – ICA WORKS

CONTENTS LIST

B 7.0 INSTRUMENTATION CONTROL AND AUTOMATION

B 7.1 Overall distributed control system

B 7.1.1 Scope

This section covers the particular requirements for the supply, installation, inspection, testing and commissioning of the distributed control, monitoring and data acquisition system (SCADA System) and the instrumentation system of the Contract. The SCADA System to be provided by the Contractor shall also comply with Volume 2 Part H of the Standard Specification.

The SCADA System and instrumentation system shall be designed to cater for the Works specified under the Contract to satisfy the following primary aims:

- Control and monitoring of the Works, including and not limited to:
  (a) the inlet work/raw water pumping station, the Water Treatment Plant, the booster pumping station, the master balancing reservoir at MADAM in Package I of the Project,
  (b) tapping points branches from the treated water trunk mains connecting from the master balancing reservoir at MADAM to the sites of Packages II to V, the union reservoirs, the re-chlorination stations at these union reservoirs and some of the large booster pumping stations for Packages II to V of the Project,

  in order to produce the required quantity of water within specified quality constraints and in a properly coordinated manner.
- Acquisition, processing and recording of operational data from the abovementioned sites to facilitate efficient management of the Works.
- Rationalisation of man-power, whilst maintaining an adequate level of security of the water supply and the Works.

B 7.1.2 General requirements

The monitoring and supervisory control of the Works, additional to that complying with the requirements as entered in Volume 2 Part H of the Standard Specification, shall be based on a stand-alone distributed control system (DCS) whereby each individual section of the Works responds automatically to changes in output or other circumstances, but which provides full operational data to the centralised display at the Central Control Room 1 (CCR-1) located in the filter building at the Water Treatment Works and Central Control Room 2 (CCR-2) located at the Project Office of TWAD at Dharmapuri and responds to operating commands being issued from these two CCRs.

The SCADA System equipment shall meet the requirements entered in Table 1 below and the system integrator/PLC programmer/Human machine interface software programmer shall meet the requirement entered in Table 2. The communication media service provider shall meet the requirement entered in Table 3. The SCADA System and communication network proposal shall include all the works for the whole Hogenakkal Water Supply and Fluorosis Mitigation Project.

The Contractor has to submit all the required information to justify that the SCADA System, the system integrator, the PLC programmer(s), the Human Machine Interface software programmer and the whole communication network can fulfill the requirements entered in Table 1, Table 2 and Table 3 prior the commencement of any work.

Table 1

Item	Equipment	Manufacturer's Experience Criteria	
		Minimum No. of years the equipment offered are in production (X)	Minimum quantity of similar capacity goods sold (Y) (in 'X' No of years of production at the due date of tender)
1	Distributed programmable logic controller at CCTP and DCCTP	15	50,000
2	Redundant programmable logic controller at LCP	15	50,000
3	Human-Machine interface software	20	50,000
4	Digital Input Modules	15	300,000
5	Digital Output Modules	15	300,000
6	Analogue Input Modules	15	150,000
7	Analogue Output Modules	15	100,000
8	Communication Modules	15	300,000

Table 2

Item	Company/Programmer	Company/Programmer's Experience Criteria	
		Minimum No. of years of past experience in relevant work	Minimum No. of project involved, with that project contract amount not less than Rs 300,000,000
1	System Integrator Company to install, test and commission the SCADA System	20	5
2	Programmer to prepare the programs for the Human Machine Interface	20	5
3	Programmer to prepare the application program	20	5

Table 3

Item	Company	Communication Media Service Provider Experience Criteria	
		Minimum No. of years of past experience in relevant work in India	Minimum No. of project involved, with that project contract amount not less than Rs 300,000,000
1	Communication media service provider (leased lines, GSM mobile lines, CDMA mobile lines etc) (see Note-2)	20	5

B 7.1.3 Interface with other contracts – general requirements

This Contract is the Hogenakkal Water Supply and Fluorosis Mitigation Project – Package I and the Employer will be procuring the remaining works of this Project under Packages II to V. The works under Packages II to V are to construct:

(a) Package II - Treated water trunk mains from Master Balancing Reservoir at MADAM to Uthangarai Union, branch pipelines, union reservoirs, panchayat reservoirs, sumps, overhead tanks, chlorination stations, booster pumping stations, instrumentation, electrical and mechanical works for Pennagaram, Nallampalli, Dharmarpuri, Mathur & Uthangarai Unions;

(b) Package III - Treated water trunk mains branching to Harur Union, branch pipelines, union reservoirs, panchayat reservoirs, sumps, overhead tanks, chlorination stations, booster pumping stations, instrumentation, electrical and mechanical works for Morappur, Pappireddipati and Harur Unions Mallapuram, TP ;

(c) Package IV – Treated water trunk mains from Booster Pumping Station near Palacode to Hosur, branch pipelines, union reservoirs, panchayat reservoirs, sumps, overhead tanks, chlorination stations, booster pumping stations, instrumentation, electrical and mechanical works;

(d) Package V - . Treated Water Trunk Mains from Main Balancing Reservoir at MADAM to Bargur Union, Branch Pipelines, Union Reservoirs, Panchayat Reservoirs, Sumps, Overhead Tanks, Chlorination Stations, Booster Pumping Stations, Instrumentation, Electrical and Mechanical Works for Pennagaram, Palacode, Karimangalam, Kaveripattinam, Krishnagiri and Bargur Unions

The Contractor has to provide all the necessary hardware and software for the SCADA System, including the Local Control Panels (LCP), the instrumentations and other devices specified, at the works at Packages II to V, to acquire and issue command to/from SCADA System for the following signals:

(1) to acquire the water levels, including the high high and low low levels, at all union reservoirs at locations as specified in Table 1-1, Table 1-2, Table 1-3 and Table 1-4 at Clause B7.1.17,

(2) to acquire the water flow rate (m^3/s), quantity of water passing through (m^3) and pressure at each tapping point branch from the treated water transmission trunk main. The locations of these tapping point branches are specified in Table 2-1, Table 2-2, Table 2-3.1, Table 2-3.2, Table 2-3.3, Table 2-3.4, Table 2-3.5, Table 2-4 at Clause B7.1.17 ,

(3) To acquire the water levels, including the high high and low low levels, at all inlet sump of the large booster pumping stations as specified in Table 3-1, 3-2, 3-3.2, 3-3.2, 3-3.3, 3-3.4 and 3-4 at Clause B7.1.17,

(4) to acquire the inlet water flow rate (m^3/s), quantity of water passing through (m^3), overall discharge water flow rate (m^3/s), quantity of water passing through (m^3), pressure at the inlet and pressure at the discharge end of the large booster pumping stations. The locations of these large booster pumping stations are specified in Table 3-1, Table 3-2, Table 3-3.1, Table 3-3.2, Table 3-3.3, Table 3-3.4 and Table 3-4 at Clause B7.1.17,

(5) to acquire the open/close/unavailable/fault status signals for all inlet and outlet isolation valves at the union reservoirs. To control the “close”, “open” of these valves. The locations of the union reservoirs are specified in Table 1-1, Table 1-2, Table 1-3 and Table 1-4 at Clause B7.1.17,

(6) to acquire the operating positions of all flow control valves and the discharge valve (discharge side of electromagnetic flowmeter) at each tapping point branch from the trunk main. To control the position of the flow control valves at the inlet to the electromagnetic flowmeter. To “close” and “open” the discharge valves, at the outlet of the electromagnetic flowmeter. All valves and actuators are to be provided under contracts of Packages II to V. The locations of these tapping point branches are specified in Table 2-1, Table 2-2, Table 2-3.1, Table 2-3.2, Table 2-3.3, Table 2-3.4, Table 2-3.5, Table 2-4 at Clause B7.1.17,

(7) to acquire the run/stop/unavailable/fault status and voltage/power/power factor at power incoming panels, of the large booster pumping stations at the works of Packages II to V. To control the "on", "off" of the booster pumps of these booster pumping stations. The locations and the general description of each booster pumping stations are specified in Table 3-1, Table 3-2, Table 3-3.1, Table 3-3.2, Table 3-3.3, Table 3-3.4 and Table 3-4 at Clause B7.1.17,

(8) to acquire the run/stop/unavailable/fault status of the chlorinators, chlorine gas leakage, other associated signals at the chlorination plants and voltage/power/power factor of the Re-Chlorination Houses incoming panels at the works of Packages II to V. One no. of Re-Chlorination House will be provided at each union reservoir, with their locations as specified in Table 1 at Clause B7.1.17.

All the above signals shall be incorporated into the SCADA system in this Contract. Human Machine Interface (HMI) pages have to be provided by the Contractor for displaying of the signals of all the devices mentioned above and for initiating control to devices mentioned in items (3), (4) and (5) above. As a minimum, 50 HMI pages shall be provided by the Contractor for displaying the plants at Packages II to V. The Contractor has to submit proposal for the HMI pages for plants at Packages II to V to the Engineer for approval.

The Contractor has to provide, as a minimum, the following instruments at the sites of Package II to V:

(a) Duty and standby level measuring instruments, which shall be ultrasonic level measuring sensors/transmitters, at all union reservoirs, the locations as specified in Table 1-1, Table 1-2, Table 1-3 and Table 1-4 at Clause B7.1.17. The ultrasonic level measuring sensors/transmitters shall conform to the requirements entered in Part G, Clause G5.3 of the Standard Specification;

(b) The high high and low low level electrodes, each be completed with its level controllers, at all union reservoirs. The level electrodes and controllers shall conform to the requirements entered in Part G, Clause G5.3 of the Standard Specification;

(c) Duty and standby level measuring instruments, which shall be ultrasonic level measuring sensors/transmitters, at all inlet sumps to the large booster pumping stations, the locations as specified in Table 3-1, Table 3-2, Table 3-3.1, Table 3-3.2, Table 3-3.3, Table 3-3.4 and Table 3-4 at Clause B7.1.17. The ultrasonic level measuring sensors/transmitters shall conform to the requirements entered in Part G, Clause G5.3 of the Standard Specification;

(d) The high high and low low level electrodes, each be completed with its level controllers, at all inlet sumps to the large booster pumping stations. The level electrodes and controllers shall conform to the requirements entered in Part G, Clause G5.3 of the Standard Specification;

(e) Flow measuring instruments, which shall be electromagnetic flow meters, and pressure sensors/transmitters, at all the tapping point branches from the trunk main, the locations as specified in Table 2-1, Table 2-2, Table 2-3.1, Table 2-3.2, Table 2-3.3, Table 2-3.4, Table 2-3.5, Table 2-4 at Clause B7.1.17. The electromagnetic flowmeters and the pressure sensors/transmitters shall conform to the requirements entered in Part G, Clause 4.2 and Clause 6.1 respectively, at the Standard Specification;

(f) Flow measuring instruments, which shall be electromagnetic flowmeters and pressure sensors/transmitters, at the inlet and discharge side of the large booster pumping stations, the locations as specified in Table 3-1, Table 3-2, Table 3-3.1, Table 3-3.2, Table 3-3.3, Table 3-3.4 and Table 3-4 at Clause B7.1.17. The electromagnetic flowmeters and the pressure sensors/transmitters shall conform to the requirements entered in Part G, Clause 4.2 and Clause 6.1 respectively, at the Standard Specification;

To facilitate the dismantling of the electromagnetic flowmeter measuring pipes (mentioned in items (e) and (f) above), each of these pipes shall be installed in conjunction with a flange adaptor and a spigot pipe (one end flange end and the other end plain end) and a flange adaptor. The tee-off pipe for the pressure sensors/transmitters, as mentioned above, at the tapping point branches from the trunk mains and at the booster pumping stations shall be provided at the body of the spigot pipes. If separate flange connected earthing ring(s) are required for the electromagnetic flowmeters, these earthing ring(s) shall be provided by the Contractor.

The electromagnetic flowmeters, the pressure transmitters at the tapping point from the trunk mains and at the large booster pumping stations, the ultrasonic level sensors/transmitters at the union reservoirs and the level electrodes/controllers at the union reservoirs, at the sites of Packages II to V, shall be supplied, installed, tested and commissioned by the Contractor.

Should the primary measuring pipes of the electromagnetic flowmeters be unable to be supplied to the other contractors when they need the measuring pipes for putting in place when they are installing their pipelines, the Contractor has to provide spool pieces of the same dimensions with the same double flange ends as the primary measuring pipe, the flange adaptors and the spigot pipes to the contractors of Packages II to V. The spool pieces, with the flange adaptors and the spigot pipes, will be used by other contractors to temporarily be installed in their pipelines. The Contractor shall be responsible for all work associated with the replacement of the spool pieces by the permanent flowmeter measuring tubes after they arrive at site, including the repeated hydraulic pressure test, if this test has already been done by these contractors with the spool pieces in place prior to the flowmeter measuring pipes be provided.

The Contractor has to provide, for each size of the electromagnetic flowmeter, as a minimum one number of spool piece. The spool piece being removed from the pipeline installation of contacts of Package II to V, after rectification of any damage and examined by the Engineer to be in an acceptable condition, can be reuse. These spool pieces shall be ultimately handover to the Employer for their future use, for temporarily put into position in lieu of any of the flowmeter primary measuring pipes, when they are required to be dismantled for maintenance or other purpose. The Contractor shall be responsible to deliver all the required spool pieces to designated storage locations of the Employer.

The Contractor shall liaise with the contractors of Packages II to V to furnish the program to install the electromagnetic flowmeter measuring tube, or alternatively, the dates to provide the spool pieces to the other contractors. The Contractor shall act in accordance with the agreed schedule. The bolts, nuts and washers for the connection between the flanges of the flange adaptors and the spigot pipes shall be provided by the Contractor.

(g) At the tapping branch points from the treated water trunk mains, the Contractor has to provide one set of GRP panels with all the necessary equipments be installed therein to serve the following purpose:

(i) Power Distribution Panel. 200A three phases and neutral incoming circuit breaker (MCCB) for accepting the power supply to provide by Tamil Nadu Electricity Board shall be installed. The incoming switch shall distribute the power to one set of outgoing switch (miniature circuit breakers of breaking capacity 6kA and rating to be determined by the load to be connected). For use by each of the contractors of Package II to V, at this Power Distribution Panel, the Contractor shall provide four numbers of three phases mcb each of rating 32A;

(ii) SCADA Equipment Panel(s). All SCADA equipment and the router switches, hub switches, modem for leased landline, modem for mobile lines shall be installed; and

(iii) UPS Panel(s).

The above three panels with all the equipments installed therein shall become the Local Control Panel (LCP), as described elsewhere in this Specification, for the SCADA System at the tapping branch points of the treated water trunk mains. Each panel shall be made of GRP and be weatherproof of index of protection IP56 as a minimum. Each panel shall possess two key lock. An overall enclosure with sunshield canopy shall be provided. As a minimum, one air intake lourve with filter and one extraction fan shall be provided to produce 20 air changes per hour at each panel. The conceptual general arrangement of this LCP has been entered in Drawing STD/SS/002/TA, which shows the basic design concept.

The Contractor will be advised by the contractors of Packages II to V of their construction programs of their works and they will allow the Contractor to access their sites to install the Local Control Panels (LCPs), to be used for the acquisition of signals and to activate the control command from/to the instruments, electrical and mechanical equipment at the sites of Packages II to V.

The Contractor has to provide and install Local Control Panels (LCPs), complying with the requirements entered in other clauses elsewhere in this Specification, at the following locations at the sites of Packages II to V:

(1) at each union reservoir site, at locations specified in Table 1-1, Table 1-2, Table 1-3, Table 1-4 at Clause B7.1.17, in the telemetry room inside the Re-Chlorination Station House,

(2) at each tapping point branch site, at locations specified in Table 2-1, Table 2-2, Table 2-3.1, Table 2-3.2, Table 2-3.3, Table 2-3.4, Table 2-3.5 and Table 2-4 at Clause B7.1.17, from the trunk mains using weatherproof panels to house all the equipment, as described above and the conceptual design being entered in Drawing STD/SS/002/TA and,

(3) at each booster pumping station building, at locations specified in Table 3-1, Table 3-2, Table 3-3.1, Table 3-3.2, Table 3-3.3, Table 3-3.4 and Table 3-4 at Clause B7.1.17, in the telemetry room therein (except Pennagaram booster pumping station at MADAM, the LCP for acquiring/sending signals to this pumping station will be located at the Telemetry and Power House. The Telemetry and Power House shall be provided by the Contractor).

The Contractor has to supply and install cables connecting all their instruments to the LCPs. The contractors of Package II to V shall supply and install the cables connecting their devices to the LCPs cable connection terminals. The Contractor has to provide the connection diagrams for each LCP to contractors of Packages II to V to enable them to connect their cables from their devices to the LCPs properly.

At each of the union reservoirs and the large booster pumping station sites, the LCP and other associated devices shall be installed in telemetry room, of size not less than 2m (depth) x 2.5m (width) at the Re-Chlorination Station House and the booster pumping station building to be provided by the contractors of Package II to V. Should the abovementioned space be not adequate for the Contractor to install their LCPs, UPS and other associated equipment, the Contractor shall inform the Engineer and submit their requirement with their substantiation design calculations. Should such requirements be only raised after the buildings at the Re-Chlorination Station House and the large booster pumping station be built, the Contractor shall bear the responsibility of all consequential abortive and double-handling work.

At the sites of the tapping point from the trunk mains, the Contractor has to provide weatherproof enclosure, to install their LCPs, UPS and other associated equipment. The UPS for the backup of the LCP load and the instruments, i.e. the electromagnetic flowmeters, the ultrasonic level sensors/transmitters, the pressure sensors/transmitters, the electrode controllers etc, shall be size to have a backup time to the connected load of, as a minimum, three hours. Sealed type maintenance free batteries shall be provided for the UPS to prevent any possibility of hydrogen gas be released during operation.

The building services facilities in the abovementioned telemetry rooms for LCPs will be provided by the contractors of Packages II to V. One single phase 230Vac 100A power supply will be provided by these contractors to each of the telemetry rooms to house the LCPs. This 100A power supply shall be shared by both the Contractor and other contractors for the equipments to be installed inside. The building services facilities of the other contractors will consist of one 9,000 BTU window type air conditioner, lightings and small power socket outlets.

The transmitters of the ultrasonic level measuring instruments at the union reservoirs and the transmitters of the electromagnetic flowmeters at the tapping point branches from the trunk mains, shall preferably be installed inside the telemetry rooms housing the Local Control Panels. However, the Contractor has to observe the requirement from the manufacturer of these instruments, regarding the maximum allowable cable length between the sensors and the transmitters. If such allowable cable length will be exceeded when the instrument transmitters are installed in the abovementioned rooms/enclosures housing the LCPs, the Contractor shall install these instrument transmitters inside a GRP weatherproof enclosure, of index of protection not less than IP56, and placed at an appropriate locations near to their sensors. The GRP weatherproof enclosures shall have two locks at the front access door and be transparent in the front door surface such that display panels of the transmitters shall be able to be read at exterior to these panels. The GRP weatherproof enclosures shall be supported by hot dip galvanized u-channels, such that the transmitter display panels will be at eye level and shall be completed with a GRP canopy to prevent direct exposure to sunlight.

The locations to install the abovementioned GRP weatherproof enclosures shall be agreed among the Engineer, the contactor of that Package responsible for the site and the Contractor.

The instruments to be provided by the Contractor shall preferably be able to communicate with the redundant programmable logic controllers in the LCPs via communication protocols, e.g. MODBUS, FieldBus or other equivalent design suitable for the Project. All the instruments shall be then wired by using bus topology back to the LCP. A weatherproof junction box shall be installed adjacent to each sensor, within which cable connection terminals shall be installed. The upper end of these cable connection terminals shall be terminated by the bus-wiring whilst the lower end of these cable connection terminals shall be terminated with the cables to connect to the sensors. This connection method is to prevent the removal of any one of the sensors to affect the acquisition of signals from other sensors by the LCPs. The Contractor shall liaise with the contractors of Packages II to V to obtain the following signals, preferably using the same communication protocols as mentioned above:

(a) voltage/power/power factor signals from the power meters at incoming panels at the booster pumping stations and the Re-Chlorination Station House and;

(b) the position signals at the electrical actuators of the flow control valves at the tapping points branches from the trunk main. Controlling of these electrical actuators shall be activated by the same connection;

The contractors of Packages II to V shall be responsible to provide at their devices the necessary dry contacts, analogue 4-20mA outputs (if they are inevitably required), and the necessary RS485 port at their power meters/actuators where communication with the DCS/PLC at LCPs are through communication protocols of MODBUS, FieldBus or other equivalent design suitable for the Project.

The Contractor shall attend monthly coordination meetings with the Engineer, the Engineer Representatives and the contractors of Packages II to V to properly coordinate all the works to be carried out. Upon the request of the Engineer, the Contractor shall also attend any ad hoc meeting with the contractors of Packages II to V to discuss any matters regarding the interface works.

Detail requirements of the work under this Contract at the sites of Package II to V are entered in Clause B7.11 and Clause B7.12.

B 7.1.4 Environmental conditions

The instrumentation, control and automation equipment shall be designed and manufactured for continuous operation under the climatic and environmental conditions at the sites as specified elsewhere.

(a) Outdoor and overall conditions

All field mounted instruments installed outdoors shall be suitable for operation under the local environmental conditions. All Plant equipment, instruments and materials shall be directly protected or shaded against heat gain or damage by solar radiation. The method to attain such protection, with installation details, shall be submitted by the Contractor to the Engineer, for approval.

(b) Indoor conditions

Indoor building areas housing equipment shall be air conditioned or ventilated with room classification and ambient temperature conditions specified in other sections of the Contract. Where field mounted instruments are installed in air conditioned or ventilated areas, the equipment shall be designed for operation under conditions of failure of air conditioning or ventilation systems.

(c) Equipment mechanical protection

For indoor areas with increased environmental conditions or aggressive/hazardous atmospheres, equipment shall be specifically designed or protected in accordance with the relevant specification clauses and reference standards.

B 7.1.5 Principal functions

The monitoring and supervisory control system shall as a minimum, perform the following functions:

- Control and monitoring of the Works to produce the required quantity of water within specified quality constraints and in a properly - coordinated and cost-effective safe manner;
- Acquisition, processing and recording of operational data to facilitate efficient management of the Works;
- SCADA Manual control to the specified site equipment from the CCRs;
- The collection, storage and presentation at the various peripheral devices, of all analogue and digital data from the entire Works;
- Rationalisation of man-power, whilst maintaining an adequate level of security of the water supply and the Works.

The system shall include, but not be limited to, the following items:

- Supervisory control and data acquisition equipment at the CCRs suitable for testing, commissioning, operating and maintaining the works;
- Local control panels (LCPs) with redundant DCS/PLCs system or intelligent outstations and associated auxiliary devices for automatic control of equipment. A touch screen panel with human machine interfaces (HMIs) graphic pages, with details agreed by the Engineer, shall be installed at the LCPs at the raw water pumping station, at each of the works at the Water Treatment Plant, the booster pumping station and the master balancing reservoir at MADAM. Such touch screen panel is not required at the LCPs at sites of Package II to V. Conventional relay technology, panel front conventional push buttons and indication lamps for manual control and monitoring of all the equipments shall be available at all the LCPs to be provided by the Contractor for controlling those devices

Each DCS/PLC at each LCP shall contain communication facilities, as shown in the Drawing. Each LCP shall perform control and supervisory duties such as stopping and starting of machines, opening and closing valves in a logical sequence, verifying the correct response from the controlled element, performing the PID (three-term) control of specified plant parameters, providing manual control facilities, providing operator interface facilities for complete control and monitoring of the plant. For LCPs to be installed at outdoor environment, an enclosure conforming to the requirements as entered in Clause B7.1.3, shall be constructed to house the LCP.

LCPs shall supply and receive analogue and digital data from measuring instruments and contacts and shall compute derived functions from this raw data, as appropriate. Each LCP shall have LED/LCD numeric displays to show the levels, flow, pressure and flow control valve position signals acquired. Also, volume flow digital display shall be incorporated. The indication at this volume flow digital display shall be synchronized with that being shown at the HMI pages.

Analogue and digital data, as specified elsewhere, shall be transmitted to the CCR equipment when interrogated or when alarms or events occur.

- Data communications network for transmitting data between LCPs and the CCR shall be as that described in Clause B7.10.
- Local instrumentation, controls, indicators, power supplies, equipment and all interconnecting cabling systems necessary for safe and efficient operation and monitoring of the works;
- Uninterruptible power supplies shall be provided to backup all the CCR equipment and the essential features within the LCPs for the PLC or distributed I/O and the instruments;
- One Off/Hand/SCADA selector shall be installed at each of the LCPs where there is conventional push button manual control. When the selection is at “Hand”, control of the plant equipments can be initiated at the LCP push buttons or the touch screen panel. When the selection is at “SCADA”, control of the plant equipments will be either “Local Auto” or “SCADA Manual”, depending on the selection at the SCADA HMI pages. “Local Auto” means automatic control by the control application program being installed at the redundant DCS/PLCs at the LCPs. “SCADA Manual” means operator manual control by activating on/off graphic push button at the HMI pages at the SCADA workstations at the CCRs. Hard wired safety interlocks for equipment protection shall operate in all modes of plant control. The hardwired interlocks and plant status indication shall function even if there is a PLC, distributed I/O or communication fault.

  For LCPs being installed at sites of Package I, the details of the conventional relay logic backup, the associated required conventional push buttons, indicating lamps etc had to be discussed and agreed with the Engineer. The Employer/Engineer has the right to request all devices that are controlled automatically under the LCP have full conventional relay logic backup, full provision of conventional push buttons and indicating lamps.

  For LCPs being installed at sites of Packages II to V, the conventional push buttons, indicating lamps, the “Off/Hand/SCADA” selector mentioned in the above and other related facilities, shall be arranged as follows:

(a) At the flow control valves sites at the tapping point to the trunk mains, the selector “Off/Hand/SCADA”, conventional push buttons for control purpose and indicating lamps for displaying the status of the valves shall be available on the LCPs. When the selection is “SCADA”, only “SCADA Manual” will be available for control the valves by operating the on/off graphic push buttons at the HMI pages. When the selection is “HAND”, and the selection at the electrical actuator is “REMOTE”, the conventional on/off push buttons at the LCPs shall act as open/close buttons and can be used for modulating the flow control valve in the open/close direction. When the selection is “HAND”, and the selection at the electrical actuator is “LOCAL”, open/close control shall be activated at the electrical actuator. A local valve position indicator shall be installed at each LCP to show the % opening of the flow control valve. Also, a local flow rate indicator, a flow volume indicator with LED/LCD numeric display shall be installed at each LCP to show the instantaneous readings obtained from the electromagnetic flow meter at each site;

(b) At union reservoir sites, the selector “Off/Hand/SCADA”, conventional push buttons for control purpose and indicating lamps for displaying the status of the valves shall be available on the LCPs. When the selection is “SCADA”, only “SCADA Manual” will be available for control the valves by operating the on/off graphic push buttons at the HMI pages. When the selection is “HAND”, and the selection at the electrical actuator is “REMOTE”, the conventional on/off push buttons at the LCPs shall act as open/close buttons and can be used for open/close the inlet valves. When the selection is “HAND”, and the selection at the electrical actuator is “LOCAL”, open/close control shall be activated at the electrical actuator. A local level LED/LCD numeric display shall be installed at each LCP for displaying the position of the inlet flow control valves (if applicable). Indicating lamps to display that the inlet and outlet isolating valves are fully opened/closed shall be provided at the LCP.

(c) At booster pumping station sites, the selector “Off/Hand/SCADA” conventional push buttons and indicating lamps shall all be located at the each of the pump starters, not at the LCP. When the selection at the selector is “SCADA”, that pump will be able to be operated at “SCADA Manual” by controlling the on/off graphic push buttons at the HMI pages. When the selection is “HAND”, the conventional on/off push buttons at the starter of that pump shall act as run/stop buttons of that pump.

B 7.1.6 Essential features

The system shall exhibit the highest degree of availability, user-friendliness, reliability and maintainability. The design shall include, but shall not necessarily be limited to, the following features:

- system change-over hardware and software shall be provided to maintain the on-line functions following any single failure;
- the system change-over design shall include various on-line system test programs which shall be uniquely designed for the system configuration; these test programs shall generate inputs and test for outputs using sets of equipment or all of the equipment designed to exercise continually critical elements of the system, and to detect and isolate malfunctions down to the major sub-system level;
- further detailed test and diagnostic programs and detailed malfunction alarms for use by the Employer's maintenance staff shall be supplied;
- the system shall be designed to recover fully from hardware, software and power supply failures;
- the system shall be protected against multiple and cascading component failures;
- the system shall reject illegal instructions, inconsistent data, inadvertent actions and unauthorised controls.

No inadvertent indication or incorrect control shall occur under any or all of the following conditions:

- single component failures;
- failure or replacement of any fuse;
- removal or replacement of a plug-in module;
- power supply switching surges and repeated on/off switching of power supplies; transient signal noise on signal and data circuits;
- operation during extreme service conditions and over noisy communications lines;
- initial switch-on or restoration after component failure, power supply failure, testing or maintenance;
- software development and debugging;
- modification and expansion facilities.

B 7.1.7 ICA equipment identification

The equipment identification convention utilised in the drawings incorporates a unique multi-field tag name for all equipment of the Works. The Contractor shall adopt a similar tag numbering scheme. Details of the tag numbering scheme shall be submitted to the Engineer for approval prior to undertaking any design.

B 7.1.8 Central Control Room (CCR) - equipment

Equipment provided for the CCRs shall include the following items:

(h) 2 Nos. of desktop computers shall be used as the data server units. Each computer shall be equipped with Intel dual processors or equivalent, operating at speed not less than 2.2GHz, hard disk of 500GB, 4GB on board RAM, DVD R/W player, 22" industrial colour LCD monitor of resolution not less than 1280x720, trackball, keyboard and other necessary features as determined by the Engineer. An internal/external tape drive capable of back-up data up to a maximum 800GB shall be provided. The tape drive shall be available with Write Once, Read Many media to protect the data stored being altered or changed. These two data servers shall be connected to redundant LAN Ethernet with the other devices as detailed in the following;

(b) 1 No. control desk with size not smaller than that shown on the Drawing. The control desk shall be constructed of high quality sheet steel with surface treatment schedule and colour to be approved by the Engineer. The control desk shall be formed by multiple cubicles being assembled together at the final installation locations. The interior of each of the cubicles of the control desk shall be able to be accessed by opening the front or the rear side removable panels. The interior of each cubicle shall be able to be divided into upper and lower compartments by an adjustable position and removable sheet steel partition plate. Power supply socket outlet shall be available at the control desk at typical location as shown in the Drawing. Openings shall be available at agreed position of the desk top of the control desk for running of cables from the equipment inside the cubicles to that on the desk top. The design of the control desk shall be submitted to the Engineer for approval;

(c) 2 Nos. complete workstations, operated from standard desktop personal computers with the same technical requirements as the data server units. Each workstation shall be equipped with two visual display unit (VDU) of industrial colour LCD monitor with size 22";

(d) 2 Nos. industrialised printers; one A3 colour ink/bubble jet type for alarm and event printing and one A4 colour laser type for report printing. The alarm and event printer shall be capable of print an alarm or an event statement whenever it is received but that paper will only be ejected when it is fully printed. The printers shall be located in a suitable stand/computer desk adjacent to the control desk;

(e) 1 No. Control Centre Telemetry Panel located in an area adjacent to the control desk. This panel shall house surge protection systems for signal and data circuits, hard-wired signal terminations, communication terminations for remote DCS facilities, other DCS peripherals requiring panel mounting, communications network connection and all features as detailed in B7.1.17;

(f) 4 Nos. approved telephones and 1 No. of approved fax machine, each terminated in a dedicated standard telecommunications socket at the control desk.

(g) 2 Nos. work desks completed with operator chairs, with storage to provide work space for two operators. The final installation positions of these work desks have to be agreed with the Engineer;

(h) 4 No. operator chairs to be located at the CCR;

(i) 1 No. uninterruptible power supply (UPS) unit to be located in an appropriate position in the CCR for supporting all the essential CCR equipment;

(j) 1 No. large digital wall mounted clock with day and date display;

(k) 2 Nos. of 3 LCD panels front projector of resolution 1280x720 and illumination lumen not less than 1500, with a fixed frame white screen of 100 inches. The projectors shall be mounted at the ceiling of the CCR and be able to accept VGA, HDMI and LAN inputs as the source of the display images. The fixed frame white screen shall be installed at the wall of the CCR in front of the control desk, at a location agreed by the Engineer. Power cable, HDMI cable, LAN cable and VGA cable shall be connected to the projector and lay to the control desk. These cables shall be of such lengths that they can reach the farthest end of the control desk.

The system shall be so designed that a total failure of the central operating station at the CCR shall not prevent the continued operation of the plant on automatic control from the LCPs. Manual control of the Plant shall be available at all times on failure of the LCP and/or the central operating station.

It shall be possible to present any display on either workstation VDU. Each graphic display page shall be selectable via a keyboard or trackball, designed for use by plant operators.

There shall be multiple levels of privileged entry, with access by means of an alpha-numeric password consisting of a minimum of eight characters. The highest level shall include the facility to review and make changes to the passwords. Historical records of password activity including frequency of access shall also be provided.

The report printer shall print statistical values from the signals representing such things as flows, levels, pressures, pH, chlorine residual, etc. as applicable. Print-outs shall occur at selected intervals, with an additional automatic print-out wherever any variable goes outside predetermined upper and lower limits. The alarm printer shall print any alarm or event on its occurrence. The print-out shall include the date and time in hours, minutes and seconds. The printers shall print on demand any data displayed on a VDU.

Operators' chairs shall be provided with raised arms. The chairs shall be of the castor swivel type of metal construction with non-combustible upholstery and filling. Each chair shall have earthing castors or other approved means of avoiding any build up of static electricity. The arms of the chairs shall be a suitable height so that they can be stowed under the desk work area when not in use. The finish and upholstery colours of the chairs shall be such as to blend with the desks and the CCR area.

Cable entry to the CCR shall be by ducting under the computer raised floor provided by the Contractor.

A cable way suitably designed to allow an additional capacity of 30% from the exterior of the filter building and the Project Office of TWAD at Dharmapuri shall be provided.

B 7.1.9 CCR area arrangement

The Contractor shall install the CCR equipment and associated furniture within control rooms in the filter house building of the Water Treatment Works and the Project Office of Tamil Nadu Water Supply and Drainage Board (TWAD) at Dharmapuri. The Contractor shall submit full details of the layout of the CCR area for the Engineers approval. The equipment supplied shall suit the environment and the layout and utilise the space available to the best advantage. Full details of the equipment proposed shall be submitted for approval before procurement.

Desks shall be designed on ergonomic principles with writing areas, visual items, and controls in convenient positions. The arrangement shall ensure comfortable positions for seated operators, with ample leg room. The area occupied by the printer shall have a basket or some approved equivalent means of catching and neatly containing the printed records. Laminate writing surfaces or the equivalent shall be provided over the whole of the work surfaces.

The finish of the desk and tables shall be similar and will be advised by the Engineer during the manufacturing stage of the Contract. Doors or removable covers shall be incorporated in the desk design to give access to each internal component and cabling. Any door or cover shall be lockable. The cabinet of the control desk shall have sufficient space to house the modem, router, hub or the like and other necessary equipment, to enable the desktop of the control desk be used to place the VDUs, keyboards, trackball, telephone sets only. The cabinet shall be adequately ventilated to avoid overheating of the equipment being installed therein.

B7.1.10 Human Machine Interface (HMI) VDU mimic displays

The Contractor shall design a series of HMI VDU images forming a clear, live, display covering the entire Works. These displays shall give a pictorial representation of each section of the Works showing the numerical value of each measurement within that section and the status of each component such as:

Machines running, stopped, failed and unavailable ('unavailable' means unavailable for SCADA, i.e. unavailable for LCP automatic or SCADA Manual control);

Valves open, closed, failed, %open (for modulating valves), no flow and unavailable ('unavailable' means unavailable for SCADA, i.e. unavailable for LCP automatic or SCADA Manual control);

Circuit breakers open, closed, tripped on fault;

Instruments flow, level, pressure, temperature and all other readings for water quality.

Status changes shall be represented by a change in colour. Failure conditions shall also cause the appropriate entries in the alarm list and, on occurrence, in the reserved banner on every page. The reserved banner on the VDU display shall be at the bottom of each HMI page and the area to occupy has to be agreed with the Engineer. The alarm messages in the banner shall be arranged to be displayed in accordance with their time of occurrence, with the latest alarm message at the top of the banner and the other messages descend downwards by time of occurrence.

All devices that can be controlled at the HMI VDU mimic display (SCADA Manual) shall be configured with a pop-up window, such that it will appear when clicking onto the device symbols that appear at any of the HMI VDU pages. The pop-up window of the device shall configured with graphic "start", "stop" and "emergency stop" buttons for controlling the devices. All SCADA controllable devices ("local automatic" or "SCADA Manual") shall be locked out from operation (both "local automatic" and "SCADA Manual") once they are failed, fault or tripped on fault. In the same pop-up window of these devices described in the above, a graphic "reset" button shall be configured for authorized operator to "reset" the devices after they resume normal from failure condition. The "start" and "stop" buttons shall only be activated when the control is at "SCADA manual" whilst the "emergency stop" and "reset" buttons shall be activated at all operating mode of the device. The buttons on the pop-up windows shall only be accessible by authorized person reaching the hierarchy of operating the device and he/she shall possess the valid password for logging into the pop-up window. The course of action being taken by the personnel "log in" shall be recorded in the event/alarm log record. The designation of that personnel who initiate a particular command shall be shown in the event log record. Therefore, when an authorized operator initiate an emergency stop to a running device that is under "local automatic" mode, the name of the person, the time he initiates such command shall be shown in the event log. All operating status, e.g. machine run, machine stop, machine fault, all details of fault, valve closed, valve opened, circuit breaker on, circuit breaker off, circuit breaker fault and the like shall be shown on the device's pop-up window.

LCP touchscreen and CCR HMI VDU mimic displays shall be drawn using the same software drawing package so that they require drawing only once. Also, future modifications shall be made to one display (either LCP or at the CCR) and then copied in file format into the other system without the need to re-draw the modification.

The Contractor shall submit drawing representations of the proposed VDU mimic displays for approval.

As a minimum, the following HMI VDU mimic pages shall be prepared:

(k) Site plan showing the raw water pumping station, water treatment plant, booster pumping station, inlet sump of the booster pumping station, master balancing reservoir at MADAM and all associated pipeline in Package I of the Project;

(l) Site plan showing the trunk main and tapping point branches of the treated water pipelines, union reservoirs, panchayat reservoirs and booster pumping stations of Package II;

(m) Site plan showing the trunk main and tapping point branches of the treated water pipelines, union reservoirs, panchayat reservoirs and booster pumping stations of Package III;

(n) Site plan showing the trunk main and tapping point branches of the treated water pipelines, union reservoirs, panchayat reservoirs and booster pumping stations of Package IV;

(o) Site plan showing the trunk main and tapping point branches of the treated water pipelines, union reservoirs, panchayat reservoirs and booster pumping stations of Package V;

(p) Intake Work and raw water pumping station overview of Package I (1 to 2 pages of HMI VDU mimic pages);

(q) Electrical supply system of the Intake Work and raw water pumping station (2 pages of HMI VDU mimic pages);

(r) Intake Works with bar screens and penstocks (1 page of HMI VDU mimic page);

(s) Raw water pumping station (1 page of HMI VDU mimic page);

(t) Water Treatment Plant (20 pages of HMI VDU mimic pages)

(u) Treated water pumping station (1 page of HMI VDU mimic page);

(v) Electrical supply system of the Water Treatment Plant and the treated water pumping station (2 pages of HMI VDU mimic pages);

(w) Booster pumping station (1 pages of HMI VDU mimic page);

(x) Electrical supply system at the booster pumping station (2 pages of HMI VDU mimic pages);

(y) Master balancing reservoir at MADAM (1 page of HMI VDU mimic page);

(z) Healthy/Fault status of all processors and communication network at the outstation LCPs and the regional telemetry panel in the CCR;

(aa) 50 pages of HMI VDU mimic pages for Packages II to V with details to be proposed by the Contractor and to be agreed by the Engineer;

(bb) 30 pages of spare HMI VDU mimic pages with details to be agreed between the Contractor and the Engineer.

Pop-up windows as mentioned in the prior sub-paragraphs shall be prepared for all SCADA controllable devices in the above HMI pages. All instruments with signals being acquired by the SCADA System shall be shown in the above HMI pages, with their real time measured parameters be displayed adjacent to their symbols in the process diagram. For level in a sump, dynamic display of water rising and falling corresponding to the real time measured level parameters shall be configured and shown at the HMI pages. The trend, historian, event log, alarm log, printing and hyperlink to other mimic pages shall be accessible at each of the HMI mimic pages. This requirement shall be achieved by configure a set of access buttons at the right hand side of each mimic page. When viewing at any one of the mimic pages, an operator shall be able to pull out the trend, historian, event log, alarm log and anyone of the other mimic pages by clicking the access buttons configured at the right hand side.

The status of the electrical distribution network (e.g. the close/open status of circuit breakers), the current, power factor, power and apparent loads taken at each incomer feed shall be shown in each of the electrical supply system HMI pages mentioned above.

B7.1.11 Geographical diagrams

HMI VDU mimic display pages shall be provided showing, on plans of the Works, the position and status of each Local Control Panel (LCP) and its associated UPS unit.

B7.1.12 Manual control

Each HMI keyboard shall have the facility to initiate the various operator commands relevant to their password assignment and the location of the HMI. Icons and pop-up windows shall also be configured and be able to be displayed at each VDU HMI displays, such that operator control commands, selection of displaying which HMI pages etc can be initiated by a trackball or keyboard.

Each section of the works shall be under the control of one keyboard or one trackball at any time as determined by the system supplied.

When a command is initiated such as starting/stopping a pump, opening/closing a valve or changing a set point, the event/alarm printer shall log full details of the action including the name of the operator responsible for that action.

Each item of plant shall be operable in manual mode, at the Motor Control Centre, at field, at the LCP and at HMI when selection is at SCADA Manual.

For devices with motor starter panels, an “Off/Hand/SCADA” selector shall be installed at the starter panel of that device. When the selection is “SCADA”, either “SCADA Manual” or “Local Automatic” (if automatic control is available for that device) will be available for control depending on the further selection at the relevant HMI pages. When selection is at “SCADA Manual”, the motor can be operated by the on/off graphic push buttons that will be configured at the HMI pages. When the selection is “HAND”, the motor can be started/stopped at the starter panel or a local pushbutton station beside the motor (if installed) depending on the further selection of a “Local/Remote” selector at the starter panel.

For devices without motor starter panel, each device shall have an “Off/Hand/SCADA” selector at the LCP. When the selection is “SCADA”, either “SCADA Manual” or “Local Automatic” (if automatic control is available for that device) will be available for control depending on the further selection at the relevant HMI pages. When selection is at “SCADA Manual”, the device can be operated by the on/off graphic push buttons at the HMI pages. When the selection is “HAND”, the device can be started/stopped at the pushbuttons on the LCP or at the devices, depending on the further selection of a “Local/Remote” selector at the device. For example, at an electrical actuated valve, the “Local/Remote” selector at the actuator shall determine where the actuator can be operated during “Hand” operation.

B7.1.13 Software control features and derived functions

The Contractor shall provide operational software to ensure the safe, efficient, economical and stable operation of the works.

The minimum requirements for the control features for the Works shall be in accordance with the Specification.

Controls shall operate valves or select pumpsets with a sufficient interval between successive adjustments for the plant to respond.

The software alarm derivation shall include but shall not be limited to:

- plant availability based on healthy status and whether having “SCADA” control selected;
- upper and lower limits for each real or derived analogue input;
- failed alarms for any item of plant failing to respond within a preset time to a command via the distributed control system.

The software shall accumulate the running times of all machines provided with "running" and "not running" status indications. Besides maintaining a total running time for each machine, the running time since the most recent servicing shall also be stored with alarms displayed when any machine exceeds the maximum interval between servicing. Facilities shall be provided to reset to zero the running time since the most recent servicing (not total running time) on each machine following its service.

B7.1.14 Interface with local plant

The distributed control system shall interface with local plant-mounted devices via local control panels (LCP) which shall contain redundant PLC's using direct communication procedures or distributed I/Os.

Additional details of the LCPs can be found in Clause B7.2.3.

The LCP shall perform the gathering, storage and local processing of data. The panel shall also perform the routing of control functions, software interlocking and provide safety assurance.

Each LCP shall include a signal marshalling section for hard wired plant signals that are essential for the safe monitoring of the Plant and for future use.

B7.1.15 Alarm system

The central operating system in the DCS shall provide a complete and comprehensive means of displaying, logging and storing every alarm and event arising from the Works and shall distinguish between critical and non-critical alarms.

Alarms will be designated as critical or non-critical during the Contractor's design phase. All the alarms as required in Clause B7.1.17 shall be included, and the following shall also typically be included:

- each chlorine gas leak alarm;
- each individual plant common failure alarm such as filter plant, lime and aluminium sulphate plant, chlorine plant, pumping stations, etc.;
- PLC healthy/failed, communications healthy/failed, UPS status;
- power failures.

The DCS alarm system shall be designed such that multiple and cascading alarms caused by events such as power failure and communication network failure are inhibited as appropriate to avoid unnecessary alarm acceptance and resetting by the operator.

B7.1.16 Uninterruptible power supplies

The Contractor shall provide uninterruptible power supplies (UPS) to backup the following:

- the Central Control Rooms essential equipment;
- each LCP, distributed I/O and other SCADA System equipment;
- chlorine gas leak detection, alarm and warning systems;
- instruments.

UPS units shall be adequately sized to provide the power for the data acquisition system, DCS/PLCs, interposing relays and signal isolators, and instruments as necessary for the safe operation of the works during mains power failure conditions for a period of at least three hours.

The UPS units shall provide a single-phase, 230 Vac, 50 Hz output with earthed neutral. The rating of each UPS shall exceed, by at least 33%, the total connected load under starting conditions. Each UPS shall be equipped with lead acid sealed type or other equivalent batteries that are maintenance free, which can provide backup to the connected load for, as a minimum, 3 hours.

Each UPS shall provide electrical surge protection for the associated load. Each UPS shall be provided with volt-free contacts for the following signals:

- Bypass active; UPS healthy;
- UPS battery discharging;
- UPS failed (includes rectifier failure).

Each of the signals listed above shall be connected to the associated LCP annunciator and connected to the common plant failure alarm as necessary.

B 7.1.17 Control Centre Telemetry Panels at CCR of Water Treatment Plant and CCR at Dharmapuri

The Contractor shall provide a Control Centre Telemetry Panel (CCTP) for the SCADA System in the Central Control Room (CCR) at the filter room of the Water Treatment Plant. Distributed Control System shall be installed in this panel. The CCTP shall be installed with, as a minimum, four pairs of hot standby distributed control processors and other communication interface modules with connections as that indicated in the Drawing. One pair of hot standby distributed control processors shall be dedicated for use to acquire and transmit signals from/to the outstation sites (plants not in the Water Treatment Plant) of this Contract, including the raw water pumping station, booster pumping station, Master Balancing Reservoir at MADAM. One pair of hot standby distributed control processors shall be dedicated for use to acquire and transmit signals from/to the Dharmapuri Control Centre Telemetry Panel at the Project Office of TWAD at Dharmapuri. One pair of hot standby distributed control processors shall be dedicated for use to acquire and transmit signals to/from all the relevant sites at Packages II to V where control and/or monitoring are required. One pair of hot standby distributed control processors shall be dedicated for use to acquire and transmit signals from/to the plants inside the Water Treatment Plant.

The Contractor shall provide a Dharmapuri Control Centre Telemetry Panel (DCCTP) for the SCADA System in the Project Office of TWAD at Dharmapuri. The DCCTP shall be installed with, as a minimum, one pairs of hot standby distributed control processors, all necessary communication modules with connections as that indicated in the Drawing.

Redundant communication links of different type of communication media shall be used for connecting the CCTP to each of the outstation sites of the Project and DCCTP. The communication links shall be leased landlines, wireless line (WLL-phone), GSM mobile lines, CDMA mobile lines, radio relay system, satellites or any other communication methods suitable for the Project. Unless that communication media cannot cover that outstation site, the Contractor has to use the combination of “leased landline or wireless line (WLL-phone)” and “GSM mobile line or CDMA mobile lines”, as the first choice of the redundant communication links. Should any one of the abovementioned first choice communication media be not available at any of the sites, the Contractor has to review the available options and proposes to the Engineer the communication solution between that site and the CCTP. All communication media shall be provided from one service provider, who should act as the specialist subcontractor of the Contract. This specialist subcontractor shall possess, as a minimum, ten years experience of operation and maintenance of all the communication media that he is to provide. The Contractor has to submit to the Engineer the qualification of this specialist subcontractor, which should include all evidences to show that the communication media they are providing can meet the abovementioned requirements and they do not need to subcontract any part of his work to others, in order to provide the necessary communication network of this Contract. The specialist subcontractor shall have his in-house team to conduct all installation, testing, commissioning, operation and maintenance of the communication network to be provided for this Contract. Sub-contracting any part of the abovementioned work to others by this specialist subcontractor will not be allowed.

All the necessary routers, hub switches and the necessary modems for the leased lines, broadband lines, GSM mobile lines, CDMA mobile lines, the antenna/the modulators/demodulators for radio links and satellite shall be installed at the CCTP and DCCTP under the Contract. Each router, hub switches and the like shall not be fully connected and, as a minimum, 30% spare connection ports shall be available at each of the abovementioned switches.

Should leased landlines, GSM mobile lines, CDMA mobile lines and wireless line connections (WLL-phone) be used, the Contractor shall make application on behalf of the Employer to that service provider. The Contractor shall provide the exact addresses of all the site locations to that service provider (including those sites at Packages II to V) and make all necessary coordination work with that service provider to enable them can satisfactorily carry out their work. The Contractor shall provide all the necessary cable ducts and draw pits that enables that service provider be possible to lay their cables to the LCPs, for those sites under the Contract. At sites of Packages II to V, these cable ducts and draw pits will be provided by the contractors of these Packages.

For signal transmission over leased landlines, the modem shall be connected to the line via an integral isolating transformer and surge suppression components. Lightning protection devices shall be incorporated in the system. As the effectiveness of the earthing cannot be guaranteed due to site constraint, the Contractor shall include any necessary preventive measures in their equipment to overcome earth potential problem.

Should radio relay stations be used, the Contractor shall conduct necessary survey which will identify the number, location and height of the radio masts. The Contractor has to make necessary application to the concerned authorities for allocation of VHF frequency channel.

The communication network among the CCTP and the LCPs within the Water Treatment Plant, including the Treated Water Pumping Station shall be formed by landlines using fibre optic transmission system, to be provided by the Contractor.

If single-mode fibres are used, the following requirements shall be satisfied:

(b) wavelength of transmission 1300 nm or 1500 nm;
(c) loss to be less than 0.5 dB per km with bandwidth > 1000 Mhzkm;
(d) optical loss budget > 9 dB.

If multi-mode fibres are used, the following requirements shall be satisfied:

(c) wavelength of transmission 1300 nm;
(d) loss to be less than 1.5 dB per km with bandwidth > 500 MHzkm;
(iii) optical loss budget > 17 dB.

The optical transmitter shall be semiconductor source which fall into one of the following categories:

(d) Light emitting diodes (LED);
(e) Injection laser diodes (ILD), and
(f) Super radiant diodes (SRD).

Low loss fusion splicing shall be used. The spliced fibre junctions shall be coated and protected in a sealed enclosure. The enclosure shall contain a splice organiser that holds and protects the spliced fibres and maintains the proper bend radius. Each of the cables shall be properly marked and labelled at both terminating ends. The Contractor shall provide samples of cables, cable joints, terminals and all equipments proposed for fibre optic signal transmission network along with samples for the approval of the Engineer.

The signals to be transmitted to the CCTP for use at the SCADA system shall be, as a minimum, including the following:

Water treatment:

DI

- Treated water pump available/running/stopped/failed (each pump);
- All alarm and tripping signals for each treated water pump and its associated motor;
- All alarms and tripping signals associated with other pumps and their associated motors;
- Mixer available/running/stopped/failed (each mixer);

- Scraper available/running/stopped/failed (each scraper, availability depending on the clarifier design)
- Filter washwater pump available/running/stopped/failed (each pump); Filter blower available/running/stopped/failed (each blower);
- All signals entered in Section 7.6;
- All valves and penstocks available/open/close/failed; Non-return valves open/close (all non-return valves);
- 33kV switchboard circuit breakers available/open/close/failed; 6.6kV switchboard circuit breakers available/open/close/failed; 400V switchboard circuit breakers available/open/close/failed;
- 33/6.6kV transformers winding over temperature, oil over temperature and other alarms available;
- 6.6kV/400V transformers winding over temperature, oil over temperature and other alarms available;
- UPS failure (all UPS);
- Battery chargers failure (all battery chargers); Mains power healthy (each supply);
- Chlorine leakage alarms high/high high (common) ; Fire alarm (common);

PI

- Total Energy consumption kWh; Inlet raw water quantity;
- Outlet treated water quantity;

AI (Should communication protocol using RS485 be used, some of these AI will not be required)

- Inlet raw water flow;
- Outlet treated water flow;
- Treated water outlet main pressure;
- Treated water reservoir level (each compartment);
- 33kV switchboard busbar 1 voltage;
- 33kV switchboard busbar 2 voltage;
- 33kV switchboard incomer 1 current;
- 33kV switchboard incomer 2 current;
- 33kV switchboard incomer 1 power factor;
- 33kV switchboard incomer 2 power factor;
- 33kV switchboard incomer 1 power, apparent power and kWh;
- 33kV switchboard incomer 2 power, apparent power and kWh;
- 6.6kV switchboard busbar 1 voltage;
- 6.6kV switchboard busbar 2 voltage;
- 6.6kV switchboard incomer 1 current;
- 6.6kV switchboard incomer 2 current;
- 6.6kV switchboard incomer 1 power factor;
- 6.6kV switchboard incomer 2 power factor;
- 6.6kV switchboard incomer 1 power, apparent power and kWh;
- 6.6kV switchboard incomer 2 power, apparent power and kWh;
- 400V switchboard busbar 1 voltage;
- 400V switchboard busbar 2 voltage;
- 400V switchboard incomer 1 current;
- 400V switchboard incomer 2 current;
- 400V switchboard incomer 1 power factor;
- 400V switchboard incomer 2 power factor;
- 400V switchboard incomer 1 power, apparent power and kWh;
- 400V switchboard incomer 2 power, apparent power and kWh;

- Treated water pumps current (all pumps);
- Outlet treated water quality detailed in Section 7.6 (all measurable parameters).

DO

- Treated water pump start/stop/emergency stop (each pump);
- Mixer start/stop/emergency stop (each mixer);
- Scraper start/stop/emergency stop (each scraper, availability depending on the clarifier design)
- Filter wash water pump start/stop/emergency stop (each pump);
- Filter blower start/stop/emergency stop (each blower);
- All valves and penstocks open/close
- All circuit breakers open/close.

AO

- All devices that required position proportional control and speed control.

Raw water pumping station

DI

- Mains power healthy (each supply);
- Raw water pump available/running/stopped/failed (each pump);
- All alarm and tripping signals for each raw water pump and its associated motor;
- Drainage pumps available/running/stopped/failed (each pump);
- All valves and penstocks available/open/close/failed;
- Non-return valves open/close (all non-return valves);
- 11kV switchboard circuit breakers available/open/close/failed;
- 3.3kV switchboard circuit breakers available/open/close/failed;
- 400V switchboard circuit breakers available/open/close/failed;
- 11/3.6kV transformers winding over temperature, oil over temperature and other alarms available;
- 3.3kV/400V transformers winding over temperature, oil over temperature and other alarms available;
- UPS failure (all UPS);
- Battery chargers failure (all battery chargers);

PI

- Total Energy consumption kWh;

AI (Should communication protocol using RS485 be used, some of these AI will not be required)

- Intake sump level (each sump);
- Outlet raw water flow;
- Raw water outlet main pressure;
- 11kV switchboard busbar 1 voltage;
- 11kV switchboard busbar 2 voltage;
- 11kV switchboard incomer 1 current;
- 11kV switchboard incomer 2 current;
- 11kV switchboard incomer 1 power factor;
- 11kV switchboard incomer 2 power factor;
- 11kV switchboard incomer 1 power, apparent power and kWh;
- 11kV switchboard incomer 2 power, apparent power and kWh;
- 3.3kV switchboard busbar 1 voltage;

- 3.3kV switchboard busbar 2 voltage;
- 3.3kV switchboard incomer 1 current;
- 3.3kV switchboard incomer 2 current;
- 3.3kV switchboard incomer 1 power factor;
- 3.3kV switchboard incomer 2 power factor;
- 3.3kV switchboard incomer 1 power, apparent power and kWh;
- 3.3kV switchboard incomer 2 power, apparent power and kWh;
- 400V switchboard busbar 1 voltage;
- 400V switchboard busbar 2 voltage;
- 400V switchboard incomer 1 current;
- 400V switchboard incomer 2 current;
- 400V switchboard incomer 1 power factor;
- 400V switchboard incomer 2 power factor;
- 400V switchboard incomer 1 power, apparent power and kWh;
- 400V switchboard incomer 2 power, apparent power and kWh;
- Raw water pumps current (all pumps).

DO

- Raw water pump start/stop/emergency stop (each pump);
- Drainage pump start/stop/emergency stop (each pump);
- All valves and penstocks open/close;
- All circuit breakers open/close.

AO

- All devices that required position proportional control and speed control.

Booster water pumping station

DI

- Mains power healthy (each supply);
- Booster pump available/running/stopped/failed (each pump);
- All alarm and tripping signals for each booster pump and its associated motor;
- Drainage pumps available/running/stopped/failed (each pump);
- All valves and penstocks available/open/close/failed;
- Non-return valves open/close (all non-return valves);
- 33kV switchboard circuit breakers available/open/close/failed;
- 3.3kV switchboard circuit breakers available/open/close/failed;
- 400V switchboard circuit breakers available/open/close/failed;
- 33/3.6kV transformers winding over temperature, oil over temperature;
- 3.3kV/400V transformers winding over temperature, oil over temperature;
- UPS failure (all UPS);
- Battery chargers failure (all battery chargers);

PI

- Total Energy consumption kWh;

AI (Should communication protocol using RS485 be used, some of these AI will not be required)

- Booster pumping station outlet main pressure;

- 33kV switchboard busbar 1 voltage;
- 33kV switchboard busbar 2 voltage;
- 33kV switchboard incomer 1 current;
- 33kV switchboard incomer 2 current;
- 33kV switchboard incomer 1 power factor;
- 33kV switchboard incomer 2 power factor;
- 33kV switchboard incomer 1 power, apparent power and kWh;
- 33kV switchboard incomer 2 power, apparent power and kWh;
- 3.3kV switchboard busbar 1 voltage;
- 3.3kV switchboard busbar 2 voltage;
- 3.3kV switchboard incomer 1 current;
- 3.3kV switchboard incomer 2 current;
- 3.3kV switchboard incomer 1 power factor;
- 3.3kV switchboard incomer 2 power factor;
- 3.3kV switchboard incomer 1 power, apparent power and kWh;
- 3.3kV switchboard incomer 2 power, apparent power and kWh;
- 400V switchboard busbar 1 voltage;
- 400V switchboard busbar 2 voltage;
- 400V switchboard incomer 1 current;
- 400V switchboard incomer 2 current;
- 400V switchboard incomer 1 power factor;
- 400V switchboard incomer 2 power factor;
- 400V switchboard incomer 1 power, apparent power and kWh;
- 400V switchboard incomer 2 power, apparent power and kWh;
- Booster pumps current (all pumps).

DO

- Booster pump start/stop/emergency stop (each pump);
- Drainage pump start/stop/emergency stop (each pump);
- All valves and penstocks open/close;
- All circuit breakers open/close.

AO

- All devices that required position proportional control and speed control.

Master Balancing Reservoir at MADAM

DI

- All valves at Master Balancing Reservoir available/open/close/failed;
- UPS failure (all UPS);
- Power supply healthy (power supply to be provided from the switchboard at Panagaram Union booster pumping station);
- Booster pump in Pennagaram Union booster pumping station (PUPS) available/running/stopped/failed (each pump);
- All alarm and tripping signals for each booster pump and its associated motor in PUPS;
- 400V switchboard circuit breakers available/open/close/failed (incomers and bussection ACB/MCCB at PUPS);
- Battery chargers failure (all battery chargers at PUPS).

PI

- Outlet treated water quantity at Master Balancing Reservoir;

AI (Should communication protocol using RS485 be used, some of these AI will not be required)

- Master balancing reservoir level (both compartment);
- Outlet treated water flow at Master Balancing Reservoir;
- Pennagaram Union booster pumping station outlet main pressure and flow;
- PUPS 400V switchboard busbar 1 voltage;
- PUPS 400V switchboard busbar 2 voltage;
- PUPS 400V switchboard incomer 1 power factor;
- PUPS 400V switchboard incomer 2 power factor;
- PUPS 400V switchboard incomer 1 power, apparent power and kWh;
- PUPS 400V switchboard incomer 2 power, apparent power and kWh

DO

- All valves open/close at Master Balancing Reservoir;

AO

- All valves that required position proportional control.

Works at Package II to V – union reservoirs (Table 1-1, Table 1-2, Table 1-3 and Table 1-4)

DI

- Mains power healthy at LCP rooms (signals to be provided under the Contract);
- Inlet and outlet isolation valves available/fully open/fully close/failed (signals to
- be provided by contractors of Packages II to V);
- UPS failure (signals to be provided under the Contract); LCP failure (signals to be provided under the Contract);
- Reservoir low level (signals to be provided under the Contract);
- Reservoir high level (signals to be provided under the Contract);
- Power supply healthy (power supply to be provided from the switchboard at Re-Chlorination Station House (CSH)) (signals to be provided by contractors of Packages II to V);
- Chlorinators available/running/stopped/failed at CSH (signals to be provided by contractors of Packages II to V);
- Motive water pumps available/running/stopped/failed at CSH (signals to be provided by contractors of Packages II to V);
- All alarm and tripping signals for each chlorinators, motive water pumps and their associated motor in CSH (signals to be provided by contractors of Packages II to V);
- 400V switchboard circuit breakers available/open/close/failed (incomers and bussection ACB/MCCB at CSH) (signals to be provided by contractors of Packages II to V);
- Battery chargers failure (all battery chargers at CSH) (signals to be provided by contractors of Packages II to V);
- Chlorine gas leakage detected at cylinder room (signals to be provided by contractors of Packages II to V);
- Chlorine gas leakage detected at chlorinator room (signals to be provided by contractors of Packages II to V).

AI (Should communication protocol using RS485 be used, some of these AI will not be required)

- The sump level of each reservoir (duty/standby level sensors/transmitters at each reservoir) (signals to be provided under the Contract);

- CSH 400V switchboard busbar 1 voltage;
- CSH 400V switchboard busbar 2 voltage;
- CSH 400V switchboard incomer 1 power factor;
- CSH 400V switchboard incomer 2 power factor;
- CSH 400V switchboard incomer 1 power, apparent power and kWh;
- CSH 400V switchboard incomer 2 power, apparent power and kWh.

DO
- Open/close of the electrically actuated inlet and outlet valves to each reservoir.

Works at Packages II to V – tapping point branches to the trunk main treated water pipeline (Table 2-1, Table 2-2, Table 2-3.1, Table 2-3.2, Table 2-3.3, Table 2-3.4, Table 2-3.5 and Table 2-4)

DI
- Mains power healthy at LCP housing (signals to be provided under the Contract);
- All flow control valves available/fully open/fully close/failed (signals to be provided by contractors of Packages II to V);
- UPS failure (signals to be provided under the Contract);
- LCP failure (signals to be provided under the Contract).

PI
- Tapping point branch treated water flow quantity (signals to be provided under the Contract);

AI (Should communication protocol using RS485 be used, some of these AI will not be required)
- Tapping point branch treated water flow rate (signals to be provided under the Contract);
- Tapping point branch pressure (signals to be provided under the Contract);
- Position of the flow control valves (signals to be provided by contractors of Packages II to V)

AO or DO
- Position control of the flow control valves;
- "Open" and "close" control of the outlet isolating valve (discharge side of the flowmeter)

Works at Package II to V – booster pumping stations (Large booster pumping stations listed in Table 3-1, 3-2, 3-3.1, 3-3.2, 3-3.3, 3-3.4 and 3-4)

DI
- Mains power healthy of each incoming power supply (signals to be provided by contractors of Packages II to V);
- Booster pump available/running/stopped/failed (each pump) (signals to be provided by contractors of Packages II to V);
- All alarms and tripping signals for each booster pump and its associated motors (signals to be provided by contractors of Packages II to V);
- All valves available/fully open/fully close/failed (signals to be provided by contractors of Packages II to V)
- UPS failure (signals to be provided under the Contract);
- LCP failure (signals to be provided under the Contract).

PI
- Inlet treated water flow quantity and overall discharge treated water flow quantity;

AI (Should communication protocol using RS485 be used, some of these AI will not be required)

- The level of suction sump;
- Discharge treated water pressure and flow rate;
- CSH 400V switchboard busbar 1 voltage;
- CSH 400V switchboard busbar 2 voltage;
- CSH 400V switchboard incomer 1 power factor;
- CSH 400V switchboard incomer 2 power factor;
- CSH 400V switchboard incomer 1 power, apparent power and kWh;
- CSH 400V switchboard incomer 2 power, apparent power and kWh;
- Incoming flow to the booster pumping station;
- Overall discharge flow from the booster pumping station;
- Inlet pressure of the booster pumping station;
- Discharge pressure from the booster pumping station

DO

- Start/stop/emergency stop of each booster pump.

The union reservoirs where ultrasonic level sensors/transmitters are to be supplied and installed by the Contractor to Packages II to V are entered in Table 1-1 to Table 1-4 as follows:

Table 1-1 Package II (UR – Union Reservoir)
(PR – Panchayat Reservoir)

Union	Quantity of reservoirs	Union reservoir(s) or panchayat reservoir(s)	Depth of the union reservoir (m)
Pennagaram	2	At Madam - Pennagaram UR (one-to-one) Billiyanur UR (one-to-one)	3
Mathur	2	Olaipatti UR (one-to-one) NagamPatti UR (one-to-one)	3 3
Dharmapuri	4	Athagapaddi UR (one-to-one) Mukkalanayakkanpatti UR (one-to-one) Lakkiampatti PR (one-to-one) Kupper UR	3 3 3 3
Dharmapuri Municipality	1	Dharmapuri Municipality (one-to-one)	3
Nallampalli	8	Konanga halli UR (one-to-one) Thadangam PR Nallampalli 1UR Nallampalli 2 UR Indur PR Palavadi PR Bommasamudiram PR Bedera Halli PR	3 3 3 3 3 3 3 3
Uthangarai	1	Uthangarai UR	3

Table 1-2 Package III

Location	Quantity of union reservoirs	Union reservoir(s) or panchayat reservoir(s)	Depth of the union reservoir (m)
Harur	2	Vettrapatti UR Settrapatti UR	3 3
Pappireddipatti	2	Moobur Metu Kottai UR	3
Dharmapuri	3	(Erikarai Near Ladies Hostel B Mallapuram) ChettiKarai UR Vellolai UR	3 3 3
Morrappur	1	Morrappur UR (Located at Dharmapuri Union)	3

Table 1-3Package IV

Location	Quantity of union reservoirs	Union reservoir(s) or panchayat reservoir(s)	Depth of the union reservoir (m)
Royakottai	4	Kelamangalam - I UR Kelamangalam – II UR Veppanapalli UR Sulagiri - I UR	3 3 3 3
Jakkeri	2	Kelamangalam - III UR Thalli UR	3 3
Thinner	1	Sulagiri – II UR	3
Hosur Municipality	1	Hosur Municipality UR	3

Table 1-4 Package V

Location	Quantity of reservoirs / Sumps	Union reservoir(s) or panchayat reservoir(s)	Depth of the Union reservoir (m)
Bargur	2	KandhiKuppam UR I KaraKuppam Sump and Salinayanapalli URII	3 3
Krishnagiri	2	Sump at Park and UR Periyamathur PR	3 3
Karimangalam	2	Thandukaranahalli UR I Thandukaranahalli UR II	3 3
Palacode	3	Jagathalam (at Valai thoppu) UR I P.ChettiHalli UR II Modugala halli PR (at Thomalla Halli)	3 3 3
Pennagaram	2	Pikkili sump O.G.Halli sump	3 3

The approximate locations of the tapping point branches to the trunk main treated water pipelines, where the Contractor has to install electromagnetic flowmeter and pressure transmitters, are entered in Table 2-1 (Package II), Table 2-2 (Package III), Table 2-3.1, Table 2.3.2, Table 2.3.3, Table 2.3.4, Table 2.3.5 (Package IV) and Table 2.4 (Package V) as follows:

Table 2-1 (UR – Union Reservoir, lpm – litre per minute, MS – Mild Steel, DI – Ductile Iron, HDPE – High Density Polyethylene)

Tapping point branch locations for sites under Package II (reference to MADAM – LS0m)	Feeding to	Name of Union	Type and size of branch pipeline (mm)	Upstream head (m)	Design Discharge (lpm)	Size of flow control valve (mm)
LS0m at MADAM	Pennagaram (gravity feed)	Pennagaram	400 DI	7.00	4257	300
LS12780m	Konanganahalli	Nallampalli	200 HDPE	46.30	877	100
LS14471m	Billiyanur	Pennagaram	75 HDPE	52.80	211	65
LS20925m	Indur, Palavadi, Dalavahalli, Bedrahalli & Bommasamudram	Nallampalli	250 HDPE	57.42	761	100
LS25910m	Athagapaddi	Dharmapuri	160 HDPE	46.72	1180	100
LS29640m	Nallampalli	Nallampalli	500 DI	56.73	4114	300
LS32499m	Lakkiampatti II	Dharmapuri	75 HDPE	63.00	156	65
LS33000m	Dharmapuri Municipality	Dharmapuri Municipality	400 DI	60.49	7404	300
LS33000m	Mukkalanaya-kkanpatti	Dharmapuri	315 HDPE	60.49	1078	200
LS34440m	after take-off of Package III		600 MS	61.37	864.5	400
LS38015m	Kuppur & 5 other panchayats	Dharmapuri	150 DI	59.77	764	100
LS65850m	Olaipatti	Mathur	150 DI	42.00	694	100
LS73508m	Nagampatti	Mathur	200 DI	53.00	2381	150
LS83460m	Uthangarai	Uthangarai	300 DI	18.97	4786	200

Table 2-2 (UR – Union Reservoir, lpm – litre per minute, MS – Mild Steel, DI – Ductile Iron, HDPE – High Density Polyethylene)

Tapping pbint branch locations for sites under Package III (reference to Mathukonapalayam – LS34440m from MADAM)	Feeding to	Name of Union	Type and size of branch pipeline (mm)	Upstream head (m)	Design Discharge (lpm)	Size of flow control valve (mm)
LS2130m	Chettikarai	Dharmapuri	90 HDPE	60.73	218	80
LS4444m	Vellolai	Dharmapuri	180 HDPE	45.72	465	100
LS12570m	Morappur	Morappur	400 DI	21.20	5646	300
LS12570m	Feeder main to B.Mallapuram	(Town Panchayat)	160 HDPE	21.20	352	100
LS37800m	Pappireddypatti	Pappire-ddy patti union	315 HDPE	5.88	2696	200
LS14940m of feeder main	Settrapatti	Harur	110 HDPE	40.92	115	80
LS16945m of feeder main	Harur	Harur	300 DI	28.68	5780	200

Table 2-3.1 (UR – Union Reservoir, lpm – litre per minute, MS – Mild Steel, DI – Ductile Iron, HDPE – High Density Polyethylene)

Tapping point branch locations for sites under Package IV (reference to common pumping station for Package IV and V at Palacode)	Feeding to	Name of Union	Type and size of branch pipeline (mm)	Upstream head (m)	Design Discharge (lpm)	Size of flow control valve (mm)
LS23070m	Mahendra-mangalam, Jittendahalli	Karimangalam	200 DI	20	942	150
LS23070m	Royakottai	Kelamangalam Sulagiri Veppanapalli	300DI / K9	106	4946	200
LS50250m	Jakkeri	Kelamangalam Thalli	400 DI	51	7158	300
LS64790m	Mathagiri	Hosur Thalli	300DI	50	3973	200
LS67075m	Thinner	Hosur Sulagiri	400DI	30	7206	300
LS67075m	Hosur Municipality	Hosur Municipality	400DI	30	8723	300

Table 2-3.2 (UR – Union Reservoir, lpm – litre per minute, MS – Mild Steel, DI – Ductile Iron, HDPE – High Density Polyethylene)

Tapping point branch locations for sites under Package IV Tapping point from FM1 from Royakottai sump to Veppanapalli	Feeding to	Name of Union	Type and size of branch pipeline (mm)	Upstream head (m)	Design Discharge (lpm)	Size of flow control valve (mm)
LS0	Royakottai	Kelamangalam	150DI	25	387	100
LS30	Royakottai Mandi	Kelamangalam	150DI	25	347	100
LS20320	Veppanapalli	Veppanapalli	350DI	40	2997	300
LS20320	Sulagiri	Sulagiri	150DI	40	582	100

Table 2-3.3 (UR – Union Reservoir, lpm – litre per minute, MS – Mild Steel, DI – Ductile Iron, HDPE – High Density Polyethylene)

Tapping point branch locations for sites under Package IV Tapping point from FM2 from Jakkeri MSR to Denkanikotai	Feeding to	Name of Union	Type and size of branch pipeline (mm)	Upstream head (m)	Design Discharge (lpm)	Size of flow control valve (mm)
LS0	Doddathimanapalli	Kelamangalam	200DI	20	612	150
LS10695	Arasakuppam BPS	Thalli	450DI	19	4436	300

Table 2-3.4 (UR – Union Reservoir, lpm – litre per minute, MS – Mild Steel, DI – Ductile Iron, HDPE – High Density Polyethylene)

Tapping point branch locations for sites under Package IV Tapping point from Feeder Pumping Main from Mathagiri BPS	Feeding to	Name of Union	Type and size of branch pipeline (mm)	Upstream head (m)	Design Discharge (lpm)	Size of flow control valve (mm)
LS0	Muduganapalli	Hosur	200DI	60	577	150
LS0	Binnamagalam	Thali	400DI	100	3751	300
LS0	Mathagiri TP	Mathagiri TP	100DI	30	766	80

Table 2-3.5 (UR – Union Reservoir, lpm – litre per minute, MS – Mild Steel, DI – Ductile Iron, HDPE – High Density Polyethylene)

Tapping point branch locations for sites under Package IV Tapping point from from FM2 from Thinnur UR	Feeding to	Name of Union	Type and size of branch pipeline (mm)	Upstream head (m)	Design Discharge (lpm)	Size of flow control valve (mm)
LS16620	Kanagondapalli	Sulagiri U	300DI	30	3417	2000

Table 2-4 (UR – Union Reservoir, lpm – litre per minute, MS – Mild Steel, DI – Ductile Iron, HDPE – High Density Polyethylene)

Tapping point branch locations for sites under Package V (reference to LS0m from MADAM)	Feeding to	Name of Union	Type and size of branch pipeline (mm)	Upstream head (m)	Design Discharge (lpm)	Size of flow control valve (mm)
LS0m at MADAM	Pennagaram	Pennagaram	200 HDPE	21.32	1060	100
LS28170m	Pikkili	Pennagaram	140 HDPE	16.68	520	80
LS1060m	Pumping Main from Booster	Palacode UR	500 DI	66.71	5687	300
LS8770m	Kanimangalam	Kanimangalam UR	315 DI	49.77	3916	200
LS15945m	Kaverpatiuam		355 HDPE	30.39	5825	200
LS29295m	Periamuthar	Krishnagiri	90 HDPE	66.59	184	80
LS32445m	Krishnagiri	Krishnagiri	300 DI	53.46	3436	200
LS35040m	Krishnagiri Municipality	Krishnagiri Municipality	500 DI	44.72	5246	350
LS48095	Kandhikuppam	Bargur	160 HDPE	29.26	646	100
LS50970	Bargur	Bargur	180 HDPE	27.29	582	100
LS52845	Karakuppam Sump	Bargur	400 HDPE	12.32	4788	200

The approximate locations of the booster pumping stations, where the Contractor has to install inlet electromagnetic flowmeters, inlet pressure transducers, overall discharge electromagnetic flowmeters and outlet pressure transducers, are entered in Table 3-1, Table 3-2, Table 3-3.1, Table 3-3.2, Table 3-3.3, Table 3-3.4 and Table 3-4 as follows:

Table 3-1

Name of Pumping Station / Number of pumps (duty/standby)	Name of Union	Type and size of inlet pipeline (mm)	Size of inlet flowmeter (mm)	Type and size of discharge pipeline (mm)	Size of discharge flowmeter (mm)	Upstream head (m)	Discharge head (m)	Design Discharge (lpm)	Sump depth (m)
Mukkalnaickenpatty (1 + 1)	Dharmapuri	110 HDPE	100	140 HDPE	100	7.0	60	712	3.0
MADAM (1 + 1)	Pennagaram	From sump	-	140 HDPE	100	3.0	38	568	3.0
Nallampalli (3 + 3)	Nallampalli	450 HDPE	450	400 DI 315 HDPE 315 HDPE	300 200 200	3.0 3.0 3.0	72 30 57	2589 1086 1537	3.0 3.0 3.0
Anjehalli (1 + 1)	Pennagaram	160 HDPE	150	140 HDPE	100	3.0			3.0
Echanahalli (1 + 1)	Nallampalli	450 HDPE	300	110 HDPE	100	3.0	50	604	3.0
Konangihalli (1 + 1)	Nallampalli	450 HDPE	300	225 HDPE	250	3.0	39	372	3.0
Thoppur (3 + 3)	Nallampalli	450 HDPE	300	300 DI	300	3.0	72	2589	3.0
Athiyamankottai (1 + 1)	Nallampalli	450 HDPE	300	200 HDPE	200	3.0	30	1086	3.0
Mittareddihalli (1 + 1)	Nallampalli	450 HDPE	300	250 HDPE	250	3.0	57	1537	3.0
Nagampatty ITM (1 + 1)	Muthur	90 HDPE	80	280 HDPE	250	3.0			3.0
Nochipatty ITM (1 + 1)	Uthangarai	110 HDPE	100	90 HDPE	80	3.0		802	3.0

Table 3-2

Name of Pumping Station / Number of pumps (duty/standby)	Name of Union	Type and size of inlet pipeline (mm)	Size of inlet flowmeter (mm)	Type and size of discharge pipeline (mm)	Size of discharge flowmeter (mm)	Upstream head (m)	Discharge head (m)	Design Discharge (lpm)	Sump depth (m)
Pappireddipati	Pappireddi-pati	315 HDPE	200	355 HDPE	200	6.0	100	5915	3.0

Table 3-3.1

Name of Pumping Station / Number of pumps (duty/standby)	Name of Union	Type and size of inlet pipeline (mm)	Size of inlet flowmeter (mm)	Type and size of discharge pipeline (mm)	Size of discharge flowmeter (mm)	Upstream head (m)	Discharge head (m)	Design Discharge (lpm)	Sump depth (m)
Common Booster Pumping Station near Palacode (1 + 1)	Package IV trunk main	-	-	800MS	600	4.0	210	33086	4.0
Kaduchettypatti	-	800MS	600	800MS	600	4.0	200		4.0
Kundumaranapalli	-	700MS	500	700MS	500	4.0	100		4.0
Royakkottai Thakkali Mardi	Kelaman-galam	From sump	-	140 HDPE	100	3.0	23	694	3.0
Sulagini	Sulagini	From sump	-	250 DI	200	3.0	65	1164	3.0
Kuriyanapatti						3.0	36	124	3.0
Pathimadugui						3.0	90	492	3.0

Table 3-3.2

Name of Pumping Station / Number of pumps (duty/standby)	Name of Union	Type and size of inlet pipeline (mm)	Size of inlet flowmeter (mm)	Type and size of discharge pipeline (mm)	Size of discharge flowmeter (mm)	Upstream head (m)	Discharge head (m)	Design Discharge (lpm)	Sump depth (m)
Arasakappam	Thali	From sump	-	400 DI	300	3.0	100	5915	3.0
Denkanikotta - I	Thali	From sump	-	200 DI	200	3.0	60	1019	3.0
Denkanikotta - II	Thali	From sump	-	300 DI	200	3.0	90	3634	3.0
Denkanikotta - III	Thali	From sump	-	100 DI	100	3.0	99	227	3.0
Denkanikotta – IV	Thali	From sump	-	150 DI	150	3.0	83	655	3.0
Denkanikotta – V	Thali	From sump	-	100 DI	100	3.0	30	192	3.0
Doddamanchi	Thali	From sump	-	150 DI	150	3.0	22	784	3.0
Jakkeri	Thali	From sump	-	150 DI	150	3.0	53	538	3.0
Kundu maranapalli	Thali	From sump	-	150 DI	150	3.0	69	498	3.0
Jagir Karuppali	Thali	From sump	-	100 DI	100	3.0	56	290	3.0
Bommathathanur	Thali	From sump	-	110 HDPE	100	3.0	55	64	3.0
Beganatherm	Thali	From sump	-	110 HDPE	100	3.0	46	198	3.0

Name of Pumping Station / Number of pumps (duty/standby)	Name of Union	Type and size of inlet pipeline (mm)	Size of inlet flowmeter (mm)	Type and size of discharge pipeline (mm)	Size of discharge flowmeter (mm)	Upstream head (m)	Discharge head (m)	Design Discharge (lpm)	Sump depth (m)
Mallasandirar	Thali	From sump	-	110 HDPE	100	3.0	36	78	3.0
Karandapalli	Thali	From sump	-	100 DI	100	3.0	62	122	3.0

Table 3-3.3

Name of Pumping Station / Number of pumps (duty/standby)	Name of Union	Type and size of inlet pipeline (mm)	Size of inlet flowmeter (mm)	Type and size of discharge pipeline (mm)	Size of discharge flowmeter (mm)	Upstream head (m)	Discharge head (m)	Design Discharge (lpm)	Sump depth (m)
Mathagiri	Hosur	From sump	-	400 DI	300	3.0	92	4565	3.0
	Thali	From sump	-	150 DI	150	3.0	115	766	3.0
Binnamangalam	Thali	From sump	-	300 DI	200	3.0	115	2490	3.0
Agalakotta	Thali	From sump	-	100 DI	100	3.0	100	150	3.0

Table 3-3.4

Name of Pumping Station / Number of pumps (duty/standby)	Name of Union	Type and size of inlet pipeline (mm)	Size of inlet flowmeter (mm)	Type and size of discharge pipeline (mm)	Size of discharge flowmeter (mm)	Upstream head (m)	Discharge head (m)	Design Discharge (lpm)	Sump depth (m)
Thumanapalli	Sulagini	From sump	-	400 DI	300	3.0	62	4553	3.0

Table 3-4

Name of Pumping Station / Number of pumps (duty/standby)	Name of Union	Type and size of inlet pipeline (mm)	Size of inlet flowmeter (mm)	Type and size of discharge pipeline (mm)	Size of discharge flowmeter (mm)	Upstream head (m)	Discharge head (m)	Design Discharge (lpm)	Sump depth (m)
Common Booster Pumping Station near Palacode (1 + 1)	Package V trunk main	900MS at trunk main	600	700MS	500	4.0	75	25523	4.0
Common Booster Pumping Station near Palacode (1 + 1)	Palacode	-	-	500HDPE	400	4.0	70	5687	4.0

Name of Pumping Station / Number of pumps (duty/standby)	Name of Union	Type and size of inlet pipeline (mm)	Size of inlet flowmeter (mm)	Type and size of discharge pipeline (mm)	Size of discharge flowmeter (mm)	Upstream head (m)	Discharge head (m)	Design Discharge (lpm)	Sump depth (m)
Krishnagiri (1 + 1)	Krishna-giri	300 DI	300	350 DI	250	3.0	155	4581	3.0
Kandikuppam (1 + 1)	Bargur	160 HDPE	160	250 DI	200	3.0	60	861	3.0
Karakuppam (1 + 1)	Bargur	180 HDPE	180	400 DI	300	3.0	43	9576	3.0

All the above signals that are alarm signals shall initiate a local alarm at the LCPs and a corresponding alarm at the CCR, with appropriate pop-ups giving recommended actions for the operator and service technician.

The above list entered the minimum required signals to be acquired from the field devices and stated the minimum requirements for the field devices to control. The Contractor shall, based on their final design, append additional signals that would be required for the satisfactory operation of the Works. The necessary input/output modules that are required accordingly shall be provided by the Contractor at no additional cost.

The Contractor has to provide 20% input/output modules additional to the scope of supply as described above, for use as contingency in the Contract. After the Contractor has satisfactorily passed the 'Test to verify Installation Completion', the Contractor and the Engineer shall examine the quantity of unused input/output modules out of this additional 20% that the Contractor has installed in the Contract. The unused input/output modules shall be handover by the Contractor to the Employer as spares.

The Contractor has to install outstation LCPs with telemetry/communication functionality, as detailed in elsewhere in this Section. For Packages II to V of the Project, the locations to install the LCPs are entered in Tables 1-1 to 1-4, Tables 2-1 to 2-4 and Tables 3-1 to 3-4 above.

In each of these LCPs panels, the Contractor shall install the necessary devices, including redundant DCS/PLCs, digital/analogue I/O modules, communication transmitter/receiver modules, leased landline modems, wireless in local loop (WLL) mobile telephone connection transmitter/receivers, GSM mobile lines modems, radio signals modulator/demodulator, satellite signal transmitters/receivers/modulator/demodulator and all the necessary communication software to enable all the signals can be acquired at the local sites and transmitted back to the CCR at the filter building for display at the HMI pages of the SCADA System. Also, all the control commands being issued from the SCADA System at both the CCRs at Water Treatment Plant and Dharmapuri can reach the LCPs, and then subsequently be used to control the end devices.

The Engineer will arrange meetings among himself, the Contractor and the contractors of Packages II, III, IV and V to agree a supply, installation, testing and commissioning program for the instrumentation, SCADA system, and telemetry network, under the scope of supply of Package I, for use at the sites of Packages II to V.

The Contractor shall liaise with the contractors of Packages II to V to furnish the programs to install the instruments to provide under this Contract, as detailed in Clause B7.1.3.

The contractors of Packages II to V shall advise the Contractor of their construction program of their works and shall allow the Contractor to access their sites to install the instruments as detailed in Clause B7.1.3 and the Local Control Panels (LCPs) for the SCADA System.

The Contractor shall arrange meetings with leased landlines, wireless lines and GSM mobile lines service provider regularly to discuss with him of his requirements at each site of the whole Project to enable the cable laying work of the leased landlines can be carried out. The Contractor has to invite the contractors of Packages II to V to attend such meetings so that they are aware of the requirements of the leased landlines service provider and will act accordingly.

Whenever that part of SCADA System at any site of any Package is ready for testing, after the redundant communication media are successfully installed to connect that site and the CCR at the Water Treatment Plant, the Contractor has to act in conjunction with the contractors of Packages II to V to:

(a) test for verification that all the signals from the primary devices (the Contractor to be responsible for the instruments provided by them at the sites of Packages II to V) shall be able to be transmitted to the SCADA system and be able to be displayed at the Human Machine Interface (HMI) display pages at the LCPs, the Central Control Room (CCR) at the Water Treatment Plant and the CCR at the Project Office of Tamil Nadu Water Supply and Drainage Board at Dharmapuri;

(b) test for verification that control command from the SCADA system being initiated at the HMI display pages at any of the two CCRs or at the LCPs can control the relevant devices at each site of Packages II to V.

The abovementioned tests shall be done in a progressive manner, at an agreed schedule among the Engineer, the Contractor and the contractors of Package II to V. The tests mentioned shall be done as soon as any part of that SCADA System is ready, instead of deferring to a late stage, to prevent the Contractor be running short of time to correct any deficiency that is discovered accordingly.

The contractors of Packages II to V will provide all the cable ducts, draw pits for the laying of cables from each of the devices, including instruments, electrical and mechanical equipment, to the LCPs at each site of these Packages.

For those instruments that are provided by the Contractor, he shall be responsible to provide and install the cables to the LCPs and make all necessary cable terminations, using the cable ducts, draw pits and the like that will be provided by the contractors of Packages II to V. For other devices that will be provided by the contractors of Packages II to V, these contractors shall be responsible to provide, lay the cables and make all necessary cable terminations. The Contractor shall provide the termination details to these contractors, at their LCPs terminal ends, so that these contractors will be able to connect their cables to the correct terminals at the LCPs.

All the equipment being installed in the CCTP, DCCTP and all the outstation LCPs shall be fully back-up supplied by uninterrupted power supplies for, as a minimum, three hours. The uninterrupted power supply system shall, in general, comply with the requirements entered in Clause B7.1.16.

The transmission speed of telemetric data shall be high enough, such that for any analogue or digital signals, the time from its occurrence or status change in the primary devices in field to such change is displayed at the HMI VDU display at the CCRs, shall be not more than 3 seconds. Also, the time from any command being issued at the HMI VDU display for initiating a control function to the end device commences to act, shall also be not more than 3 seconds. The test to verify the speed of data transmission shall be carried out at the stage when all the signals required for the whole Project are connected to the SCADA System under full operation condition. This criterion shall be the generic measure to examine whether the means of data transmission method being adopted; the operating speed of the hardware and software of the SCADA System, can attain an overall acceptable speed of operation. Should the system be unable to achieve such performance requirement, the Contractor shall review the reason constituting such deficiency and provide the appropriate solution for rectification. All cost that is to incur to make rectification to the SCADA System, including the communication system to attain the acceptance criteria shall be borne by the Contractor.

During the test of the transmission speed, the Contractor has to show to the Engineer the speed of transmission of the signal loop, at these two parts: (a) from the primary devices via the data transmission media to reach the DCS application program and (b) from the DCS application program to the HMI application program.

B 7.2 Local instrumentation and control - General

B 7.2.1 Scope

This section covers the general requirements for instrumentation and control equipment. This local instrumentation shall operate in conjunction with the equipment specified in Clause B7.1 to form a comprehensive distributed control and monitoring system.

B 7.2.2 General requirements

The local control systems shall be designed for the safe efficient and economical operation of the whole Works and, in the absence of any or all of the centralised equipment or of its partial or total failure, shall continue to ensure the continued safe and efficient operation of their own areas of the Works.

The Contractor shall base the system design on standard relay technology with distributed I/O to transfer the data to the CCRs for LCP's with minimal control requirements and microprocessor-based PLC system for more complicated control requirements subject to the approval of the Engineer. Compact type PLCs shall not be used, PLCs shall be fully expandable.

Each local system shall be fully integrated into the overall system so that data may be transferred quickly and efficiently between the LCPs and CCRs. The system shall permit the coordination and efficient implementation of optimisation and overriding commands from the CCRs. On failure of the CCRs or due to a communication failure, the control system shall, in no way, compromise the continuation of safe and efficient operation. Analogue and sequence controllers shall be locally based and shall be capable of normal operation without the central equipment. Where PLC based systems are provided, remote set-point adjustment facilities shall be provided. All local manual controls (under "Hand" selection operation mode) shall be operable under failure conditions of the PLC or intelligent outstation.

Each measuring instrument shall have an integral indicator, and shall be mounted as near to the tapping or measurement point as possible subject to the overriding considerations of environmental compatibility and maintenance/servicing considerations.

Paint colour of all panels, cubicles etc shall be agreed with the Engineer.

The entire system shall be designed so that failures of components or power supplies initiate alarms or protective action and do not lead to any potentially hazardous condition or mask any actual alarm or unhealthy state.

All items of Plant with an automatic control functions shall be started automatically under controlled parameters.

Alarms initiated by the failure to fulfil a command shall incorporate a delay appropriate to the implementation time of the equipment concerned.

When a particular measurement is required in two or more other areas, the required number of isolated outputs shall be provided from the local control panel in the area in which the measurement takes place. The primary loop from each analogue instrument shall be used as the PLC/outstation input for use within the DCS. Secondary (isolated) loops shall be used for transmission to other locations as described above.

B 7.2.3 Local Control Panels (LCP)

Each LCP shall contain control relays and dedicated I/Os and redundant DCSs/PLCs supplied under the Contract for that area and shall also act as marshalling cubicle for connections with the monitoring and distributed control system.

For the LCPs at sites of Package I, including the raw water pumping station, water treatment pumping station and booster pumping station, each LCP shall form part of the motor control centre within the ICA section where appropriate. The LCPs of various plants at the Water Treatment Plant shall be installed at locations adjacent to the equipment of these plants at locations agreed by the Engineer. The LCP at the master balancing reservoir at MADAM shall be installed at the telemetry and power house. For the LCPs to be installed at sites of Package II to V, the LCPs shall be installed in telemetry rooms at large booster pumping station sites and the re-chlorination station sites. At the sites of the tapping points from the treated water transmission trunk main, the LCPs shall be installed in a telemetry house close to the electromagnetic flowmeter chamber. Only when the available space is not enough for the provision of the telemetry house, the LCP shall be installed in lockable weatherproof panel(s) with index of protection, as a minimum, IP56, at a position agreed by the Engineer. Each of these enclosures shall be prevented from directly exposure to sunlight by the installation of a top canopy. Should such arrangement is inevitably adopted, a detail installation proposal shall be submitted to the Engineer for approval.

Each LCP shall also contain panel front controls, indications and alarms to enable the operator to operate the plant in hand-mode when the automatic control has failed.

The Contractor shall indicate on a drawing the proposed position of each LCP for approval of the Engineer.

LCP panel-front facilities shall continue to function in the event of a failure of the central DCS or communications network. Local manual control of the associated plant shall also be possible during failure conditions of the PLC/intelligent outstation within the LCP.

The transmitters of the instruments, e.g. ultrasonic level devices, flow measuring devices can be installed adjacent to the LCPs and inside the enclosures housing the LCPs. For these measuring instruments, whose transmitters with indicator display is not legible from the vicinity of the LCP, a separate indicator shall be provided on the front of the panel. Panel front indicators shall be of the digital display type and shall have a minimum of 4.5 digits unless otherwise specified.

The associated transmitter scale lengths shall not be less than 150mm.

When there is a constraint to the cable distance between the instrument sensors and the transmitters, and when installing these transmitters adjacent to the LCP is not feasible because it fails to fulfill the allowable maximum cable length requirement; under such circumstances, the transmitters shall be installed inside a lockable weatherproof enclosure of index of protection, as a minimum, IP56, at a position close to the sensor and agreed by the Engineer. Each of these enclosures shall be prevented from directly exposure to sunlight by the installation of a top canopy. The front of this weatherproof enclosure shall be transparent to allow the display of the transmitters, being installed inside the enclosure, can be seen from the exterior without opening the weatherproof enclosure door. For these measuring instruments, whose transmitters with indicator display is not legible from viewing at the exterior of the transparent front enclosure, a separate indicator shall be provided on the front of the panel. Panel front indicators shall be of the digital display type and shall have a minimum of 4.5 digits unless otherwise specified. The associated transmitter scale lengths shall not be less than 150mm.

The front of the LCPs shall include a composite alarm/event annunciator for displaying local alarms where more than 10 alarms are required to be displayed.

All redundant DCSs/PLCs provided shall be the product of a major manufacturer and for which technical assistance and advice, spares and servicing are readily available in the State of Tamil Nadu, India. When required to perform analogue control, three-term proportional, integral, derivative (PID) algorithms shall be used.

The DCSs/PLCs, where used, shall be capable of data communication and shall have an RS232 V24 port for local program interrogation. The communications protocol shall enable third party products to be installed without the need for specialist bespoke interfere software being developed. The PLC shall be capable of being programmed either from the CCRs via the communication network or locally with a portable plug-in device. A portable plug-in main programming device shall be provided to enable PLCs to be interrogated and programmed at the associated LCPs. The programming device shall permit access to all parts of the programs. If the programming device is a notebook type personal computer, the Contractor shall provide all necessary software, connection cables, adaptors and software licences to enable access to the DCSs/PLCs. This notebook is to complete with the necessary software and accessories to perform the aforementioned function and is to be supplied under the Contract.

The DCSs/PLCs, shall be equipped with modules with RS485 ports such that they are able to communicate with the end devices by standard communication protocols.

The PLC program shall be held initially in the random access memory but after experience of satisfactory operation has been gained, the program shall be transferred to EPROM. Extension cables and a folding shelf shall be provided in each LCP for the programming device, so that it may be used from a sitting position.

Instrumentation analogue transmitters, trip amplifiers, signal conditioning devices and relays shall be operated from a 24 volt dc power units backed up by the LCP uninterrupted power supply. The uninterrupted power supply shall, in general, comply with the requirements entered in Clause B7.1.16. Ventilation shall be provided for the UPS as recommended by the UPS manufacturer.

The marshalling section of the LCP shall contain the termination facilities for each external connection and distribution boards for 230V ac and 24V dc supplies to each item of internally mounted and associated external equipment. Each supply circuit shall be protected by an MCB with auxiliary contacts. PLCs shall be provided with an isolator and protected by an MCB with auxiliary contacts. The contacts of these devices shall be used to operate the appropriate channels of the local alarm annunciator and, using separate contacts, corresponding alarms in the central DCS. Signal and data cables shall be terminated into surge protection devices.

Terminals in the LCPs shall have an integral means of isolating the two parts of the circuit connected to them. The terminals shall be grouped according to the following classification, each group having a separate terminal cover, marked to identify the group:

- 230Vac power circuits;
- 24Vdc power circuits;
- Instrument earths;
- digital inputs;
- analogue inputs;
- pulsed inputs;
- digital outputs;
- analogue outputs;
- pulsed outputs.

The digital outputs shall be sub-divided if the circuits use differing voltages. Spacing terminals shall be provided between each group and sub-group. Terminals for power cables shall be segregated from terminals for control, signal and data cables.

B 7.2.4 Alarm annunciator

The following alarms arising shall be input to the local alarm annunciator system.

- Mains supply healthy/failed;
- UPS healthy/failed;
- UPS battery discharging;
- PLC healthy/failed or IOS healthy/failed (if used);
- PLC communications healthy/failed.

All the fault signals as detailed in Clause B7.1.17 shall be input to the alarm annunciator. However, these alarms shall not be displayed as individual alarm at the alarm annunciator window facia, but as a group alarm showing that there is a fault at that piece of equipment or that particular site. The signals input to the alarm annunciator shall not be repeated from the output modules of the PLC. Interposing relays shall be installed to duplicate the primary contacts of the incoming signals whenever necessary. The following group alarm shall be displayed at the alarm annunciator of their associated LCP:

At treated water pumping station LCP

- Treated water pumps failed
- Treated water pumping station electrical system failed

At raw water pumping station LCP

- Raw water pumps failed
- Raw water pumping station electrical system failed Alarm signals as mentioned in Clause B7.5.1

At booster pumping station LCP

- Booster pumps failed
- Booster pumping station electrical system failed

At clarifier plant LCP

- Clarifier plant failed
- Alarm signals as mentioned in Clause B7.6.1

At filters main LCP

- Filters failed
- Alarms signals as mentioned in Clause B7.6.2.4

At chemical plant LCP

- Chemical plants failed
- Alarm signals as mentioned in Clause B7.6.4

At sludge plant LCP

- Sludge plants failed

The local alarm system shall include the alarm annunciator, alarms acknowledge and alarm reset facilities on the LCP front and an audible device mounted in a position to be agreed with the Engineer.

B 7.2.5 Intelligent outstation (IOS), if used

An intelligent outstation is any proprietary RTU device that is microprocessor based, connects directly to the communication network and carries out one or more control or monitoring function(s).

An intelligent outstation may be housed in a free-standing or surface-mounting cubicle. UPS power shall be provided to support the components within the IOS in the event of a power failure.

The intelligent outstation shall be the means of communicating with the monitoring and distributed control system and shall pass data to and from the CCR. Any internal failure of its communication link with the rest of the system shall cause operation failure alarm.

B 7.2.6 Valve controls

Solenoid valves and pneumatic valves shall be provided with a selector switch at LCP with 'Field/LCP' selection and open/close push-buttons at LCP and at a local control unit adjacent to that valve. For motorised valves, the local/remote selector which is an integrated part of the electrical actuators, shall perform the function of 'Field/LCP' selector switch. Open/close push-buttons shall be both available at the actuator and the LCP. At the electrical actuators, the required open/close push-buttons can be an integrated button at the actuators that can perform the dual function of opening and closing of the valves.

B7.2.7 Communications highway

Details of the communications highway linking local systems with the other parts of the SCADA System are detailed herein and Clauses B7.1.17.

The Contractor shall provide a communications network linking all LCPs and the CCRs equipment. The Contractor shall design the communication network to respond in accordance with the performance criteria detailed in Clause B7.1.17 and the Standard Specifications. The Contractor shall submit details of the communications network for approval.

The Tenderer shall submit details of the proposed communications network as part of his Tender.

The network shall enable each LCP to connect with every other LCP as well as with the CCR equipment. A communication switch shall be provided within each LCP to provide, as a minimum, 30% additional connectivity to the network for future expansion, commissioning and troubleshooting activities via the Engineer's notebook as stipulated in B7.2.3. If necessary, to give the required speed of operation, the Contractor shall provide additional communication links within the network, such that signals can be distributed to be transmitted at these additional communication links.

Connections between a LCP and the network junction box shall be by means of a high-quality connector. Communication network failure alarms shall be displayed and printed at the CCR.

The route, support and protection arrangements for the communications network shall be mechanically protected throughout its length.

Each network link shall be protected against damage from electrical storms as appropriate and each network shall have at least 50% spare capacity.

Lightning protection system shall be provided should copper cables be used for analogue data transmission.

B 7.2.8 System inputs and outputs

Inputs and outputs required for the monitoring and distributed control systems shall be designed by the Contractor in accordance with the control philosophy and associated drawings.

Any measured value signal used for control purposes within the area of measurement or received as an isolated signal from a measurement in another area shall be monitored and local and system alarms shall be initiated if the signal falls below 4mA or such other value indicative of a transmitter, analogue signal isolator or other failure.

B 7.2.9 Personnel and plant protection devices

Items of equipment detecting conditions representing potential hazards to personnel and plant, such as gas leak detectors, pump suction, dry run protection and delivery pressure trips, etc. shall be wired direct to the warning device, protection circuit or switchgear. Each device of this kind shall have a further set of contacts, isolated from other contacts, to initiate the monitoring system.

Interposing relays shall be used for devices which a second set of contacts cannot be obtained.
The interposing relay shall be mounted within the same enclosure as the device.

The protected devices shall be designed to lock-out until manually reset when the protection device operates.

B7.2.10 Power failure

In the event of a mains power failure, the automatically controlled systems shall be designed to fail safe, with the LCPs and DCS/PLC remaining energised by UPS backup. The water treatment works, the raw water pumping station and the booster pumping station at the sites of Package I will all be supplied by two independent incoming supplies from Tamil Nadu Electricity Board. The incoming supplies shall be designed in accordance with the Electrical section of this Specification.

Upon restoration of power, the automatically controlled parts of the plant shall be logically re-energised by the distributed control system.

On mains power failure (on both supplies) all power operated valves/penstocks except clarifier desludging valves and filter outlet valve shall remain `held' in the position they were prior to the power failure. Clarifier desludging valve actuators shall be provided with spring return and shall `fail close'. Air receivers of the compressed air plant shall be sized to close the filter outlet valves.

On restoration of the mains power supply all drives in manual mode, if they are required to operate, must be restarted by re-actuating the relevant pushbuttons. Drives in auto mode shall start according to request of the control application program at the relevant LCPs of the SCADA System. The control system shall be designed to ensure two or more drives cannot be started simultaneously. The Contractor shall submit details of the plant re-start programme to the Engineer for approval.

Should a filter be washing automatically when power failure occurs, then on restoration of power, the automatic filter wash sequence shall re-set to the beginning of the drain down or wash and shall not start until manually initiated.

B 7.3 Site instrumentation installation

B 7.3.1 General

The Contractor shall provide all instrumentation, at the sites of Package I, as necessary to control and operate the proposed plant in a safe and efficient manner. As a minimum, the instrumentation as detailed on the outline P&IDs and herein shall be provided. At the sites of Packages II to V, the Contractor shall provide the instruments as detailed in Clause B7.1.3. All site instrumentation shall be installed in accordance with the manufacturer's requirements and the relevant electrical/ICA standards.

The Contractor shall submit a schedule of instrumentation identify tag numbers, description of instrument, instrument type (including measuring principle), manufacturer, the range, output signals, size of instrument, voltage, proposed location of transducer/transmitters for the approval of the Engineer.

Field mounted site instrumentation shall be housed in suitable enclosures for the environmental conditions associated with the mounting location. Instrument power and signal cables shall be protected against damage from electrical storms at the instrument and at the power source (for power cables) and signal terminals (for signal cables). The Contractor shall submit details of the protection systems to the Engineer for approval.

Each instrument shall have its own means of isolation and shall be protected by an individual MCB.

B 7.3.2 Instrument ranges and units of measurement

The ranges of display instruments and measuring systems shall be selected so that the maximum reading under normal operating conditions correspond approximately to the following:

- Levels 100% of Scale
- Flows 90% of Scale
- Pressures 70% of Scale
- Valve position 100% of Scale (fully closed to fully open)
- Temperature 60% of Scale
- Water quality Multiple range selection

All alarms and trips derived from an analogue instrument signal shall be adjustable over the full range of the instrument.

Units of measurement for use on measurement systems and displays and documentations shall be as follows:

Parameter	Units				
Length	mm	m	km		
Mass	mg	g	kg	t(tonne)	
Time	s	min	h	d	
Area	m^2	ha			
Volume	ml	l	m^3	Ml	
Temperature	°C				
Velocity	mm/s	m/s	m/h		
Speed	rpm	spm			
Torque	N.m				
Volumetric flow:					
- liquids	ml/s	l/s	l/h	Ml/d	
- gases	Nm^3/min	Nm^3/h			
Mass flow	mg/s	g/s	kg/h		
Pressure	mbar	bar	mH_20		
Concentration					
- solids in liquids g/m^3	mg/l	g/l	kg/m^3	%w/w	%w/v
- gases in gases	Vppm	mg/m^3			
Power	W	kW			
Current	mA	A			
Voltage	mV	V			
Noise	dB(A)				
Frequency	Hz				
Colour	°Hazen				
Conductivity	µS/cm (at 25°C)				
Turbidity	NTU				
spm-	Strokes per minute				

Ml-	million litres
Ml/d-	million litres per day (one day = 86,400 seconds)
Vppm-	parts per million by volume
Nm3 -	volume at 1.013bar, 0°C

B 7.3.3 Flow measurement

The main process pipework flowmeters shall be of the electromagnetic type provided with a separate transmitter with visual display unit. The transmitters shall be mounted adjacent to the LCP or enclosure adjacent to the flowmeter chamber, depending on the allowable maximum cable distance between the measuring tubes and the transmitters. The flow rate of each flowmeter shall also be displayed on the relevant LCPs and transmitted to the CCR.

A dismantling joint shall be provided in the pipework adjacent to each flowmeter to allow flowmeter removal. The flowmeter shall be installed in accordance with the manufacturers' instructions and, as a minimum, shall be installed in a straight section of pipework (i.e. no valves or bends) to allow five pipe diameters upstream and downstream of the flowmeter.

Where flowmeters are installed below ground, they shall be housed in a suitably sized flowmeter chamber with adequate space for all maintenance and operational activities.

Variable area flowmeters shall be used for the chemical dosing plant in accordance with the process specification and shall be provided with flow limit volt-free contacts for alarm purposes.

B 7.3.4 Parshall flume flowmeter

The intake flow to the Water Treatment Works shall be measured by Parshall flume flowmeter. The Parshall flume which is a constriction of the intake open channels will develop a hydraulic head which is proportional to flow. The flume open channel shall be construct on site. The Contractor has to submit the detail design of the flume channel, the installation position of the level measuring equipment and the mounting method.

The flume open channel shall be constructed such that the floor section is level longitudinal and transversely. The flume floor's elevation shall be established such that submergence condition at maximum flow can be prevented. The flume installation shall be planned properly to allow access for installation of the flume in order to ensure correct elevation and leveling of the floor. The Contractor has to provide details of the access design for the approval of the Engineer. An approach channel shall be constructed with length long enough to create a symmetrical, uniform velocity distribution and a tranquil water surface at the flume entrance. This straight run shall have a length of, as a minimum, ten times the width of the flume channel.

B 7.3.5 Level indicators and controllers

Level instruments of the conductivity type, float switch type, ultrasonic non-contact level transducer type and pressure-transducer type shall be used to provide level alarms and controls.

The mode of operation of each controller being used to control level, shall be such that, on failure of the controller, the final control element reverts to a `safe' condition. The mode of operation used for alarm signalling shall be such that, on failure of the controller, an instrument fault alarm is activated whether or not an alarm condition exists.

Pressure type level transmitters and conductivity type level switches for low low and high high level or overflow alarms shall be used for all treated water tanks including the treated water reservoir and washwater storage tanks. All other levels shall be measured with non-contact ultrasonic type level transmitters and conductivity type level switches for low low and high high level or overflow alarms.

The transmitters shall be mounted adjacent to the LCP or enclosure adjacent to the sensing device, depending on the allowable maximum cable distance between the sensors and the transmitters. Should the level transmitters be mounted adjacent to the sensing device, the installation positions shall be accessible to enable easy calibration and display. The transmitter or external trip amplifier shall include at least five volt-free adjustable limits and an instrument failure alarm. The transmitter shall display the level of the wetwell and shall be calibrated to read 0.00m at wetwell floor level.

The level alarms and level signals from the above shall be displayed on the LCPs and transmitted to the CCR.

B 7.3.6 Pressure instruments

The Contractor shall provide all pressure gauges and pressure transducers in accordance with the control philosophy.

Pressure switches provided for pump protection systems shall be operable in both hand and automatic functions.

The Contractor shall provide all pumps with suitably scaled and calibrated pressure gauges for local indication of both the suction and discharge pressures.

B 7.4 ICA cabling and earthing

B 7.4.1 ICA cabling

The Contractor shall provide a comprehensive cabling system for the distributed control system comprising signal, control and UPS and non-UPS power cabling from the local control panels to field instruments with power and signal cable, connection from the transmitters to the sensors, interconnection between MCC and LCP for power and signals, connection from PLCs and distributed I/O to the field output/input devices, between the PLCs, between PLC and distributed I/O, connection to the network servers, from the network servers to the workstations and printers, etc. to form a complete system.

The cables shall be grouped as follows:

- power cables - 230 Vac;
- control cables - 24 Vdc;
- Signal cables - process signals (e.g. 4-20 mA, 24 Vdc to 48 Vdc status signals);
- data cables - modulated signals (e.g. serial data communication signals); and
- fibre optic cables.

The Contractor shall design a comprehensive system for the support, accommodation and protection of all cabling provided under the Contract. Cabling under a suspended floor or over a suspended ceiling shall be supported by cable ladder rack or cable tray. The cabling design shall be based on the following requirements:

- cabling to the desk at the CCR shall enter through the base of the desk from ducts installed by the Contractor;
- cabling shall enter panels and enclosures through gland plates and shall be supported by cable ladder racks and tray as appropriate;
- control and instrumentation cabling shall be suitably segregated from electrical power cabling to ensure there is no risk of electromagnetic interference;
- cabling systems shall comply with requirements described in the Standard Specification.

The Contractor shall provide all cabling necessary to interconnect instrumentation, control and monitoring circuits with the plant to provide the specified instrumentation control and automation facilities.

B 7.4.2 Instrumentation signal earth

The Contractor shall provide insulated earth cables to connect the instrumentation earth bars in each panel to the station earth system. The instrumentation signal earth cables shall have different outside insulation colour to the power earth cables in order to make them easily detectable. To prevent any circulating current to circulate at the screenings when both sides of the cables are earthed, when there are different potentials at these earthing points; all instrumentation cables shall be earthed at one end only. Earthing system design shall comply with local regulations.

B 7.4.3 Lightning protection of instrumentation systems

The Contractor shall provide all terminating equipment for all I/O and communications signals including bus cable transmitted between buildings on a copper cable with lightning protection barriers. The barrier shall be installed in a barrier panel which shall be located adjacent to the main cable entry point into the building or in a small enclosure adjacent to the transmitter. The barriers shall be earth bonded in accordance with manufacturers' recommendations and the standard specification.

B 7.5 Raw water pumping station plant – particular requirements

The raw water pumping station shall be provided with a LCP to provide monitoring via the DCS. The LCP shall be housed in the raw water pumping station and shall form part of the raw water pumping station low voltage switchboard.

The transmission method to link this LCP with other devices of the Works shall be as that mentioned in Clause B7.1.17 and other relevant clauses elsewhere in the Specification.

The system shall be provided with all necessary additional accessories to ensure a reliable system. The Contractor shall submit detail proposal for the communication system for the approval of the Engineer.

B 7.5.1 Raw water pumping station

The raw water pumping station and intake wells are located within a structure in the Cauver River. One of the possible configurations of the pumping station is to have three separate wetwells as that shown in the Drawing. The pumping station shall be isolated above flood level on top of the wetwells.

The raw water LCP shall provide instrumentation signals to the DCS where applicable as well as providing signal marshalling facilities and a location for analogue signal isolators and digital signal interposing relays as required by the hard wired system.

The LCP shall incorporate an MCB distribution board to supply small power services to the instrumentation.

The raw water pumpsets can be operated manually or automatically. Under manual operation mode, the pumps shall be capable of being operated from the following pre-selected locations:

- at the individual LCUs adjacent to each pumpset located on the walkway as agreed with the Engineer;
- at the LCP or the motor starters;
- remotely at the CCR when the selection at the HMI page is at "SCADA Manual".

The Contractor shall determine the most appropriate method of starting the pumpsets with consideration to water hammer and surge. The pump starters shall enable smooth starting and stopping with reduced stress. Where the Contractor recommends starting the pumpset against a close valve, the actuated valve shall be automated to operate the valve when the pumps are started/stopped.

The control of any auxiliary drives required by the pump shall be included with the necessary interlocking. The auxiliary drives including valves actuator shall be automated to perform the required function when the main pumps are started/stopped.

As a minimum, the pumpsets shall be protected in all modes of operation from dry running and no flow protection. The Contractor shall provide a pressure switch with selected limit values to detect no flow for each pumpset. Concurrently, a limit switch shall be installed at the non-return valve of each pump to sense the opening or The low low level conductivity probes for each wetwell compartment shall be used to trip the associated pumpsets for dry run protection.

Two ultrasonic level sensors/transmitters and conductivity probes for low low and high high level shall be installed in each wetwell chamber. The ultrasonic level transmitters shall provide volt-free contacts for the high and low level alarms. The low level alarm shall be set slightly above the low low level conductivity probe. Also, the high level alarm shall be set slightly below the high high level conductivity probe.

The two ultrasonic level sensors/transmitters at each wetwell shall be selected by a selector switch at the LCP to determine which one to be used as the duty instrument. On the HMI pages at the workstations at CCR, the same selector switch shall be configured performing the same function. This selector switch shall take precedence should the selection at the LCP be different with the selection at the HMI page.

The total discharge flow being developed by the raw water pumping station shall not exceed the maximum capacity of the Water Treatment Plant. The number of pumps to operate shall be adjusted and controlled to attain that requirement. The PLC program shall incorporate such part of control in order to attain a flow input to the Water Treatment Plant not exceeding its maximum handling capacity.

One electromagnetic flowmeter completed with transmitter and testing simulator shall be installed at the common discharge of the booster pumping station. Flow rate and the flow volume signals shall be available at the electromagnetic flowmeter and shall be send to the SCADA System.

The signals to be monitored and display, and the devices to be control at the LCP shall comply with the minimum requirements entered in Clause B7.1.17.

The LCP shall also display and monitor signals derived from the Water Treatment Plant including:

- Inlet raw water flow rate obtained from the Parshall Flume flowmeter;
- Water treatment works power failure alarm;
- Overflow alarms (common);
- Levels of the two compartments of the treated water reservoir;
- Outlet treated water flow rate and flow volume.

B 7.5.2 11 kV Switchgear, 11/3.3kV transformers and 3.3kV motor control centres

The 11kV switchgear, 11/3.3kV transformers and 3.3kV motor control centres shall be located above the flood level of the raw water pumping station at intake works.

The DCS system shall monitor and display the signals and analogue values from these equipment as detailed in the electrical specification and from the surge protection facility. The information is available as potential free contacts and as RS 485 port or similar. The Contractor shall provide a LCP to interface with the data highway.

B 7.6 Water Treatment Plant – particular requirements

The Water Treatment Plant shall be provided with, as a minimum, seven sets of local control panels (LCPs) to provide monitoring via the DCS. The LCPs shall be housed in the clarifier plant, the filter plant, the sludge treatment plant, the treated water pumping station, the treated water motor control centre room, the chlorine plant and the lime/aluminium sulphate plant. As signals being obtained from each filter will be connected to its dedicated auxiliary local control desk (ALCD), the local control panel at the Filter Plant shall be named as the main local control panel (MLCP).

The Contractor shall provide fibre optic communication cable to connect these LCPs and the CCR.

The data transmission method to link the LCPs at Water Treatment Plant with other LCPs outstation of the Works shall be as that mentioned in Clause B7.1.17 and other relevant clauses elsewhere in the Specification.

The system shall be provided with all necessary additional accessories to ensure a reliable system. The Contractor shall submit detail proposal for the communication system for the approval of the Engineer.

B7.6.1 Clarifier plant

Plant control shall provide automatic control of the pneumatically operated desludging valves. The clarifier local control panel (LCP) shall be located in a suitable area adjacent to the plant and shall, if provided, form part of the clarifier distribution switchboard as specified in the electrical section.

The desludging of the clarifiers shall be fully automatic and shall be designed to carry out both intermittent and continuous desludging.

The clarifier LCP shall be provided with its own independent sludge control system. The control system shall be provided with multi-range adjustable timers for setting duration (length of draw-off) and interval (time between draw-offs) for each valve. The Contractor shall use a proven proprietary desludging control system specific to his design. The specified time-controlled desludging system shall be supplied in addition to any proprietary system offered by the Contractor.

The automatic desludging system shall be provided with manual override facilities both for the initiation of a discharge sequence and for the operation of individual valves. It shall be possible to initiate continuous desludging of the clarifier. The desludging valves shall be provided with local push button control for local manual operation. It shall also be possible to operate the desludging valves manually by handwheel or similar.

The operation of the desludging system shall be inhibited by a high level in the clarifier sludge balance tank and the condition shall be annunciated as a sludge balance tank level high alarm and clarifier desludging inhibit alarm at the LCP and at the CCR. The high level alarm shall be set to ensure adequate volume is available in the clarifier sludge balance tank for the desludging operation.

The clarifier LCP shall provide control, alarm and status indications for the clarifier plant as detailed below. These alarms and status conditions shall be monitored from the CCR.

- raw water flow and totalised flow;
- works inlet (at aerated water tank outlet) overflow alarm;
- adjustable desludging interval timer with display;
- adjustable desludging duration timer with display;
- open/close push-buttons for manual operation of desludge valves;
- desludge valve available, open/closed/failed indication lamps;
- desludging inhibited lamp (derived from the sludge treatment LCP alarm signal for clarifier sludge balance tank high level);
- facilities for monitoring proprietary desludging facilities (where provided);

- running/failed indication lamps for any mechanical drive used;
- electrical MCC signals as detailed in the electrical specification.

If Lamella clarifiers or any other clarifier system are provided instead of sludge blanket clarifiers, the Contractor shall provide the according control, alarm and status indications. These alarms and status conditions shall be monitored from the CCR.

The LCP door shall be arranged logically to represent the layout of the plant. Facilities for each clarifier and the associated desludging facility shall be grouped together.

The raw water flow shall be measured by Parshall flume flowmeter on the raw water channel supplying the works inlet.

B 7.6.2 Filtration plant

B 7.6.2.1 General

The filtration plant operation shall be monitored and controlled by the local control desk and relevant data displayed via the DCS at the following locations as specified:

Local control units (LCU) adjacent to each pneumatic valves; Individual filter auxiliary local control desks (ALCD); Filters main local control panel (MLCP); at the workstation at CCR.

Filter washing shall be controlled by the ALCDs with a link to the MLCP for control of common filter wash facilities as described below. The filter control system shall provide a semi-automatic filter wash sequence with manual initiation as detailed herein. The filters shall be designed to operate on constant level controlling the filter outlet valve.

B 7.6.2.2 Primary filter plant and instrumentation

(a) Wash plant

Common filter wash plant includes air scour blowers, blower unloading device (where applicable), the washwater supply control valve and the compressors and receivers for the actuated valve air supply as well as valves and controls to interconnect the common plant with each filter.

(b) Filter plant

Each filter shall be provided with the following automated equipment:

- pneumatic modulating open/close type inlet penstock; pneumatic open/close type washout valve;
- pneumatic open/close type wash inlet valve; pneumatic open/close type air inlet valve;
- pneumatic modulating open/close filtered water outlet valve;
- pneumatic open/close type air release valve (according to the Contractor’s design).

(c) Instrumentation

Each filter shall be provided with the following instrumentation:

- ultrasonic type level transmitter with adjustable volt-free contacts;
- manometer for loss of head with alarm contacts;
- analogue position of the filtered water outlet valve;
- any other instrument required to execute the wash sequence specific to the Contractor’s design.

The filters shall be provided with the following common instrumentation:

- electromagnetic flowmeter for clarified water;
- electromagnetic flowmeter for washwater flow;
- electromagnetic flowmeter for used washwater recycle pumped flow;
- conductivity probe for the filter inlet channels overflow alarm;
- pressure gauge for common air scour pipework.

B 7.6.2.3 Auxiliary local control desks (ALCD)

Each filter shall be provided with an auxiliary local control desk (ALCD) located on the viewing walkway in the upper gallery opposite each filter. The ALCDs shall house equipment for wash control of the associated filter including either distributed I/O or a PLC or equivalent. The ALCDs shall be free standing enclosures constructed to an IP54 protection rating.

The filter ALCDs shall be connected to the MLCP via a serial communications network. Unless otherwise specified, the serial communications network shall be used to transfer data required for the operation and monitoring of the filters.

The PLC shall contain the filter control logic for washing the filter.

Each ALCD shall include a key operated switch for selecting local, remote and out of service located on the console of the desk.

Each ALCD shall be provided with a permanent melamine mimic display located on the console facia of the panel. The console facia shall represent the associated filter with data displayed as listed below:

- a graphical representation of the filter based on process and instrumentation diagrams (P&ID);
- opened, closed, available and failed status indication lamps for each of the pneumatically operated actuated valves and penstocks associated with the filtration, the filter drain-down and filter wash;
- position indication for the modulated valves and penstocks;
- active digital displays for each measured analogue value associated with the filter as well as the washwater flow rate and the common filtered water turbidity;
- filter status lamps for filter available for drain-down or washing (according to the level in the used washwater holding tank, common inlet channel and elevated water storage tank), pneumatic valve compressor plant available, drain down, combined air/water wash, rinse, surface flush, filter re-start, manual, automatic, out of service and failed;
- air blowers available, running and failed status;
- filter water level and high high level and high head loss alarm;
- LCD type timer display of filter run time since last wash - displayed in hours;
- LCD type filter wash sequence count down timer - displayed in mm:ss counting down to zero;
- PLC status lamps for communication failure and PLC failure.

The following facilities shall be on the console facia to enable manually initiated drain down, wash functions and filtration:

- a selector switch for automatic/manual/off wash sequence;
- a selector switch for automatic/manual/off filtration;
- open/close push button for each actuated valve/penstock;
- facilities to adjust each intermediate position of a modulated valve/penstock;

- air blowers start/stop push button;
- an LCD type manual wash timer (displayed in hh:mm:ss);
- reset push-button;
- lamp test push-button.

The following push-buttons shall also be provided for normal manual operation of the filter wash and drain down facilities which shall provide semi-automatic control of the filters as described herein:

(γ) drain down;
(η) rapid drain down (also called 'dump');
(ι) air/water wash;
(φ) rinse;
(κ) surface flush;
(λ) slow start/return to service.

B 7.6.2.4 Filtration main local control panel (MLCP)

The filters shall be provided with a main local control panel (MLCP) provided as part of the filter building MCC located in the filter building switchroom. The MLCP shall include a PLC with an annunciator panel to monitor the overall status of the filter plant.

The MLCP shall include the following functions:

- remote monitoring of each filter status;
- monitoring facilities for the air scour blowers and the compressors for the pneumatic actuated valves;
- facilities to allow monitoring of the shared, common wash plant;
- facilities for the monitoring of filter gallery drain pumps;
- facilities for the monitoring of the filter outlet valve position;
- facilities for the monitoring of the works water supply pumps;
- facilities for the monitoring of the washwater recycle pumps;
- facilities for the monitoring of the elevated water storage tank levels;
- facilities for the monitoring of the used washwater holding tank levels.

The PLC shall contain the control logic for operating the common filter wash plant.

The annunciator and analogue displays depicting the filters shall include the following:

- the filter wash system providing the status of each associated filter (e.g. filtering, draining, washing, returning to service, fault, out of service, etc.);
- the status of each air blower (available, running and failed);
- the status of the works water supply pumps (available, running and failed);
- the status of the used washwater recycle pumps (available, running and failed);
- facility for adjusting the backwash delay time - this delay time is associated with time between the start of the air scour blower(s) and the start of the backwashing sequence during the combined air/water wash cycle;
- facility for adjusting the period of application of the automatic combined air/water wash;
- facility for adjusting the period of application of the water rinse;
- filter plant overflow alarm;
- used washwater holding tank level, overflow and low low alarm and wash inhibit;
- common inlet channel (to the used wash water holding tank) overflow alarm and inhibit;

- elevated water storage tank level, overflow and wash inhibit alarm;
- display of the common filtered water turbidity;
- display of clarified water flow rate and totalised flow;
- display of washwater flow rate and totalised flow;
- display of used washwater recycle pumped flow rate and totalised flow;
- filter gallery drain pump status (running and failed);
- electrical plant monitoring signals as detailed in the electrical specification.

The clarified water flow shall be measured by the electromagnetic flowmeter in the pipe connecting the clarifiers and the filters.

The washwater flow shall be measured by the electromagnetic flowmeter in the pipe connecting the elevated water storage tank to the common filter washwater pipework.

The used washwater recycle pumped flow shall be measured by the electromagnetic flowmeter in the pipe connecting the used washwater tank to the works inlet aerated water tank.

The works output shall be computed from totalised clarified water flow and washwater flow over 24-hour period and shall be updated every hour.

B 7.6.2.5 CCR workstations

The Contractor shall provide at the CCR workstations the following facilities relating to the filters:

- Graphic displays that are identical (file copies) to those described in the ALCD and MLCP sections above and display the same information;
- UPS status data associated with the primary filters ALCDs and MLCPs including healthy, discharging, failed;
- For the filtration and washing sequence the semi automatic and automatic functions shall be provided to be controlled at the monitor;
- PLC/outstation status for each ALCD and MLCP associated with the filters;
- archive trending of filter data including:
  - individual filter level
  - calculated clarifier sludge flow rate;
  - clarified water flow rate;
  - washwater flow rate;
  - calculated works output flow rate;
  - tabular list of the last 25 washes and filtrations of each filter including the completion date and time.

B 7.6.2.6 Filter level control

The filters shall be designed to operate on a constant level basis with modulating outlet valves.

The filter inlets shall have flow division weirs to ensure equal flow sharing by the filters in service. The level in the channel and filters will tend to rise and fall when plant flow increases or decreases respectively. Hence the control system shall be arranged to open or close all of the individual filter outlet flow control valves (in service). This control will allow the flow through the filters to increase and decrease accordingly to maintain the level in the filters.

The filter level controller shall have an analogue input process variable of filter level and an operator set point, common for all filters, to set the desired level in each filter.

As filters become progressively clogged in service, individual filter outlet valves shall be opened automatically to maintain the desired "set point" filter level. Equal flow through all filters in service shall be provided by the filter inlet weirs arranged for equal flow distribution.

When a filter is taken out of operation, the remaining filter outlet valves shall then open to offset the change in level. It can be seen therefore that the filters shall be designed to accept whatever water is provided at the inlet (within plant hydraulic limits).

B 7.6.2.7 Filter wash control

Filter washing shall be manually initiated and controlled using the PLC's located in the ALCDs and MLCP for the running of common wash plant. The operator shall select filters for washing based on time since last wash, visual condition of filter, rising filter level alarm, head loss alarm or filtered water turbidity measured manually.

The filter wash controls shall incorporate a check that the washwater supply is adequate and the used washwater holding tanks can accept a complete wash.

Facilities shall be provided at each filter to provide local hand control of the wash sequence as described above.

The filter drain down shall be with closed inlet valve and via the filtered water outlet valve. The drain down operation of each filter shall be initiated manually. It shall be possible to drain down filters simultaneously. Drain down shall be manually initiated and terminated when a pre determined water level is reached in the filter. Failure to complete the drain down in a pre set time period shall be alarmed as drain down failure.

It shall be possible to accelerate the drain down manually by opening the washout valve instead of the filtered water outlet valve (dump).

The initiation of an automatic wash cycle shall be manual and, on completion of the wash, the filter shall be arranged for manual return to service. On return to service, the filter inlet penstock shall be opened slowly over a period time adjustable in the range 0 – to 30 minutes.

All necessary safety features, including interlocks to prevent more than one filter being washed simultaneously and a filter being washed until its drain down is complete shall be provided.

Inadequate capacity in the used washwater collection tanks to accept a complete filter wash and/or inadequate volume of water in the washwater storage tank to completely wash a filter shall inhibit a filter wash being started. The drain down of a filter while another is washing shall be possible.

(a) Manual wash initiation

Individual filters shall be selected for washing based on the following information:

visual inspection of the filters;

loss of head measured by a manometer and alarm contact or by filter outlet valve position by high water level in the filter;

elapsed filter run time since last wash;

(e) Automatic washing

The normal mode of operating the filters shall include automatic filter washing following manual initiation of the drain down and wash stages separately. The control system shall exercise control and monitoring of all the filters and the common wash plant. Satisfactory filter condition shall be maintained by periodically and selectively washing filters as described in (a) above.

Washing of filters shall require the assistance of an operator. If a filter wash failure occurs, the associated filter shall be classified as "failed" and the affected filter isolated. The failed alarm status (not out of service) shall be displayed on the affected filter's ALCD, MLCP and CCR.

Filters will be manually selected for washing at the ALCD.

(c) Manual washing

Manual washing facilities shall be provided at the ALCD.

Manual washing of a filter shall involve the operator selecting the appropriate equipment to control and carry out each stage of the wash manually. The sequence used by the operator should normally follow that which is defined elsewhere; however the operator shall have the facilities at the ALCD to alter the sequence by use of the push buttons described below.

Manual washing of a filter at its ALCD shall require the key selector switch on the ALCD to be set to local. The operator shall then press the appropriate Plant push buttons (P/B) to complete the manual wash.

It shall also be possible to wash the filters completely manually by operating the valves and penstocks manually by using the hand wheels or the actuators and operating the blowers at the MCC.

(d) Wash sequence

The filter wash sequence shall be set by the program in the PLCs located within the individual filter ALCDs and MLCP. Each filter program shall be the same. The PLCs shall provide software interlocking to ensure that dangerous operation of the filters is not possible. The automatic filter wash sequence which will be controlled by the operator at the ALCD is described below in the required order of occurrence.

(e) Drain down

This step in the wash sequence shall close the inlet penstock. The filter outlet valve shall maintain its last position and be removed from the filter level control. When the inlet penstock begins to close, the filter shall drain down into supply, until the filter water level reaches an adjustable preset wash level. The filter outlet valve shall be automatically closed to achieve the adjustable preset wash level.

To overcome excessive drain down time due to excessively clogged filter media, a manually operated rapid drain down facility comprising, closure of the inlet penstock (if already not closed) and outlet valve followed by the opening of the washout valve shall be provided.

The rapid drain down shall be inhibited if the used washwater holding tank does not have the capacity available to accept the volume of the drain down water.

(f) Combined air/water wash

This step in the wash sequence shall ensure the filter inlet penstock and filter outlet valve are closed and the drain down water level has been reached. The program shall then start the air blower(s) (operate the blower unloading device, if applicable); open the appropriate filter air inlet valve and open the filter washout valve. After successfully starting the air blower(s) and opening the washout valve and filter air inlet valve, the program shall wait for a preset adjustable washwater delay time (0-3 minutes) and then open the appropriate filter washwater inlet valves. The program shall continue for a pre set time and then stop the air blower(s) and close the appropriate filter air inlet valve. The washwater sequence shall continue to operate until the preset period of application of the automatic combined air/water wash has elapsed. A settling period may be introduced at this point of the automatic wash sequence for air release from the under floor (open air release valve if provided) or similar operation at which time the washwater sequence shall stop. If a settling period is not introduced, the control system can step directly to the rinse step of the sequence without stopping the washwater sequence.

At the start of the combined air/water wash, the wash sequence count down timer shall be reset to a time corresponding to the preset adjustable air/water wash time and count down to zero to indicate the time remaining in the combined air/water wash step. If a settling time is introduced, the wash sequence count down timer shall include for the time remaining in the settling period.

(g) Rinse

This step of the wash sequence shall open the filter wash inlet valve and any other washwater supply valves. The rinse shall continue for a preset adjustable time. The program shall then stop the wash sequence and close the filter wash inlet valve including any other washwater valves and the filter washout valve.

At the start of the rinse, the wash sequence count down timer shall be reset to a time corresponding to the preset adjustable back wash time and count down to zero to indicate the remaining back wash time.

(h) Surface flush

Surface flush or cross wash shall form part of the rinse step. The start of the rinse step shall open the inlet penstocks (or surface flush penstocks) and close at the end of the rinse phase.

(i) Completion of wash

Returning of the filter to service following completion of the wash shall be manual. This step of the wash sequence shall check for successful completion of the previous steps and that the filter is ready for re-start. The filter run time since last wash timer shall be reset to zero. The checks shall include confirmation that all wash related valves are correctly set. The program shall then release the filter from the wash sequence.

(j) Filter Re-start

When starting the filter, the opening of the inlet penstock shall follow the slow start routine which shall ensure that the filter inlet penstock is opened in small steps over a pre-set adjustable slow start period of 0 to 30 minutes.

The operator shall then return the filter to automatic mode which shall allow the filter to return to automatic filter level control with the other filters once the filter restart sequence is complete.

B 7.6.2.8 Washwater flow rate

The washwater supply to the filters shall be provided with an electromagnetic flowmeter. The rate of washwater flow shall be controlled by a butterfly valve located downstream of the flow measuring element. Operation of the valve shall be manual unless the Contractor requires it to be automated for applying two different rates for combined air-water wash and the rinse. The valve shall be provided with a position indicator and a locking device where applicable. The maximum velocity through the control valve shall not exceed 5 m/s. The valve shall be provided with access for operation and maintenance.

The rate of flow shall be indicated local to the control valve to assist in the setting of the valve position.

If the Contractor requires to use two different wash water flow rates, he shall automatically control the washwater flow by a PID controller using a closed loop control system. The controller shall have a low flow set point for air/water washing period and a high flow set point for the rinsing period. The controller shall monitor the washwater flow rate and the position of the control valve to determine the position of the valve for the different flow set points.

B 7.6.2.9 Interlocks

In addition to the interlocks and features described above, the Contractor shall provide necessary interlocks to protect plant and personnel to ensure safe and efficient operation of the plant.

B 7.6.2.10 Air scour blower station

Each air scour blower shall be controlled automatically from the ALCD. The blowers shall be provided with LCUs to provide manual control adjacent to the air scour blower.

The MLCP shall be provided with a 4-position selector switch:

Position 1	Blower 1/2 duty
Position 2	Blower 2/3 duty
Position 3	Blower 1/3duty
Position 4	Blower 1/2/3alternating

In automatic mode, the preselected duty blowers shall be operated from each ALCD during the wash sequence.

The Contractor shall provide a pressure switch to monitor the high and low pressure on the common discharge pipe.

B 7.6.2.11 Used washwater recycle pumping station

The used washwater recycle pumpsets shall be automatically controlled via the MLCP to operate on a duty/standby basis. The duty pump shall start on intermediate level and stop when a low level is reached. Overflow level shall be used to initiate an alarm at the relevant local panel and at the MLCP.

A three-position selector switch selects the duty pump.

Position 1	Pump 1 duty
Position 2	Pump 2 duty
Position 3	Pump1/ Pump2 alternating

Manual control shall be available adjacent to the pumpsets, at the MLCP or CCR.

The MLCP shall monitor the pump condition and used washwater holding tank levels and display these as % full tanks.

Each compartment shall be provided with an ultrasonic level transmitter to measure the level in the used washwater holding tank. The ultrasonic level transmitter shall provide volt-free contacts for the high and low level alarms and to inhibit a rapid drain down or a filter wash. The level for filter wash inhibit shall be set such that if the inhibit level is reached during a rapid drain down or a filter wash each process is allowed to continue to a conclusion. The inhibit level shall be set on the assumption that both the compartments are available. The overflow and low low level conductivity be set to operate outside the limits of the ultrasonic level settings to avoid spurious pump trips.

The MLCP shall be provided with a selector switch to allow either used wash water holding tank No1 or No2 to be selected as the measuring device.

As additional security an overflow conductivity probe shall be installed in the common inlet channel to the used wash water holding tank. An alarm shall be given by reaching this level, but an ongoing filter wash or drain down sequence shall be finished. If this level is still existing when a following drain down or filter wash sequence is initiated, then this sequence shall be inhibited.

Dry run protection shall be provided in manual and auto mode by the low low level.

The pipeline between the used washwater recycle pumping station and aerated water tank shall be provided with an electromagnetic flowmeter.

The used washwater holding tank inlet shall be provided with an overflow alarm.

B7.6.2.12 Works water supply pumps and elevated water storage tank

The works water supply pumps located adjacent to the chemical building shall be automatically controlled via the MLCP to operate on a duty/standby basis. The duty pump shall be controlled by the level of the elevated wash storage tank and start on intermediate level and stop when a high level is reached. Overflow level shall be used to initiate an alarm at the relevant local panel and at the CCR.

A three-position selector switch selects the duty pump.

Position 1	Pump 1 duty
Position 2	Pump 2 duty
Position 3	Pump1/ Pump2 alternating

Manual control shall be available adjacent to the pumpsets, at the MLCP or CCR.

The MLCP and CCR shall monitor the pump condition and elevated water storage tank levels and display these as % full tanks.

Each elevated water storage tank shall be provided with a pressure level transmitter to measure the level in elevated water storage tank. The level transmitter shall provide volt-free contacts for the automatic control of the pumps and for the high and low level alarms and for inhibiting filter wash. The level for filterwash inhibit shall be such that if the inhibit level is reached during a filter wash, the process is allowed to continue to a conclusion. The inhibit level shall be set on the assumption that only one compartment is available. The overflow and low low level conductivity probes shall be set to operate outside the limits of the analogue level settings to avoid spurious pump trips.

The MLCP shall be provided with a selector switch to allow either elevated water storage tank No1 or No2 to be selected as the measuring device.

No flow protection for the works water supply pumps shall be provided in manual and auto mode by a pressure switch with selected limit values to detect no flow for each pump.

Dry run protection for the works water supply pumps shall be provided in manual and auto mode by a conductivity switch installed in the suction line of each pump.

B 7.6.2.13 Sampling pumps

Sample pumps shall be provided with locally mounted DOL starters adjacent to each pumpset. The starters shall be housed in a weatherproof and robust enclosure and shall be located in an accessible location. The pumps shall be arranged to operate continuously and raise an alarm to the MLCP and CCR when a pump failure is detected.

Each pump shall be protected against dry running.

B 7.6.2.14 On-line analyse instruments

The on-line analyse instruments shall be installed in the laboratory as detailed in the water treatment works specification.

The MLCP shall provide isolation amplifier, trip amplifier for alarms and status indication for these instruments as detailed below. These alarms and status conditions shall be monitored from the MLCP, from the CCR and from the LCP where the analyse values are needed for the dosing rate:

- Chlorine residual value;
- Chlorine residual value high/low;
- Chlorine residual instrument failure;
- PH value;
- PH value high/low;
- PH instrument failure.
- Turbidity value;
- Turbidity value high;
- Turbidity instrument failure.

The CCR shall provide trends for all water quality data.

B 7.6.3 Treated water pumping station plant

The treated water pumping station plant shall be provided with a local control panel (LCP) to provide monitoring via the DCS. The LCP shall be housed in the treated water pumping station and shall form part of the treated water pumping station low voltage switchboard.

The transmission method to link this LCP with other devices of the Works shall be as that mentioned in Clause B7.1.17 and other relevant clauses elsewhere in the Specification.

The system shall be provided with all necessary additional accessories to ensure a reliable system. The Contractor shall submit detail proposal for the communication system for the approval of the Engineer.

B 7.6.3.1 Treated water pumping station

The treated water pumping station shall intake from the two compartments of the Treated Water Reservoir.

The treated water pumping station LCP shall provide instrumentation signals to the DCS where applicable as well as providing signal marshalling facilities and a location for analogue signal isolators and digital signal interposing relays as required by the hard wired system.

The LCP shall incorporate an MCB distribution board to supply small power services to the instrumentation.

The treated water pumpsets can be operated manually or automatically. Under manual operation mode, the pumps shall be capable of being operated from the following pre-selected locations:

- at the individual LCUs adjacent to each pumpset located on the walkway as agreed with the Engineer;
- at the LCP or the motor starters;
- remotely at the CCR when the selection at the HMI page is at “SCADA Manual”.

The Contractor shall determine the most appropriate method of starting the pumpsets with consideration to water hammer and surge. The pump starters shall enable smooth starting and stopping with reduced stress by built-in functionality of adjustable ramping up speed during starting of pumps and adjustable ramping down speed during stopping of pumps. Where the Contractor recommends starting the pumpset against a close valve, the actuated valve shall be automated to operate the valve when the pumps are started/stopped.

The control of any auxiliary drives required by the pump shall be included with the necessary interlocking. The auxiliary drives including valves actuator shall be automated to perform the required function when the main pumps are started/stopped.

As a minimum, the pumpsets shall be protected in all modes of operation from dry running and no flow protection. The Contractor shall provide a pressure switch with selected limit values to detect no flow for each pumpset. The low low level conductivity probes at each chamber of the Treated Water Reservoir shall be used to trip the associated pumpsets for dry run protection.

Two ultrasonic level sensors/transmitters and conductivity probes for low low and high high levels shall be installed in each compartment of the Treated Water Reservoir. The ultrasonic level sensors/transmitters shall provide volt-free contacts for the high and low level alarms. The low level alarm shall be set slightly above the low low level conductivity probe. Also, the high level alarm shall be set slightly lower than the high high level conductivity probe.

The two ultrasonic level sensors/transmitters at each compartment shall be selected by a selector switch at the LCP to determine which one to be used as the duty instrument. On the HMI pages at the workstations at CCR, the same selector switch shall be configured performing the same function. This selector switch shall take precedence should the selection at the LCP be different with the selection at the HMI page.

One electromagnetic flowmeter completed with transmitter and testing simulator shall be installed at the common discharge of the booster pumping station. Flow rate and the flow volume signals shall be available at the electromagnetic flowmeter and shall be send to the SCADA System.

The signals to be monitored and display, and the devices to be control at the LCP shall comply with the minimum requirements entered in Clause B7.1.17.

B 7.6.3.2 33 kV Switchgear, 33/6.6kV transformers and 6.6kV motor control centres

The 33kV switchgear, 33/6.6kV transformers and 6.6kV motor control centres shall be located above the flood level of the treated water pumping station.

The DCS system shall monitor and display the signals and analogue values from these equipment as detailed in the electrical specification and from the surge protection facility. The information is available as potential free contacts and as RS 485 port or similar. The Contractor shall provide a LCP to interface with the data highway.

B 7.6.4 Chemical plant

Instrumentation, control and automation (ICA) of individual chemical plant is defined in the sections that follow and in the drawings. The hydrated lime and aluminium sulphate dosing plant shall be provided with a common LCP. The LCP shall form a separate compartment of the chemical building MCC as detailed in the electrical works specification.

The DCS system shall monitor and display the signals and analogue values from the local MCCs as detailed in the electrical specification.

B 7.6.4.1 Hydrated lime plant

The hydrated lime plant shall be manually controlled from the chemical local control panel and monitored by the CCR.

Each item of plant shall be provided with local control units to enable the operators to perform the following sequence of operation:

- The slurry tank shall be partly filled with water by opening the water supply valve;
- The operator shall then start the slurry tank preparation mixer from a local control unit pushbutton start/stop device which shall be positioned adjacent to the operating platform;
- The tank shall be charged with lime by emptying the required number of whole bags using the bag loader provided;
- Fill the tank with water to the maximum water level;
- The operator shall then select the available slurry preparation tank, open the selected slurry transfer pump suction and delivery isolating valves and start the selected pump to deliver slurry to the associated saturator;
- The Contractor shall provide local control units to start/stop the duty/standby slurry transfer pumps adjacent to the appropriate saturator;
- When the lime slurry in the saturator is at the appropriate level the operator shall open the water supply valve and set the flow rate by manually adjusting the flow control valve to maintain a flow rate as detailed in the water treatment specification. The dosing rate will be set by a variable area flowmeter;
- A hydrometers shall be provided to verify the concentration of the slurry and a conductivity meters shall be provided to verify the concentration of the saturated solution as detailed in the water treatment works specification.

The slurry transfer pumpsets shall be protected against low flow by undercurrent device located in the pumpset starter and against low low in slurry tanks by level probes. The operator shall manually start the standby pump when the duty pump fails.

The slurry preparation tanks shall be provided with an ultrasonic level sensor to provide an alarm at the local control panel. If conductivity probes are used they shall be adequately spaced and designed to prevent bridging by lime.

The quantity pumped to the saturators shall be measured by an electromagnetic flowmeter. At the LCP the flow shall be displayed and the quantity shall be counted by two counters, one without reset and one with manual reset.

The local control panel shall monitor and display the condition of all items of plant and transmit the status to the CCR. No remote operation of the chemical plant shall be required at the LCP or CCR.

The following states, alarms and indications at the LCP and to be transmitted to the CCR shall include:

- Lime slurry preparation tanks high, low and low low level alarms;
- Lime slurry preparation tanks level;
- Lime slurry preparation tank mixer running and failed;
- Slurry transfer pumps running and failed;
- Flow and quantity to the saturators;
- Raw water flow, used washwater recycle flow, clarified water flow and works outlet flow;
- Works outlet water quality data;

Interlocks shall be provided to ensure that the equipment is protected from damage against abnormal operations. An alarm shall be displayed on the LCP to indicate no raw water flow and/or no clarified water flow, to warn the operator to shut-down the appropriate chemical dosing system until flow is restored. The operator shall be warned when the flow is restored.

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B 7.6.4.2 Aluminium sulphate plant

The aluminium sulphate plant shall be manually controlled from the chemical local control panel and monitored by the CCR.

Each item of plant shall be provided with local control units to enable the operators to perform the following sequence of operation:

- The saturated solution shall be prepared by partly filling the saturators with water followed by manually charging the saturators with the required quantity of aluminium sulphate. The tank shall then be filled to the maximum level by manually opening the water supply valve until the float valve stops the supply;
- The operator shall manually set the valves to recirculate to the same saturator for pre determined period for mixing. When the valves are set the operator shall start one of the saturated solution recirculation/ transfer pumps from a local control unit pushbutton start/stop device which shall be positioned adjacent to the operating platform;
- The operator shall then set the valves to transfer saturated solution to the stock tanks;
- The operator shall stop the recirculation/transfer pump when the required level is reached in the stock tank. Water shall then be added to the stock tank until the maximum level is reached. The operator shall then start the mixer. The stock tank levels shall be displayed on the LCU to enable the transfer pumps to be started and stopped at the required level and to start/stop the mixer;
- When the stock tank/s are filled, the operator shall start the constant head tank feed pumps from a local LCU. The excess flow into the constant head tank shall be arranged to be returned to the duty stock tank. The pumps will be stopped automatically when a low level in the stock tank is detected;
- The dosing rate will be manually set by a variable area flowmeter;
- Hydrometers shall be provided as specified to verify the concentration of the saturated solution and the stock solution.

The feed pumps shall be protected against low flow by undercurrent device located in the pumpset starter and against low low level in stock tanks by level probes. The operator shall manually start the standby pumps when any of the duty pump fails.

The local control panel shall monitor, display and control the condition of all items of plant and transmit the status to the CCR. No remote operation of the chemical plant shall be required at the LCP or CCR.

The following states, alarms and indications at the LCP and to be transmitted to the CCR shall include:

- Stock tanks level and high/low/low low level alarms;
- Recirculation/transfer pump running and failed;
- Stock tank mixer running and failed;
- Constant head tank feed pump running and failed;
- Constant head tank high and low level alarms.

Interlocks shall be provided to ensure that the equipment is protected from damage against abnormal operations.

B 7.6.4.3 Chlorine plant

(n) Chlorine plant - general

Plant control shall be automatic for the following chlorine plant:

- drum changeover;
- chlorine plant ventilation.

The chlorine plant shall be provided with a common LCP. The LCP shall form a separate compartment of the chloride building MCC as detailed in the electrical works specification.

The complete Plant including the control system shall be designed to `fail safe'.

Interlocks shall be provided to ensure that the equipment is protected from damage against abnormal operations.

The DCS system shall monitor and display the signals and analogue values from the local MCC as detailed in the electrical specifications.

(p) Chlorine drum changeover

The basis of chlorine drum changeover shall be by pressure in the liquid chlorine manifolds measured by pressure switches. Each manifold shall be provided with a pressure indicator.

The controls to be provided for drum changeover shall include:

- Changeover AUTO and MANUAL selector switch.
- FULL indicator to inform which drum bank is full.
- Drum selector switch to enable the selection of drum banks between the DUTY and STANDBY.

With the changeover mode switch set to AUTO, the motorised valve of the bank of duty chlorine drums shall be opened.

When the pressure in the liquid chlorine manifold falls to a pre-set `low' value the changeover from the empty drum bank to the full drum bank shall be initiated and the changeover panel shall satisfy the following functions:

- Close the motorised valve of the bank of drums that has just become empty;
- Open the motorised valve of the standby bank of drums.

If the low pressure in the manifold is sustained after the changeover has been completed, a changeover failure alarm shall be annunciated on the local control panel and at the CCR.

Other states, alarms and indications to be provided on the local control panel and at the CCR shall include:

- Manifold pressure;
- DUTY and STANDBY status indications for each bank of drums;
- Motorised valves open/close positions;
- Motorised valves fault.

(t) Chlorine dosing plant

The controls to be provided for chlorine dosing plant shall include:

- Start/stop push button for operation of pre-chlorination motive water pump;
- Start/stop push button for operation of the ventilation plant;
- Start/Stop push buttons for operation of post-chlorination motive water pumpsets;
- Raw water flow, clarified water flow and works outlet flow to enable the operator to manually set the dosing rates;
- Motive water pumpset selector switches.

Start/stop operation and the disinfection chlorine dosing rate of the post and pre-chlorinators shall be manual. The local control panel shall display all flow rates necessary to enable the operator to set the dosing rates from within the chlorinator room.

On failure of one of the post-chlorine chlorinators on low or high vacuum or motive water pumpsets, the standby unit shall be started manually from the local control panel and the failure condition shall annunciate an alarm at the local control panel and at the CCR. Operation of changeover valves shall be carried out manually on the plant.

An alarm shall be displayed on the LCP to indicate no works throughput, to warn the operator to shut-down the chemical dosing system until flow is restored.

(v) Chlorine plant ventilation

The chlorine ventilation control panel shall be provided with auto/manual/off selector switch for the ventilation system. The chlorine ventilation control panel shall monitor and display the condition of the chlorine leak detector panel in both manual and automatic mode.

Prior to an operator entering the chlorine drum store or chlorinator room, the ventilation shall be switched to automatic or manual. In manual mode the ventilation fans will run continuously until a chlorine leak level `high' is sensed by the leak detection system in the respective area the corresponding ventilation system shall stop if running. A high level leak shall inhibit the manual starting of the ventilation system in the respective area. In automatic mode, the ventilation fans will run when a low level chlorine leak is detected and will stop when a high level chlorine leak is detected.

Key operated over-ride switches shall be provided on the local control panel to manually override the automatic operation and allow ventilation fans to be operated manually from the motor control centre.

The ventilation control panel shall provide a two tone visual/audible alarm for low level and high level alarms.

The following information shall be displayed and monitored on the local control panel and repeated at the CCR:

- Ventilation auto/manual states;
- Chlorine leak low/high in each area;
- Chlorine plant failure.
- Vacuum regulator/pressure relief valve fault;
- Chlorine vacuum high and low;
- Chlorinator motive water running/fault;
- Ventilation system fans running/fault;
- Motorised valves open/closed position;
- Motorised valves fault;
- Raw water flow rate;
- Clarified water flow rate;
- Works water outlet flow;
- Works outlet water quality data;
- Emergency shutdown.

B 7.7 Sludge treatment plant – particular requirement

B 7.7.1 General

The plant operation shall be monitored by the local control panel and relevant data displayed via the DCS at the treatment plant network server (CCR).

The local control panel in the thickened sludge pump house shall be provided with all necessary control switches, state indications and alarms for routine monitoring, commissioning, manual and automatic operation, testing and maintenance of the plant.

The sludge treatment plant shall be provided with a common LCP. The LCP shall form a separate compartment of the sludge treatment MCC as detailed in the electrical works specification.

The complete plant including the control system shall be designed to `fail safe'.

Interlocks shall be provided to ensure that the equipment is protected from damage against abnormal operations.

The DCS system shall monitor and display the signals and analogue values from the local MCC as detailed in the electrical specification.

B 7.7.2 Sludge balance tanks

The sludge balance tanks shall comprise of two compartments. Each compartment shall be provided with a submersible mixer provided with Hand/off/Auto selector switches. In automatic mode mixers shall run when a predefined level has been reached and stops when a low level is detected.

The mixers shall be capable of being operated at individual local control units (LCUs) adjacent to each mixer in a position as agreed with the Engineer or at the motor control centre.

The ultrasonic level transmitters shall provide volt-free contacts for the high, mixer start, mixer stop and low level controls. The overflow and low low level conductivity probes shall be set to operate outside the limits of the ultrasonic level settings to avoid spurious pump trips.

In all mode of operation the mixer shall be tripped, when a low level is detected. The operating range of levels in the sludge balance tanks shall be selected to ensure that the mixer remains submerged with the minimum required water depth all the time.

The information to be provided on the local control panel with repeat indication at the CCR shall include:

(κ) Mixer status;
(λ) Sludge balance tank No1 level;
(μ) Sludge balance tank No2 level;
(ν) Sludge balance tank No1 low low and overflow level;
(ο) Sludge balance tank No2 low low and overflow level.

The sludge balance tank No1/2 level shall be used to generate a clarifier desludge inhibit for the clarifier LCP when inadequate volume is available for desludging. The inhibit level shall be set such that if the inhibit level is reached during desludging operation, the process is allowed to continue to a conclusion. The inhibit level shall be set on the assumption that both the compartments are available.

B 7.7.3 Thickener feed pumps

The thickener feed pumps shall be selected for off, hand or automatic operation. The pumps shall be capable of being operated at individual local control units (LCUs) adjacent to each pumpset in a position as agreed with the Engineer or at the motor control centre.

Under normal operation, the four thickeners feed pumps shall be arranged as two sets of duty/standby pumps with each set configured to discharge to individual sludge thickeners. When a sludge thickener is out of service the normally closed valve in the pump discharge manifold will be opened manually to enable the two duty pumps to discharge to a common sludge thickener.

For each pumpset the controlling measuring point shall be selected by a selector switch (measuring point 1/2) at the LCP. In automatic mode, the selected ultrasonic level transmitters shall be used to control the operation of both sets of duty and standby pumps. The duty pump selection shall be made by the operator via a three-position selector switch for each pumpset which shall be provided with the following selection:

(a) Position 1Pump No1 duty/Pump No2 standby

(b) Position 2Pump No2 duty/Pump No1 standby

(h) Position 3Pump 1/2 alternating

Each duty pump shall automatically start when a clarifier sludge balance tank medium level is detected by the ultrasonic level transmitter and stop when a low level is reached. Changeover from duty to standby pumps shall be manual in the event of a duty pump failure and the failure shall be annunciated at the LCP. The control system shall be designed to ensure two or more pumps cannot be started or stopped simultaneously.

The pumpsets shall trip in both manual and automatic mode when a sludge balance tank low low level is detected by the conductivity probe. The pumpsets shall also be protected in all modes of operation from no flow protection. The Contractor shall provide a pressure switch with selected limit values to detect no flow for each pumpset.

Dry running protection shall be provided with a conductivity switch installed in the suction line of each pump.

The information displayed and monitored on the local control panel with repeat indication at the CCR shall include:

(δ) Thickener feed pump status.

B 7.7.4 Thickener

The two sludge thickener scrapers shall be provided with individual hand/off selector switches. The scrapers shall be arranged to run continuously and shall be protected by a torque switch.

Desludging of the sludge thickeners with the pneumatic thickener sludge outlet valve shall be controlled from the LCP and initiated on time basis which shall be monitored by frequency and duration timers. The system shall be provided with manual override facilities with a local LCU adjacent to each valve.

The information displayed and monitored on the local control panel with repeat indication at the CCR shall include:

- Sludge thickener scraper motor status;
- Thickener sludge outlet valve open/close/fault status;
- Desludge frequency and duration times.

B 7.8 Drainage pumps

The following locations as detailed within the water treatment works shall be provided with drainage pumpsets:

- raw water wet well;
- filter pipe gallery;
- chemical building;
- thickener feed pump basement;
- treated water pumping station;
- any other location where drainage pumps are installed.

The duty pump shall start on intermediate level. The assist pump shall start on high level. Both pumps shall stop on low level. The duty and assist pump shall be selectable. The assist pump shall start on intermediate level if the duty pump fails. High high level shall be used to initiate an alarm at the relevant local control panel and at the CCR. There is no standby pump for this arrangement however pump failures shall be annunciated at the relevant local panel and at the CCR.

The drainage pumps shall be provided with conductivity probe level electrodes for pump operation with a float operated level detector for the high high level alarm.

Each drainage pump system shall be controlled from the nearest LCP. The appropriate LCP shall display and monitor the following drainage pump signals and repeat them to the CCR:

- Sump high high level alarm;
- Sump pump 1/2 running/fault.

B 7.9 Booster pumping station plant – particular requirement

The booster pumping station shall be provided with a LCP to provide monitoring via the DCS. The LCP shall be housed in the booster water pumping station and shall form part of the booster water pumping station low voltage switchboard.

The data transmission method to link this LCP with other the LCPs at the Water Treatment Plant shall be as that mentioned in Clause B7.1.17 and other relevant clauses elsewhere in the Specification.

The system shall be provided with all necessary additional accessories to ensure a reliable system. The Contractor shall submit detail proposal for the communication system for the approval of the Engineer.

B 7.9.1 The booster pumping station

The booster pumping station shall draw water from its inlet sump, through DN1500 suction manifold. Water shall be pumped to MADAM Master Balancing Reservoir located about 3.5km away.

The booster pumping station LCP shall provide instrumentation signals to the DCS where applicable as well as providing signal marshalling facilities and a location for analogue signal isolators and digital signal interposing relays as required by the hard wired system.

The LCP shall incorporate an MCB distribution board to supply small power services to the instrumentation.

The booster water pumpsets can be operated manually or automatically. Under manual operation mode, the pumps shall be capable of being operated from the following pre-selected locations:

- at the individual LCUs adjacent to each pumpset located on the walkway as agreed with the Engineer;
- at the LCP or the motor starters;
- remotely at the CCR when the selection at the HMI page is at “SCADA Manual”.

The Contractor shall determine the most appropriate method of starting the pumpsets with consideration to water hammer and surge. The pump starters shall enable smooth starting and stopping with reduced stress. The pump starters shall enable smooth starting and stopping with reduced stress by built-in functionality of adjustable ramping up speed during starting of pumps and adjustable ramping down speed during stopping of pumps. Where the Contractor recommends starting the pumpset against a close valve, the actuated valve shall be automated to operate the valve when the pumps are started/stopped.

The control of any auxiliary drives required by the pump shall be included with the necessary interlocking. The auxiliary drives including valves actuator shall be automated to perform the required function when the main pumps are started/stopped.

As a minimum, the pumpsets shall be protected in all modes of operation from dry running and no flow protection. The Contractor shall provide a pressure switch with selected limit values to detect no flow for each pumpset. The low low level conductivity probes at each wetwell of the inlet chambers shall be used to trip the associated pumpsets for dry run protection.

Two ultrasonic level sensors/transmitters and conductivity probes for low low and high high level shall be installed at the inlet sump of the Booster Pumping Station. The ultrasonic level transmitters shall provide volt-free contacts for the high and low level alarms. The low level alarm shall be set slightly above the low low level conductivity probe. Also, the high level alarm shall be set slightly below the high high level conductivity probe.

The two ultrasonic level transmitters shall be selected by a selector switch at the LCP to determine which one to be used as the duty instrument. On the HMI pages at the workstations at CCR, the same selector switch shall be configured performing the same function. This selector switch shall take precedence should the selection at the LCP be different with the selection at the HMI page.

One electromagnetic flowmeter completed with transmitter and testing simulator shall be installed at the common discharge of the booster pumping station. Flow rate and the flow volume signals shall be available at the electromagnetic flowmeter and shall be send to the SCADA System.

The signals to be monitored and display, and the devices to be control at the LCP shall comply with the minimum requirements entered in Clause B7.1.17.

B 7.9.2 33 kV Switchgear, 33/3.3kV transformers and 3.3kV motor control centres

The 33kV switchgear, 33/3.3kV transformers and 3.3kV motor control centres shall be located above the flood level of the booster water pumping station.

The DCS system shall monitor and display the signals and analogue values from these equipment as detailed in the electrical specification and from the surge protection facility. The information is available as potential free contacts and as RS 485 port or similar. The Contractor shall provide a LCP to interface with the data highway.

B 7.10 Master balancing reservoir at MADAM – particular requirement

The LCP at master balancing reservoir at MADAM shall provide instrumentation signals to the DCS where applicable as well as providing signal marshalling facilities and a location for analogue signal isolators and digital signal interposing relays as required by the hard wired system.

At the inlet to each compartment of the balancing reservoir, an inlet isolating valve (DN1500) shall be provided. Valve "closed", "opened" and "fault" signals shall be acquired by the LCP. The SCADA System shall be able to control the "close" and "open" of these two valves.

For connecting to Package II treated water transmission trunk main (DN1000 MS pipe)

From the outlet of each compartment of the balancing reservoir, an outlet isolating valve (DN1000) shall be provided. The discharge ends of the two outlet valves shall then be connected in common to an electromagnetic flowmeter (DN1000), where at the discharge side, an outlet valve (DN1000) shall be provided. With this arrangement, the electromagnetic flowmeter can be isolated by closing the two valves from the reservoir compartments and this outlet valve at the discharge side of the flowmeter. The valve "closed", valve "opened" and valve "fault" signals of all the abovementioned valves shall acquired by the LCP. Also, the SCADA System shall be able to control the "close" and "open" of all the abovementioned valves. The flow rate and the volume of flow signals available at the electromagnetic flowmeter shall be acquired by the LCP.

For connecting to Package V treated water transmission trunk main (DN1500 MS pipe) Exactly the same arrangement at that described in the above for Package II connection, except that, all outlet pipes and valves from the reservoir compartments shall be of size DN1500.

At each compartment of the balancing reservoir, two ultrasonic level sensors and transmitters shall be installed for measuring the water level at that compartment of the reservoir. These level signals shall be acquired by the LCP.

Within the site boundary of MADAM, the contractor of Package II will construct the Pennagaram booster pumping station and provide all the necessary electrical and mechanical there. The signals from the devices therein shall be acquired by the LCP and the control signals from the LCP shall be wired to the devices in the Pennagaram booster pumping station.

The signals to be monitored and display, and the devices to be control at the LCP shall comply with the minimum requirements entered in Clause B7.1.17.

B 7.11 Booster pumping stations at Packages II to V (at locations as entered in Table 3-1 to Table 3-4) – particular requirement

The LCP shall incorporate an MCB distribution board to supply small power services to the site instrumentation.

The booster pumpsets shall be automatically controlled from the LCP. When “SCADA” is selected at the local switchgear “Off/HAND/SCADA” selector and “SCADA Auto” is concurrently selected at the relevant HMI pages, the duty pump(s) shall be started automatically when the inlet pressure is above a pre-determined low pressure and the delivery pressure is below a pre-determined high pressure. The pumps shall be automatically stopped when a low inlet pressure or high delivery pressure is detected.

The Contractor shall submit a control philosophy for each booster pumping station to meet the requirements in the Specification for the Engineer’s approval.

When “HAND” is selected, the booster pumpsets shall be operated from individual Local Control Units (LCUs) adjacent to each pumpset located on the walkway at a position as agreed with the Engineer and the contractor of the site (when the “Remote/Local” selector is at “Local”) or at the motor starters in the electrical switchboard/motor control centre (when the “Remote/Local” selector is at “Remote”).

The LCP shall monitor and display the following signals, with volt-free contacts for inputting to the digital input modules and analogue signals inputting to LCP by 4-20mA or communication protocol of FieldBus, Modbus or other equivalent. These parameters shall be able to be displayed at the LCP and the HMI of the SCADA System:

- Booster pump available, running, stop and fault signals;
- Reservoir high and low level alarms;
- Reservoir level;
- Inlet mains pressure;
- Delivery mains pressure(s) (for each delivery main);
- Surge protection device status, if provided.

The normal operating regime for the booster pumping stations shall be on a duty/standby basis with automatic changeover of the duty pump on failure. When more than two pumps are available in the booster pumping station (for example, six pumps), the pumps shall be arranged as “first duty start”, “second duty start”, “third duty start”, “first standby”, “second standby” and “third standby” (100% standby) so on and so forth. The duty pumps shall be automatically started sequentially. The assist pump shall be stopped when intermediate inlet and delivery pressures have been achieved. The control system shall ensure no two pumpset shall be started simultaneously.

The Contractor shall determine the most appropriate method of starting the pumpsets with consideration to water hammer and surge. The pump starters shall enable smooth starting and stopping with reduced stress. The pump starters shall enable smooth starting and stopping with reduced stress by built-in functionality of adjustable ramping up speed during starting of pumps and adjustable ramping down speed during stopping of pumps. Where the Contractor recommends starting the pumpset against a close valve, the actuated valve shall be automated to operate the valve when the pumps are started/stopped.

The control of any auxiliary drives required by the pump shall be included with the necessary interlocking. The auxiliary drives including valves actuator shall be automated to perform the required function when the main pumps are started/stopped.

As a minimum, the pumpsets shall be protected in all modes of operation from dry running and no flow protection. The Contractor shall provide a pressure switch with selected limit values to detect no flow for each pumpset. The low low level conductivity probes at each wetwell of the inlet chambers shall be used to trip the associated pumpsets for dry run protection.

Two ultrasonic level sensors/transmitters and conductivity probes for low low and high high level shall be installed at the pump sump of the Booster Pumping Station. The ultrasonic level transmitters shall provide volt-free contacts for the high and low level alarms. The low level alarm shall be set slightly above the low low level conductivity probe. Also, the high level alarm shall be set slightly below the high high level conductivity probe.

The two ultrasonic level transmitters shall be selected by a selector switch at the LCP to determine which one to be used as the duty instrument. On the HMI pages at the workstations at CCR, the same selector switch shall be configured performing the same function. This selector switch shall take precedence should the selection at the LCP be different with the selection at the HMI page.

For booster pumping station with pump sump, one electromagnetic flowmeter completed with transmitter and testing simulator shall be installed at the common discharge of the booster pumping station. Flow rate and the flow volume signals shall be available at the electromagnetic flowmeter and shall be send to the SCADA System.

For booster pumping station with inlet pipework, e.g. water taken from the upstream pumping station, two electromagnetic flowmeters shall be installed. One electromagnetic flowmeter shall be installed at the inlet to the booster pumping station and the other electromagnetic flowmeter shall be installed at the common discharge of the booster pumping station. Both flowmeters shall be completed with transmitter and testing simulator. Flow rate and the flow volume signals shall be available at the electromagnetic flowmeters and shall be send to the SCADA System.

The signals to be monitored and display, and the devices to be control at the LCP shall comply with the minimum requirements entered in Clause B7.1.17.

B 7.12 Re-Chlorination Station at Package II to V (with locations as entered in Table 1-1, Table 1-2 and Table 1-4) – particular requirement

The LCP shall incorporate an MCB distribution board to supply small power services to the site instrumentation.

The Contractor shall provide an LCP for each re-chlorination station. The Contractor shall submit a control philosophy for each re-chlorination station to meet the requirements in the Specification for the Engineer's approval. The Contractor shall also incorporate all safety interlocks recommended by the equipment supplier and detailed in the chlorination process specification.

(i) Chlorine plant control - general

Plant control shall be automatic for the following chlorine plant:

- cylinder changeover;
- chlorine plant ventilation;

The complete Plant including the control system shall be designed to `fail safe'.

Interlocks shall be provided to ensure that the equipment is protected from damage against abnormal operations.

(c) Chlorine cylinder changeover

The basis of chlorine cylinder changeover shall be by pressure in the liquid chlorine manifolds measured by pressure switches. Each manifold shall be provided with a pressure indicator.

The controls to be provided for chlorine cylinder changeover shall include:

- Changeover Off/AUTO/HAND selector switch.
- FULL indicator to inform which cylinder bank is full.
- Cylinder selector switch to enable the selection of cylinder banks between the DUTY and STANDBY.

With the changeover mode switch set to “AUTO”, the motorised valve of the bank of duty chlorine cylinder shall be opened.

When the pressure in the liquid chlorine manifold falls to a pre-set ‘low pressure’ value the changeover from the empty cylinder bank to the full bank shall be initiated and the changeover panel shall satisfy the following functions:

- Close the motorised valve of the bank of cylinder(s) that has just become empty;
- Open the motorised valve of the standby bank of cylinder(s).

If the low pressure in the manifold is sustained after the changeover has been completed, a changeover failure alarm shall be annunciated on the LCP and at the relevant SCADA HMI pages.

Other states, alarms and indications shall be provided on the LCP, with volt-free contacts for inputting to the digital input modules and analogue signals inputting to LCP by 4-20mA or communication protocol of FieldBus, Modbus or other equivalent. These parameters shall be displayed at the LCP and the HMI of the SCADA System and shall, as a minimum, include the following:

- Manifold pressure;
- DUTY and STANDBY status indications for each bank of cylinder(s);
- Motorised valves open/close positions;
- Motorised valves fault.

(iii) Chlorine dosing plant

The controls to be provided for chlorine dosing plant shall include:

- Start/stop push button for operation of motive water pumpsets;
- Start/stop push button for operation of the ventilation plant;
- Off/AUTO/HAND selector switch at each motive water pumpset starter panel.

Start/stop operation and the disinfection chlorine dosing rate of the chlorinator(s) shall be manual. At the starter panels of the chlorinators, only “Local/Remote” selector shall be installed. Both the chlorinator starter panels and the LCP shall display the flow rate of chlorine dosing to enable the operator to set the dosing rate inside the motor control centre room or the LCP room.

On failure of the chlorinator(s) on low or high vacuum or motive water pumpset failure, the standby unit shall be started manually from the LCP or the motor starters, depending on the position of the “Local/Remote” selector at the starter panels. The failure condition shall annunciate an alarm at the LCP and the relevant HMI pages. Operation of changeover valves shall also be able to be carried at the LCP or the starter panel.

Other states, alarms and indications to be provided on the LCP and volt-free contacts for inputting to the digital input modules at the LCP of the SCADA System shall include but not limited to the following:

- Motive water pumpset status (running/fault);
- Chlorine system fault;

(iv) Chlorine plant ventilation

The chlorine ventilation control shall be provided with auto/manual/off selector switch for the ventilation system. The chlorine LCP shall monitor and display the condition of the chlorine leak detector panel in both manual and automatic mode.

Prior to an operator entering the chlorine cylinder store or chlorinator room, the ventilation shall be switched to automatic or manual. In manual mode the ventilation fans will run continuously until a chlorine leak level `high' is sensed by the leak detection system in the respective area. The corresponding ventilation system shall stop if running. A high level leak shall inhibit the manual starting of the ventilation system in the respective area. In automatic mode, the ventilation fans will run when a low level chlorine leak is detected and will stop when a high level chlorine leak is detected.

Key operated over-ride switches shall be provided on the LCP to manually override the automatic operation and allow ventilation fans to be operated manually from the fan motor starters;

The ventilation control shall provide a two tone visual/audible alarm for low level and high level alarms.

Other states, alarms and indications to be provided on the LCP volt-free contacts for inputting to the digital input modules at the LCP of the SCADA System shall include but not limited to the following:

- Ventilation auto/manual states;
- Chlorine leak low/high in each area;
- Ventilation system fans running/fault;

(v) Transmission Main pressure monitor

The Contractor shall provide a pressure transmitter and associated fittings to monitor the pressure of the transmission main upstream of the chlorine injection point. The mains pressure shall be displayed on the LCP and an analogue signal provided for the SCADA System.

B 7.13 Telephone and fax

At the raw water pumping station, water treatment plant, booster pumping station and master balancing reservoir at MADAM, the Contractor shall provide complete telephone and fax system, with detailed scope of work as follows:

Intake Work and raw water pumping station

Telephone sets shall be provided in the raw water pumping station motor hall and the Low Voltage Switchroom. The exact locations to install the telephone sets shall be proposed by the Contractor and agreed by the Engineer.

Water Treatment Plant

Telephone sets shall be provided in the treated water pumping station pump hall, the Low Voltage Switchroom, the Central Control Room (as a minimum four nos.), chemical house, sludge treatment plant, the filter hall and the chlorine plant. As a minimum, four telephone lines from the service provider shall be provided and a site EPABX system shall be provided. In the Central Control Room, one all-in-one fax/scan/copy machine shall be provided. The location to install the telephone sets and the fax/scan/copy machine shall be proposed by the Contractor and agreed by the Engineer.

Booster pumping station

Telephone sets shall be provided in the booster pumping station pump hall and the Low Voltage Switchroom. The exact locations to install the telephone sets shall be proposed by the Contractor and agreed by the Engineer.

Master balancing reservoir in MADAM

One telephone set shall be provided in the telemetry and power house. The exact location to install the telephone set shall be proposed by the Contractor and agreed by the Engineer.

The Contractor shall make application on behalf of the Employer to the service provider for the providing of the telephone and fax lines as stated above. The Contractor shall provide the exact addresses of all the site locations to the service provider and make all necessary coordination work to enable this service provider can satisfactorily carry out their work. The Contractor shall provide all necessary facilities required by the service provider within all the site boundaries of all the abovementioned plants, e.g. telephone lines/fax lines cable draw pits, cable ducts, cable trays, cable trunkings and the like to enable all works of the service provider can be successfully installed and be functioning properly.

The telephone lines and fax lines shall be registered under the name of the Employer at the service provider. The Contractor shall be responsible to pay all application and installation fees and the monthly tariffs of these lines until the Completion of the whole Works.

B 7.14 Closed Circuit Television System (CCTV)

B 7.14.1 General Requirement

The Contractor shall provide a CCTV System that shall include, but not be limited to, the provision of CCTV Day/Night cameras, CCTV infra-red floodlights and control panel, video signals data servers and panel enclosure complete with router/hub, CCTV data server workstations, CCTV LCD monitors, digital video recorders, surge and lightning protection devices, made necessary configuration, user licenses of any software for the System and associated equipment fittings and cabling necessary for the completion of the works.

B 7.14.2 Operation requirement

The video pictures being captured by the CCTV cameras shall be digitized, compressed and transmitted together with the telemetric data signals of the LCPs, through the redundant communication link as specified in Clause B7.1.17, back to the CCRs.

Images at each of the locations in the following CCTV outstations shall be captured by CCTV cameras:

Intake Works/Raw Water Pumping Station CCTV camera outstation

- Intake Works/Raw Water Pumping Station compound wall main gate;
- Intake Works/Raw Water Pumping Station motor hall
- Intake Works/Raw Water Pumping Station pump hall

Video signals shall be transmitted through the communication link between the Raw Water Pumping Station LCP and the CCR at Water Treatment Plant.

Booster Pumping Station CCTV camera outstation

- Booster Pumping Station compound wall main gate
- Booster Pumping Station motor hall
- Booster Pumping Station pump hall

Video signals shall be transmitted through the communication link between the Booster Pumping Station LCP and the CCR at Water Treatment Plant.

Water Treatment Plant CCTV camera outstation

(c) Water Treatment Plant main compound wall main gate
(d) Clarifier Plant overview
(e) Filter Plant overview

Video signals shall transmitted through the optic fibre Ethernet network at the Water Treatment Plant to its CCR.

Treated Water Pumping Station CCTV camera outstation

(xiii) Treated Water Pumping Station motor hall
(xiv) Treated Water Pumping Station pump hall
(xv) Treated Water Reservoir sump 1
(xvi) Treated Water Reservoir sump 2

Video signals shall be transmitted through the optic fibre Ethernet network at the Water Treatment Plant to its CCR.

Master Balancing Reservoir at MADAM CCTV camera outstation

(xviii) Master Balancing Reservoir at MADAM compound wall main gate
(xix) Master Balancing Reservoir sump 1
(xx) Master Balancing Reservoir sump 2

Video signals shall be transmitted through the communication link between the LCP at Master Balancing Reservoir at MADAM and the CCR at Water Treatment Plant.

All video data from each location at all CCTV camera outstations shall be sent back to the CCTV data server workstation at CCRs. Camera touring feature shall be provided. The operator shall be able to view through all cameras of the same outstation and/or different outstations by selection. Presentation of video data shall be in quadrant pictures for every 4 cameras within the same or different outstations and in full frame display from any one camera. The date, time, outstation & camera identification number shall be displayed with the picture. The video picture shall be able to be viewed at the 22" LCD monitor of the CCTV data server workstation and/or at the LCD front projector at each of the two CCRs.

The operator at the CCRs shall be able to switch on the floodlights and camera wipers at each camera installation location; and initiates pan, tilt, zoom and focusing functions to each camera remotely from any one of the CCTV data server workstations at the two CCRs.

B 7.14.3 Equipment at each CCTV camera outstation

At each CCTV camera outstation, the Contractor shall provide, as a minimum, the following equipments:

(xxiii) Video signals data servers collecting the analogue video image signal from each CCTV camera within that CCTV outstation and digitize the analogue video image to MPEG2 digital format or the like. The video servers shall be equipped with 10 baseT (RJ-45) twisted pair Ethernet plug for connection to the hub/router switch dedicated for use by these data servers, which shall in turn be connected to the router switch at the LCP. The data servers shall be configured for specific IP addresses such that the CCTV data server workstation can get access and obtain the digitized signals. As a minimum, 4 spare data signals analogue input shall be available at the each video server for future expansion;

(xxiv) One (1) contactor control panel for on/off of floodlights at each CCTV camera within that CCTV outstation. A SCADA/off/Local selector shall be installed at the panel. When the selection is at "SCADA", on/off of the infra-red floodlights shall be initiated at the CCR. Operators from the CCRs shall be able to turn on/off the floodlights at HMI pages with graphic on/off pushbuttons for these floodlights. When the selection is at "Local", the floodlights can be turned on/off via the local push button station beside each camera. Control interface between this contactor control panel and the SCADA System can be via the digital output points at the LCP;

(xxv) Control panel for the installation of the lightning arrestors for the CCTV camera video input and all the serial connection from the local telemetry receivers to be connected here using RS485 daisy chain topology. The daisy chain end shall be connected to the hub/router switch for the data servers as mentioned in sub-paragraph (a) above. Each telemetry receiver beside each CCTV camera shall be configured with an IP address such that CCRs can access the camera site to command the pan, tilt, zoom, focus and wiper on/off function at each camera;

(xxvi) one (1) set of digital video recorder (DVR) with 8 channels. The DVR shall provide multiplexer functionality with built-in digital recording. It shall record high-resolution pictures from all CCTV cameras to its built-in IDE hard drive of at least 160GB capacity.

At each of the location where the CCTV cameras are installed, the Contractor shall provide, but not limited to, the following equipment:

(b) Day/Night CCTV camera with zoom, auto-focus function and enclosed in a camera housing with an index of protection of not less than IP56. The housing shall be completed with wiper and a bracket for mounting of two infra-red floodlights specified in (b) below. Each camera shall be complete with all necessary mounting accessories including poles such that the cameras can be installed in a position able to capture the image required by the Engineer. The Day/Night Camera shall, as a minimum, be:

(ι) Horizontal resolution : 350 lines
(ιι) Minimum illumination : 0.5 lux
(ιιι) Low AC/DC supply voltage
(ιϖ) F1.4, 18X motorized optical zoom, auto focus lens or better
(ϖ) Pan travel : 360 degree
(ϖι) Tilt travel : 90 degree
(ϖιι) Camera housing shall be weatherproof of IP56

(c) Two infra-red floodlights to mount on the CCTV housing bracket;

(d) Pan/Tilt motors for each CCTV camera;

(e) Telemetry receiver for accepting the pan, tilt, zoom, focus, wiper on/off command signals issued from the CCTV data server workstation at CCRs. The command signals shall be transmitted by RS485 bus connection using communication protocol;

(f) A local on/off switch for turning on/off the infra-red floodlights.

All equipments at the CCTV outstations and the locations for the installation of the CCTV camera shall be supplied from the UPS for the LCP.

B 7.14.4 Equipment at each CCR

At each of the CCRs, the Contractor shall provide, as a minimum, the following equipment:

b One (1) CCTV data server workstation completed with 22" LCD monitor. The specification of this workstation shall be identical with that for Operator Workstation as specified in Clause B7.1.8. The CCTV data server workstation shall be installed with proprietary HMI program being supplied with the video signal data servers as mentioned in B7.13.3(a) above. The HMI pages, as a minimum, shall enables the operator to pan, tilt, zoom, focus, turn wiper on/off, show digitized images from camera (at various format as mentioned in Clause B7.13.2 above) connected to any of the video servers. The software program shall also be able to automatic record all images to the hard disk at the CCTV data server workstation in selectable different image resolution and time frame. All recorded images shall be stored in a data base automatically created by the software. Stored video image shall be able to be accessed by typing the specific date and time of the image required;

(c) A CCTV functional control keyboard designed for control of CCTV camera.

All CCTV equipments at the CCRs shall be supplied from UPS.

VOLUME 2 OF 7 PART B

PARTICULAR SPECIFICATIONS – CIVIL WORKS

CONTENTS LIST

PREAMBLE TO CIVIL WORKS SPECIFICATION

This volume contains the Particular Specification for the civil engineering works. The Particular Specification contains a description of the civil works to be designed and constructed including any applicable design criteria that have to be met. The general civil Specification is contained in Volume 3 Part K of the Standard Specification, and includes the standards to be met in the design and construction of the works. Civil works shall comply with all other relevant provisions elsewhere in the Specification.

B 8. CIVIL PARTICULAR SPECIFICATION

B 8.1 Scope

B 8.1.1 This section describes the civil works to be designed and constructed under the Contract. This includes the intake works/raw water pumping station; raw water transmission main; water treatment works; the inlet sump to the booster pumping station; the booster pumping station; the master balancing reservoir at MADAM and the treated water transmission mains.

B 8.1.2 The principal units include: an integrated raw water intake and raw water pumping station; raw water transmission pipeline; treatment plant inlet chamber with Parshall flume flowmeter, and clarifier flow division chamber; clarifier structures; rapid sand filters building; contact tank for chlorine dosing; treated water reservoir; used washwater holding tanks; clarifier sludge balancing tanks; thickeners; washwater storage tank; sludge drying beds; chemical building; chlorine building; treated water pumping station; inlet sump to the booster pumping station; booster pumping station, MADAM master balancing reservoir, treated water transmission mains and other works necessary for the completion of the Contract. The civil works include associated structures and buildings, water supply system, overflows, drainage, roads, compound wall, staff housing, plant compound walls, landscaping, pipe bridge and other associated works necessary for the Contract.

B 8.1.3 Mechanical plants shall be provided as per the Mechanical Specification in Part B2 of the Particular Specification. Electrical plants shall be provided as per the Electrical Specification in Part B4 of the Particular Specification. Lighting and small power shall be provided as per the Building Services Specification in Part B6 of the Particular Specification. Instrumentation, Control and Automation plants shall be provided as per the ICA Specification in Part B7 of the Particular Specification.

B 8.1.4 Conceptual drawings are provided for the Works. The conceptual drawings are provided to indicate one of the possible suitable arrangements only. The Contractor has to provide their most optimum civil works design for each of the works and is not mandatory to follow the arrangements shown on the Drawings, unless otherwise stated in the Particular Specification. However, design deviates from the performance requirements entered in the conceptual drawings and the Specification shall be approved by the Engineer prior any construction work to be carried out. Also, the civil works shall comply with all the basic criteria given in this Particular Specifications and the Standard Specification in Part K.

B 8.1.5 The Contractor shall provide all the civil works necessary for the Works under the Contract notwithstanding any omission in the Particular Specification.

B 8.1.6 The civil works shall be sufficient to provide for all the requirements of the plant specifications.

B 8.1.7 Payment for all civil works shall be against the Schedule of Prices in the Contract.

B 8.2 Intake Works/Raw Water Pumping Station Structure

The intake works and the raw water pumping station shall be located at the upstream of river Cauvery, at a distance of 45km west of Dharmapuri. One raw water transmission main of approximate length 6.25 km is to connect the raw water pumping station to the Water Treatment Works. The civil works shall, as a minimum, include: inlet wells, pumpwells, a motor hall with loading bay above these wells, and adjacent switchgear rooms, transformer room and battery room. Staff house shall be provided in the plant area. The intake works/raw water pumping station shall be accessible via a surfaced access road and shall have appropriate compound walling to prevent public access.

B 8.2.1 The intake wells shall have inlets at different levels to provide for extraction at upper levels as the water level in the Cauvery river varies. Each inlet shall be screened and have an isolating penstock to each of the pumpwells, as per the requirements of the Mechanical Specification. Each inlet well shall also be able to isolate from river Cauvery by insertion of stoplogs. Inlets shall be sized to carry flow at no more than 1m/s at any time.

B 8.2.2 The intake well shall have inclined screens for manual raking as described in the Mechanical Specification. The design shall provide suitable access platforms from which the screens can be safely raked. The platform shall be easily accessible from the motor hall, for a person carrying raking equipment and removing screenings.

B 8.2.3 The motor hall shall be situated above the pump well and shall be at a level such that the soffit of the floor slab shall be, as a minimum, 1.5m above the maximum flood level, as indicated on the Drawings.

B 8.2.4 The structures shall be designed to take account of all possible load combinations. Part of the structures that may be submerged shall be designed to withstand the most onerous combination of uplift, differential head across the structure, wave action, wind and seismic forces. Design shall include an analysis of the vibration cause by the mechanical plant and appropriate mitigation. Supports shall be well founded on solid strata using piles and anchors as necessary. Principal load bearing members shall be of reinforced concrete. All engineering metalwork for ladders, handrails and platforms shall be of aluminium alloy. Water retaining structures shall be reinforced concrete with sloped or screeded floors at not less than 0.5% to drainage channels and sumps. As far as possible drainage shall be by gravity, otherwise sumps for submersible pumps shall be provided. Other structures may have reinforced concrete frames and brick infill for non load bearing walls. All roofs shall be flat with a minimum fall of 1 in 250. On no account shall water retaining structures be formed of concrete with a cement render(plaster) finish.

B 8.2.5 The pumpwell shall be of reinforced concrete and one possible arrangement is to have three compartments with dividing walls, as shown on the Drawing. The Contractor might provide different arrangement to the pumpwell depending on his final design of the pumping station.

B 8.2.6 The plan area and shape of each compartment shall be in accordance with approved codes of practice such as BHRA ‘The hydraulic design of pump sumps and intakes’ by MJ Prosser. The Contractor shall design the wells in collaboration with the pump supplier to ensure that the flow conditions approaching the pumps under all operating conditions are smooth and uniform and that the angle of the swirl entering any pump inlet does not exceed 5 degrees or such value as is deemed acceptable by the pump supplier in order that the guarantees he has provided with respect to efficiency and maintenance are met. In addition the sump design must ensure that no air, entrained by flow plunging into the sump or by other features of the proposed design, is carried through to pump inlets. The Contractor shall demonstrate the appropriateness of the design to meet these requirements using physical modelling or other means that may be agreed with the Engineer.

B 8.2.7 Each compartment shall have a cover slab and safe, easy access via a manhole cover and staged ladders. Each compartment shall also have a separate manhole entry no less than 1.2x1.2m. The Contractor shall provide a cradle for lowering operatives into the well via this manhole. The cradle shall be sized to fit through the manhole opening and carry two operatives in safety to the bottom of the well. The cradle shall be stable even when unevenly loaded, have safety rails and safe, secure means of access. The cradle shall be capable of carrying at least 300kg and shall bear a plate stating the safe working load.

B 8.2.8 The Contractor shall provide skips and other accessories, as mentioned in Clause B2.5.8 for silt removal. The system shall be appropriate for handling manually and with the overhead crane. The skips shall be designed to be moved, lowered and raised using the overhead crane.

B 8.2.9 Manhole covers shall be raised at least 50mm above floor level. The raised area shall be profiled smoothly down to the floor to avoid making trip hazards.

B 8.2.10 The plan area and shape of the motor hall should generally follow the layout on the Drawings. Enough space shall be provided between adjacent motors and between a motor and the wall such that the maintenance staff can have sufficient room to perform the dismantiling and subsequent reassembly work of the pumps, motors, valves, pipework etc. Sufficient space shall be provided to enable the dismantled pumps, motors, valves, pipework etc to be moved into the loading bay using the overhead travelling crane. The structure shall have enough head clearance to accommodate an overhead travelling crane that can lift the largest piece of plant with at least 0.5m clearance from any obstruction. The motor hall shall be a clean, well lit, well ventilated, rainproof structure with adequate access to all items of the Plant. Raised platform of removable floorings shall be provided above the pipework to provide clear, easy access to valve actuators, penstock actuators and pump motors, should the operating actuators/handwheels of these valves, penstocks and any parts of the motors that required operation and maintenance are not conveniently accessible with operators standing at the floor of the motor hall. These raised platforms shall be provided with access ladders, handrailings and the like, as that shown in the Drawing. The structure shall be provided with external navigation lights.

B 8.2.11 The building shall incorporate a loading bay in the motor hall. The overhead travelling crane shall be designed to travel into the loading bay and place the largest piece of plant directly onto the back of a suitable vehicle. The loading bay shall have a roller shutter door and be sized to accommodate a suitable vehicle that would be used to transport the largest piece of Plant, with at least 1.0m clearance on either side and to the end of the roller shutter when it is completely opened.

B 8.2.12 A high-voltage switchgear room shall be provided adjacent to the motor hall, large enough to house the switchgear and allow easy access for removal and maintenance. The general arrangement of the room shall make provision for incoming and outgoing power and control cabling, by either placing the switchgear on raised flooring or providing cable trenches. The room shall have adequate provision of space for removal of switchgear. It shall be possible to remove any panel from the room or install additional panel with the same size as the installed panels into the room through the door of the room, without the need to temporarily shifting the installed panels.

B 8.2.13 A separate low voltage switchgear room shall be provided for the equipment other than the pump motors, including small power, lighting, ventilation etc. The room shall have enough space to house the switchgear and allow easy access for maintenance and removal of the panels, in a way same as that mentioned in Clause B8.2.10 above.

B 8.2.14 A separate auxillary transformer room shall be provided for the installation of station transformers, for providing power to the load other than the pump motors; including small power, lighting, ventilation etc. The room shall have enough space to house the indoor type transformers and allow easy access for maintenance and removal.

B 8.2.15 The structure shall be provided with adequate facilities for rainwater drainage and wastewater removal. The structure shall have a flat roof falling to gutters that shall empty the collected rainwater to the river Cauvery via downpipes. Wastewater shall be connected to a septic tank inside the Plant area.

B 8.2.16 An outdoor 11kV intake electrical sub-station shall be provided for the HV metering panels, HV switchgear, 11/3.6kV transformers, ancillary plants and associated control systems. Those structures that are to be used by the Tamil Nadu Electricity Board (TNEB) and the cable ducts/draw pits/cable trenches for TNEB's incoming cable shall be constructed to conform to their requirement. Individual transformer bays and HV switchroom complying with the Electrical Specification in Part B4 of the Particular Specification.

B 8.2.17 Staff housing shall be provided for the operators, helpers and watchers. One no. of type A and two nos. of type B accommodation units shall be located at this Plant, as typically shown on the Drawings. The layout of the houses shall be generally as shown on the standard drawings.

B 8.2.18 Each staff house shall be provided with the following minimum requirements:

- After erection, painted inside and outside with an approved paint;
- All utilities including electricity, water and sanitation;
- An external elevated cold-water storage tank with capacity of at least 3,000 litres in order to obtain a minimum head equal to 3m of water at the outlets;
- Lighting and small power outlets fed from a 230Vac MCB distribution board. The electrical supply for the staff houses shall be provided from the nearest main switchboard;
- Good-quality locks on all doors with two keys for each lock;
- Suitable mosquito screens on all outside doors and windows;
- Each bathroom shall be provided with the following:
  Showers with mixer taps and drain;
  Suitable electric 30 litre hot-water heater for each shower;
  Flush toilet and drain;
  Wash basin, mirror and drain.
- The kitchen shall be provided with the following:
  Kitchen-sink unit with basin and draining boards;
  Work-surface with cupboards above and below;
  Kitchen stove and refrigerator. The stove shall be a four-plate stove, complete with grill, oven and splash back. The refrigerator shall have a volume of at least $0.3m^3$.

B 8.2.19 The intake works/raw water pumping station and the outdoor electrical sub-station shall be fenced off from the exterior by compound walling of, not less than, 2m height. A double leaf access door, the main gate, for vehicles and a single leaf access door, the side gate, for operation personnel shall be provided at the compound wall. The main gate and the side gate shall be positioned adjacently. The distance in between the gate and the roller shutter of the pumping station shall be enough for the vehicle to transport the largest piece of the Plant, as mentioned in Clause B8.2.12, to turn freely after it enters the Plant with the main gate closed behind. Compound walling shall be rendered brickwork with painted finish in accordance with the standard detail drawings. The main and side gates shall be anti-intruder painted steel gates.

B 8.2.20 The intake works/raw water pumping station shall be linked with other facilities in the whole Plant by walkway and access roads. Access roads shall be of, as a minimum, 5m wide for all major structure and equipment in the Plant area. The design of these walkways and access roads shall be submitted in conjunction with the layout of the whole Plant for the approved of the Engineer. Provision shall be made for safe turning for delivery vehicles. Road areas shall contain space for manoeuvring large vehicles. Covered parking for at least six cars shall be provided adjacent to the intake works/raw water pumping station building. Roads and parking areas shall be surfaced with bituminous macadam.

B 8.2.21 Landscaping of the final site shall be provided including tilling and seeding soil and planting suitable species of trees and shrubs as agreed with the Engineer. All grassed areas shall be irrigated.

B 8.2.22 All land around the compound walling disturbed by the works shall be reinstated upon completion of the civil works by tilling the topsoil and seeding with grass mix as per the Specification.

B 8.3 Raw Water Transmission Main

B 8.3.1 The civil works for the raw water transmission main shall include provision, laying, jointing, backfilling and reinstatement between the raw water pumping station and the treatment works.

B 8.3.2 The pipe shall be welded mild steel. Buried pipe shall be factory coated with internal epoxy coating and external coal tar enamel wrap. Exposed pipe shall be factory coated with external epoxy or polyurethane coating and internal epoxy coating. The pipe shall be supplied with spigot/sleeve joints for in-situ welding. Internal and external coatings shall be made good in-situ. External protection at joints shall be heat shrink polyethylene sleeving. Cathodic protection shall be applied to the mild steel pipelines, as per the requirements of Clause B8.8. Epoxy coating shall conform to Clause K17.5.1.6.

B 8.3.3 The pipeline shall generally be laid in accordance with the Drawings and include all fittings shown. The final pipeline route and exact locations of fittings and chambers shall be agreed on site between the Contractor and the Engineer following a preliminary survey to be done by the Contractor. The Contractor shall provide the design of any items not shown on the drawings such as pipe supports, anchor blocks etc. The main shall have a washout at the lowest point

B 8.3.4 The pipeline shall have an outside diameter of no less than 1.5m. Pipe wall thickness shall be in accordance with the Specification.

B 8.3.5 The pipeline shall be commissioned with a complete programme of pressure testing, swabbing/flushing, and disinfection.

B 8.3.6 The Contractor has to conduct all trench excavation and all other necessary work, as specified at Clause K9.5.4 in Volume 3 of the Specification, when the raw water pipeline is required to cross or run along any road. The pipeline shall be buried in the trench and all work to be performed shall conform to the abovementioned clause. As a minimum, the raw water pipeline is required to cross a road from Hogenakkal to Thirupatthur, S.H. 60. Should other road crossings be required along the route of the raw water/treated water pipelines, the Contractor shall conduct the work in accordance with the Specification and any other requirements from relevant department. The cost for the aforesaid work is deemed to be included in the Contract. For pipeline being buried beneath a road, the pipeline works shall be fully completed before the road is surfaced.

B 8.4 Water Treatment Works

B 8.4.1 The civil works for the treatment works shall include all earthworks to form the site area to appropriate levels, and all the structures necessary, including, but not limited to; inlet chamber, Parshall flume channel, flow division chamber; clarifiers, rapid gravity filters; contact tank; treated water reservoir; filter control building; chemical building; chlorine building; sludge thickeners; thickened sludge collection tank; sludge pipeline, sludge drying beds and overflow pipelines/channels as specified in Clause B3.4.2. Additional works shall include all site access roads, drainage, compound wall etc. All structures shall be reinforced concrete unless otherwise stated.

B 8.4.2 The original site comprises a hilly area that shall be excavated to provide a level area for the treatment works. The layout drawings give formation levels that the Contractor shall comply with. The Contractor shall provide all the earthworks and any associated structures such as retaining walls needed to establish the formation levels shown on the Drawings. Any excess excavation arising from the works shall be disposed of to an approved site.

B 8.4.3 Structures for the treatment processes shall be designed to meet the requirements given in the water treatment works specification. Water retaining structures shall be reinforced concrete with sloped or screeded floors at not less than 0.5% to drainage channels and sumps. As far as possible drainage shall be by gravity, otherwise sumps for submersible pumps shall be provided. Other structures may have reinforced concrete frames and brick infill for non load bearing walls. All roofs shall be flat with a minimum fall of 1 in 250.

On no account shall water retaining structures be formed of concrete with a cement render (plaster) finish.

B 8.4.4 Water retaining structures shall be designed to resist water loading due to external water level at ground level. Uplift forces on reservoirs, tanks and pipes shall be calculated assuming that they are empty and the factor of safety against flotation in this condition shall be not less than 1.1.

B 8.4.5 All open tanks shall be provided with handrail protected access walkways all around at the top level of the tank walls. Ladders shall only be provided within chambers. Steps shall be provided to all external access platforms unless it can be demonstrated that steps are impracticable and ladders are absolutely the only alternative. All engineering metalwork for ladders, handrails and platforms shall be of aluminium alloy.

B 8.4.6 All covered tanks shall be provided with approved ventilation cowls. All chambers shall be provided with manholes and approved hinged covers. Manhole openings shall be 750x750mm minimum. Chambers and tanks shall be provided with aluminium ladders. Ladders over 3m long shall have cages.

B 8.4.7 Where a standard Drawing is provided for an item, such as handrails, ladders etc, that item shall comply with that standard detail unless the Contractor submits an alternative detail that is subsequently approved by the Engineer.

B 8.4.8 All pipe work shall be laid in trenches complying with the standard details provided in the Drawings. All valves on buried pipelines shall be in chambers unless otherwise stated. All stop valves shall be butterfly valves unless otherwise stated.

B 8.4.9 The inlet work design shall suit the requirement of Water Treatment Plant Specification at Part B3 of the Particular Specification. It shall, as a minimum, consists of a Parshall flume channel for measuring the inlet flow to the treatment plant, mixing chambers and the flow diversion chambers to the clarifiers.

B 8.4.10 The flow division chamber shall have weirs dividing the flow. The weirs shall discharge into separate chambers feeding separate clarifiers.

B 8.4.11 Clarifiers shall be either sludge blanket or lamella or pulsators or any other design suitable for the Project. At least six clarifiers structures shall be provided, and space left for two additional units to be added in the future. Flocculation shall be carried out hydraulically within sludge blanket clarifiers, and mechanically in separate tanks for Lamella clarifiers. Therefore, when the Contractor choose to provide Lamella clarifiers, separate flocculation channels/chambers, in additional to the Lamella clarifier structures have to be provided. Each Lamella type clarifier shall be equipped with its flocculation chamber that shall comprises of at least two equal and parallel streams and each stream comprises of at least two equal size compartments connected in series. Lamella clarifiers shall be fully enclosed in a building.

B 8.4.12 Ten rapid gravity filters shall be provided. The filters shall be of the duplex type comprising two equal size beds. Space shall be left for an additional two units to be added in the future. The filters shall have a covered central gallery accommodating filter wash consoles, pipework and filtered water channel. The filter walls shall be tiled, tiles to be approved by the Engineer.

B 8.4.13 A two storey filter building shall be provided to house air scour blowers, air compressors, electrical switchgear, store room and separate ladies' and men's toilet/washrooms at ground level. The filter building shall be provided with a covered area for the 33kV/0.433kV transformers adjacent to the electrical switchgear rooms. The air blower and compressor room shall be adequately soundproofed. The building shall have a flat roof accommodating an elevated water storage tank. The upper floor shall have a floor area not less than 300 m^2 and shall accommodate no less than 3nos. offices, 1no. laboratory with chemist's office, 1no. central control room and 1no. mess room. The layout shall generally be as shown on the drawings and façade of the building and the layout shall be approved by the Engineer. The Contractor shall provide all the necessary furniture, which shall include but not be limited to:

- **Each office**

  - 1 No. writing desk-1.5x0.7x0.75m high;
  - 1 No. table of similar dimensions;
  - 6 Nos. wooden or metalwork chairs suited to the desk and tables;
  - 2 Nos. wooden shelving units-1.8m high x0.9m wide x0.4m deep-with four shelves per unit;
  - 1 No. lockable filing cabinet with four drawers;
  - 1 No. wall mounted white board, 2m wide x 1m high, with coloured marker pens;
  - 1 No. washbasin and mirror.

- **Mess room**

  - 4 Nos. tables 1.5x0.7x0.75m high;
  - 10 Nos. wooden or metalwork chairs suited to the desk and tables;
  - 2 Nos. wooden shelving units-1.8m high x0.9m wide x0.4m deep-with four shelves per unit;
  - 1 No. wall mounted white board, 2m wide x 1m high, with coloured marker pens;
  - Facilities for hanging clothing;
  - 2 Nos. washbasins.

At least two Western style separate gents' and ladies' toilets/washroom shall be provided at the ground floor of the filter building. Each toilet/washroom shall have a single western-style toilet, a wash hand basin and a shower stall with shower head. The shower and washbasin shall have an electrically powered hot water supply to provide hot water on demand. The gents' toilet room shall also be provided with a urinal. During the Operation and Maintenance Period, washbasins shall be provided with soap and a handtowel that shall be changed and washed two times per week. The Contractor shall maintain adequate supplies of toilet roll. He shall ensure that the daily cleaning of the toilet areas includes cleaning and disinfection of toilet bowls and seats. Wastewater shall be removed via a waterborne sewerage system, which shall connect to a septic tank at least 30m from the building.

B 8.4.14 Offices and mess room shall have at least one window on each exterior wall, of individual area not less than $2m^2$. Rooms shall be painted to a colour scheme approved by the Engineer and windows shall have curtains to match the colour scheme. Floors of rooms and corridors shall be tiled with polished stone tiles, type and colour to be approved by the Engineer. A separate emergency exit shall be provided. A first aid station shall be placed in the mess room with posters giving basic first aid guidance.

B 8.4.15 A works water supply pump house shall be provided for works water supply pumps located adjacent to the filters and contact tank. The motors and switchgear shall be at a suitable level to avoid flooding.

B 8.4.16 A chlorine contact tank shall be provided adjacent to the filters. The design of the contact tank shall comply with Clause B3.10.1. The tank shall be divided in half lengthwise by a central wall. Baffle walls shall be provided in each half. Flow shall discharge to the treated water reservoir via weirs with adjustable weir plates. The roofs shall be coated internally with approved epoxy paint. The roof surface shall have a waterproof membrane and shall be covered with a 150mm layer of 10mm clean gravel chippings.

B 8.4.17 A treated water reservoir shall be provided. The design of the treated water reservoir shall comply with Clause B3.10.2. The tank shall have two similar compartments fitted with baffles. Each compartment shall have a sump with inverted bellmouth outlet pipe connected to a common manifold connected to the treated water main. The diameter of the outlet pipes shall be not less than 1.5m. Each outlet pipe shall have a butterfly valve. The roof shall be coated internally with approved epoxy paint. The roof surface shall have a waterproof membrane and shall be covered with a 150mm layer of 10mm clean gravel chippings.

B 8.4.18 A sludge balancing tank shall be provided to receive sludge from the clarifiers. The design of the sludge balancing tank shall comply with Clause B3.11.2. One tank with two equal compartments of combined capacity adequate to balance sludge discharges shall be provided. The two compartments shall be interconnected by low level aperture no less than 0.3 x 0.3m with isolating gate and external operating mechanism.

B 8.4.19 A sludge pump house shall be provided for sludge thickener feed pumps. The pump house shall have a common wall to the sludge balancing tank. Motors and switchgear shall be at a suitable level to avoid flooding. The design of the sludge pump house shall comply with Clause B3.11.3.

B 8.4.20 Two circular sludge thickening tanks shall be provided. Each shall have an inwardly sloping floor to a central well, and a peripheral launder. Tanks shall be provided with rotating mechanical scrapers. The design of the sludge thickening tanks shall comply with Clause B3.11.4.

B 8.4.21 A rectangular tank shall be provided for used filter washwater. The design of the used filter washwater tank shall comply with the requirements entered in Clause B3.9.3. It shall have two interconnected compartments, being isolated by a penstock with low level aperture no less than 0.3m x 0.3m with isolating gate and external operating mechanism. The capacity of each compartment of the tank shall be adequate to store as a minimum, the washwater from two consecutive filter washes.

The Contractor shall include sufficient pedestrian access-ways in reinforced concrete, which shall be fitted with handrailing and kick-plates on both sides of the tank and on the common wall throughout their full length, to enable the operational staff to have ready access around each compartment and to the inlet channel. Means of access shall be provided into each compartment of the washwater recovery tank.

B 8.4.22 A chemical building shall be provided for storage, handling, slurry or solution preparation and dosing of aluminium sulphate and hydrated lime. The design of the building shall comply with Clause B3.12.2. It shall include lime and aluminium sulphate storage, aluminium sulphate solution preparation and dosing plant, lime slurry preparation and dosing plant, lime saturator and aluminium sulphate head tank, a switch room and a washroom with washbasin, toilet and shower head. Safety showers and eye baths shall be provided in the solution/slurry preparation area. The requirements to the toilet shall be the same as that specified in Clause B8.4.21.

B 8.4.23 A chlorine building shall be provided for storage, metering and dosing of chlorine gas. The design of the building shall comply with Clause B3.15.2. The building shall incorporate a main area for drum storage with overhead monorail and travelling hoist, and separate rooms for chlorinators, motive water pumps, ejectors and switchgear. There shall be no access between each room. Safety showers with eye baths shall be provided at the entrances of the chlorine drum store. The main area shall be provided with a roller shutter or concertina folding door to provide enough space for delivering and removing 1000kg drums of chlorine using the overhead monorail, which shall extend and be supported outside the building if necessary. All items within the chlorine building shall be of approved fire resistant materials.

B 8.4.24 The elevated water storage tank shall be provided on the roof of the filter building. The design of the elevated water storage tank shall comply with Clause B3.17.2. It shall be fully covered and have two interconnected compartments of equal capacity with isolating facilities to enable one compartment to be taken out of service for cleaning and maintenance. Each compartment shall have a high level inlet and low level outlet. The tank shall have an overflow. The roofs shall be coated internally with approved epoxy paint. The roof surface shall have a waterproof membrane and shall be covered with a 150mm layer of 10mm clean gravel chippings. Stairs shall be provided for access to the roof of the tank. Access to the inside shall be provided via a manhole with inclined aluminium ladder 2.4m long, to a reinforced concrete platform with aluminium handrailing. Reinforced concrete steps shall be provided down to the floor. Platform and steps shall have approved non-slip surface finishes.

B 8.4.25 A minimum of eight drying beds shall be provided and shall be used in rotation each being in various stages of filling, dewatering and emptying. The design of the drying beds shall comply with Clause B3.11.9.

B 8.4.26 The sludge drying beds shall be constructed to the levels shown on the Drawings. Individual beds shall be separated by reinforced concrete walls which shall provide a minimum of 300mm freeboard when the higher of adjacent drying beds is overflowing. The height of the drying beds shall be designed such that the capacity of the drying beds shall comply with the requirements as entered in Clause 3.11.9 and all the sludge drying beds shall fit into the assigned area shown in the Contract Drawing. The drying beds shall be of water retaining concrete structure

B 8.4.27 Site drainage, drainage from water retaining structures, overflows, basements and underdrains shall be discharged to the point specified outside the site boundaries. A septic tank shall be provided for domestic wastewater.

B 8.4.28 The site shall have access roads at least 5m wide to all major process units, chemical building, chlorine building, electrical intake sub-station, raw water pumping station, sludge lagoons and ancillary works, as indicated on the drawings. Provision shall be made for safe turning for delivery vehicles. Road areas shall contain space for manoeuvring large vehicles. Covered parking for at least six cars shall be provided adjacent to the filter building. Roads and parking areas shall be surfaced with bituminous macadam.

B 8.4.29 Underdrains shall be provided below reservoir floors and other water retaining structures as necessary. Outlets from underdrains shall be designed so that leakage can be easily identified. Flows from underdrains shall be collected in sumps and pumped to drainage or overflow system.

B 8.4.30 Buildings shall have all necessary provisions for services such as trenches, ducts, cable trays, racks etc. External service trenches shall be provided for cables and chemical dosing and sampling lines, which shall be neatly arranged on racks to be visible and easily accessible. Where several services run in parallel they shall normally be grouped in a common trench with provision for man access, except that chlorine lines shall not be run in the same trench as cables. Trenches in roads shall be provided with continuous removable covers designed to withstand vehicle loading. Trenches shall be clearly identifiable and shall not be covered with road surfacing.

B 8.4.31 The Contractor shall provide permanent signboards for the treatment works, intake work/raw water pumping station, booster pumping station and the MADAM master balancing reservoir. The signboards shall bear text and logos as defined by the Engineer. The signboard shall typically be 2.5m wide by 2m deep. The sign shall be corrosion resistant, weatherproof and mounted on painted steel posts set in concrete. The design shall be approved by the Engineer.

B 8.4.32 The Contractor shall provide outdoor 33kV or 11kV intake electrical sub-station for the HV metering panels, HV switchgear, 33kV or 11kV/12kV or 3.6kV transformers, ancillary plants and associated control systems. Those structures that are to be used by the Tamil Nadu Electricity Board (TNEB) and the cable ducts/draw pits/cable trenches for TNEB's incoming cable shall be constructed to conform to their requirement. Individual transformer bays and HV switchroom complying with the Electrical Specification in Part B4 of the Particular Specification.

B 8.4.33 Staff housing shall be provided for the operators, helpers and watchers. One no. of type A and four nos. of type B accommodation units shall be located at this Plant, as typically shown on the Drawings. The layout of the houses shall be generally as shown on the standard drawings. Each staff house shall conform to the requirements as entered in Clause B8.2.18.

B 8.4.34 All the structures of the Treatment Plant as mentioned in Clause B8.4, including the outdoor electrical sub-stations and also the Treated Water Pumping Station as mentioned in Clause B8.6, shall be fenced off from the exterior by compound walling of, not less than, 2m height. A double leaf access door, the main gate, for vehicles and a single leaf access door, the side gate, for operation personnel shall be provided at the compound wall. The main gate and the side gate shall be positioned adjacently and the main gate shall be positioned to at a location as agreed with the Engineer, or as that stated in the Drawing. Compound walling shall be rendered brickwork with painted finish in accordance with the standard detail drawings. The main and side gates shall be anti-intruder painted steel gates.

B 8.4.35 Landscaping of the final site shall be provided including tilling and seeding soil and planting suitable species of trees and shrubs as agreed with the Engineer. All grassed areas shall be irrigated

B 8.5 Treated Water Pipeline

B 8.5.1 The Contractor shall provide a pipeline from the Treated Water Pumping Station to the inlet sump of the Booster Pumping Station as shown on the Drawings. The pipe shall be 1.5m external diameter welded mild steel and with the requirements same as Clause 8.3. The pipe shall be laid with a minimum cover of 1.2m.

B 8.5.2 Pipes shall be welded mild steel, factory coated with internal cement mortar coating and external coal tar enamel wrap for buried pipes. External coating for exposed pipe shall be factory applied sprayed polyurethane or fusion bonded epoxy. The pipe shall be supplied with spigot/sleeve joints in-situ welding. Internal and external coatings shall be made good in-situ. External protection at joints on coal-tar coated pipe shall be made good with either coal tar enamel or polyethylene heat shrink wrap. External protection at joints on all other coatings shall be made good with polyethylene heat shrink wrap. Cathodic protection shall be applied to the mild steel pipelines, as per the requirements of Clause B8.8.

Mild steel pipe of diameters equal to or less than 900mm may be used for certain crossings. The Contractor may provide these pipes with butt welded joints provided that he can demonstrate that the internal lining at the joints can be made good in-situ to the same standard as provided elsewhere. Alternatively, he may provide these pipes with flanged joints, in which case he shall design the flanges to withstand all the structural loads, and submit his calculations to the Engineer for approval. The Contractor may propose an alternative form of joint, which shall be subject to the approval of the Engineer.

B 8.5.3 The pipe shall be flushed, disinfected and pressure tested. The blank end shall be a flanged end fitted with a blank flange. The blank end shall be buried and a marker post placed stating the date of burial and the depth of cover.

B 8.5.4 The Contractor has to supply, install all necessary pipe bridges for pipelines crossing rivers, nallas and the like. As a minimum, the treated water pipeline will be required to run across River Chinnar. The pipe bridge to provide shall conform to the requirements entered in Drawing I/500/008/TA and Volume 3 of the Specification. Should other river/nalla/culvert crossings be required along the route of the treated water pipelines, the Contractor shall conduct the work in accordance with the Specification and any other requirements from relevant department. The cost for the aforesaid work is deemed to be included in the Contract.

B 8.6 Treated Water Pumping Station and Booster Pumping Station Structures

B 8.6.1 The intake pipeline to the Treated Water Pumping Station inlet pipe manifold shall be taken from the treated water reservoir. The discharge of the Treated Water Pumping Station shall be connected to the inlet sump of the booster pumping station as detailed in Clause B8.10, via the treated water pipeline as detailed in Clause B8.5. The intake pipeline to the Booster Pumping Station shall be taken from the outlet of the inlet sump to the Booster Pumping Station and shall be connected to the inlet pipe manifold of the Booster Pumping Station. The Contractor shall be responsible to provide and install this pipeline that shall be welded mild steel and conform to the same requirements as Clause 8.3. The discharge of the Booster Water Pumping Station shall be connected to the MADAM master balancing reservoir, via the booster pumping station transmission main detailed in Clause B8.7.

The requirements as entered in Clauses B8.6.2 to B8.6.14 shall be applicable to both the Treated Water and Booster Pumping Station Structures.

B 8.6.2 The structures shall be designed to take account of all possible load combinations. Parts of the structure that may be submerged shall be designed to withstand the most onerous combination of uplift, differential head across the structure, wave action, wind and seismic forces. Design shall include an analysis of the vibration cause by the mechanical plant and appropriate mitigation. Supports shall be well founded on solid strata using piles and anchors as necessary. Principal load bearing members shall be of reinforced concrete. All engineering metalwork for ladders, handrails and platforms shall be of aluminium alloy. Water retaining structures shall be reinforced concrete with sloped or screeded floors at not less than 0.5% to drainage channels and sumps. As far as possible drainage shall be by gravity, otherwise sumps for submersible pumps shall be provided. Other structures may have reinforced concrete frames and brick infill for non load bearing walls. All roofs shall be flat with a minimum fall of 1 in 250.

B 8.6.3 The pump hall shall be of reinforced concrete and one possible arrangement is that as shown on the Drawing. The Contractor might provide different arrangement to the pump hall depending on his final design of the pumping station.

B 8.6.4 The plan area and shape of the pump hall should generally follow the layout on the Drawings. Enough space shall be provided between adjacent motors/pumps and between a motor/pump and the wall such that the maintenance staff can perform the dismantiling and subsequent reassembly work of the pumps, motors, valves, pipework etc. Sufficient space shall be provided to enable the dismantled pumps, motors, valves, pipework etc to be moved into the loading platform using the overhead travelling crane. The structure shall have enough head clearance to accommodate an overhead travelling crane that can lift the largest piece of plant with at least 0.5m clearance from any obstruction. The pump hall shall be a clean, well lit, well ventilated, rainproof structure with adequate access to all items of the Plant. A raised platform of removable flooring shall be provided above the pipework to provide clear, easy access to valve actuators, pumps motors, should the operating actuators/handwheels of these valves, any parts of the motors and the pumps that required operation and maintenance are not conveniently accessible with operators standing at the floor of the pump hall. The structure shall be provided with external navigation lights.

B 8.6.5 The building shall incorporate a loading platform in the pump hall. The overhead travelling crane shall be designed to travel into the loading bay and place the largest piece of plant directly onto the back of a suitable vehicle. The loading bay shall have a roller shutter door and be sized to accommodate a suitable vehicle that would be used to transport the largest piece of Plant, with at least 1.0m clearance on either side and to the end of the roller shutter when it is completely opened.

B 8.6.6 A high-voltage switchgear room shall be provided adjacent to the pump hall, large enough to house the switchgear and allow easy access for removal and maintenance. The general arrangement of the room shall make provision for incoming and outgoing power and control cabling, by either placing the switchgear on raised flooring or providing cable trenches. The room shall have adequate provision for removal of switchgear. It shall be possible to remove any panel from the room or install additional panel with the same size as the installed panel into the room through the door of the room, without the need to temporarily shifting other panels.

B 8.6.7 A separate low voltage switchgear room shall be provided for the equipment other than the pump motors, including small power, lighting, ventilation etc. The room shall have enough space to house the switchgear and allow easy access for maintenance and removal of the panels, in a way same as that mentioned in Clause B8.6.8 above.

B 8.6.8 A separate auxiliary transformer room shall be provided for the installation of station transformers, for providing power to the load other than the pump motors; including small power, lighting, ventilation etc. The room shall have enough space to house the indoor type transformers and allow easy access for maintenance and removal.

B 8.6.9 A room shall be provided for the use as a workshop for the operators. The room shall have a floor area not less than $80m^2$ and shall have a fully equipped washroom with washbasin attached. There shall be a first aid station with posters giving basic first aid guidance. The requirements of the equipment, furniture and the like are entered in Part B2 of the Mechanical Specification of the Particular Specification.

B 8.6.10 The workshop shall have at least three windows on the exterior wall, of individual area not less than $2m^2$. The room shall be painted to a colour scheme approved by the Engineer. The room shall have a roller shutter accessing to the loading platform into the pump hall.

B 8.6.11 Each of the two structures shall be provided with adequate facilities for rainwater drainage and wastewater removal. The structure shall have a inclined roof falling to gutters and convey to the bottom of the structures via downpipes. Rainwater collected shall be diverted and distributed evenly to the nearby forests. Wastewater shall be connected to a septic tank inside the Plant area.

B 8.6.12 An outdoor HV intake electrical sub-station building shall be provided for both pumping station structures. HV metering panels, HV switchgear, pump motor transformers, ancillary plant and associated control systems. Those structures that are to be used by the Tamil Nadu Electricity Board (TNEB) and the cable ducts/draw pits/cable trenches for TNEB's incoming cable shall be constructed to conform to their requirement. Individual transformer bays and HV switchroom complying with the Electrical Specification in Part B4 of the Particular Specification.

B 8.6.13 Staff housing shall be provided for the operators, helpers and watchers. One no. type A and two nos. type B accommodation units shall be located at the Booster Water Pumping Station Plant, as typically shown on the Drawings. The layout of the houses shall be generally as shown on the standard drawings. Each staff house shall conform to the requirements as entered in Clause B8.2.18.

B 8.6.14 The Booster Pumping Station structure and its associated outdoor electrical sub-stations shall be fenced off from the exterior by compound walling of, not less than, 2m height. A double leaf access door, the main gate, for vehicles and a single leaf access door, the side gate, for operation personnel shall be provided at the compound wall. The main gate and the side gate shall be positioned adjacently. The distance in between the gate and the roller shutter shall be enough for the vehicle to transport the largest piece of the Plant, as mentioned in Clause B8.6.4, to turn freely after it enters the Plant with the main gate closed behind. Compound walling shall be rendered brickwork with painted finish in accordance with the standard detail drawings. The main and side gates shall be anti-intruder painted steel gates. The Treated Water Pumping Station and its associated outdoor electrical sub-stations shall form part of the Treatment Plant and shall be fence off by compound wall as specified in Clause B8.4.34.

For Booster Pumping Station Plant, the double leaf access gate as mentioned above shall be installed at the side of the compound wall where the inlet pipework from the inlet sump to the Booster Pumping Station is located. This double leaf access gate shall lead to an access road from the Booster Pumping Station Plant to its inlet sump.

B 8.6.15 Landscaping of the final site shall be provided including tilling and seeding soil and planting suitable species of trees and shrubs as agreed with the Engineer. All grassed areas shall be irrigated.

B 8.6.16 All land around the compound walling disturbed by the works shall be reinstated upon completion of the civil works by tilling the topsoil and seeding with grass mix as per the Specification.

B 8.7 Water Pipeline from Booster Pumping Station

B 8.7.1 The Contractor shall provide a pipeline from the Booster Pumping Station to the MADAM master balancing reservoir as shown on the Drawings. The pipe shall be 1.5m external diameter welded mild steel and with the requirements same as Clause 8.3. The pipe shall be laid with a minimum cover of 1.2m.

B 8.7.2 The protection coating for the water pipelines shall comply with Clause B8.5.2.

B 8.7.3 The pipe shall be flushed, disinfected and pressure tested. The blank end shall be a flanged end fitted with a blank flange. The blank end shall be buried and a marker post placed stating the date of burial and the depth of cover.

B 8.8 Cathodic protection

B 8.8.1 General

Cathodic protection of the pipelines shall be attained by Impressed Current Cathodic Protection (ICCP) and boosting the protection by the use of sacrificial anodes, whenever it is necessary. The cathodic protection system to provide shall conform to the requirements of the ICCP system entered in Clause K23 “Cathodic Protection of Steel Pipelines” in Volume 3 of the Specification and the sacrificial anode cathodic protection system requirement entered in Clause B8.8.3 below. Additional to the standards that are entered in Clause K23, the cathodic protection system shall also conform to the following standards:

BS 7361 Part 1 1991 'Cathodic Protection Part 1 - Code of Practice for Land and Marine Applications' British Standards Institution, U.K;

BS EN 12473 General principles of cathodic protection in sea water;

BS EN 12474 Cathodic protection for submarine pipelines;

BS EN 12696 Cathodic protection of steel in concrete Part 1: Atmospherically exposed concrete;

BS EN 12954 Cathodic protection of buried or immersed metallic structures – General principles and application for pipelines;

BS EN 13173 Cathodic protection for steel offshore floating structures;

BS EN 13174 Cathodic protection for harbour installations;

NACE INTERNATIONAL (NACE) SP0169 (2007) Control of External Corrosion on Underground or Submerged Metallic Piping Systems;

NACE INTERNATIONAL (NACE) SP0572 (2007) Design, Installation, Operation and Maintenance of Impressed Current Deep Groundbeds.

The Contractor shall employ and appoint a "Corrosion Engineer" to supervise, inspect, test and commission the installation of the cathodic protection system. The "Corrosion Engineer" shall be an engineer with certification or licensing that includes education and experience in cathodic protection of buried or submerged metal structures, or a person certified by relevant authority as a cathodic protection specialist. Such a person shall have not less than five years experience in the cathodic protection of underground buried pipelines. The Contractor shall submit evidence to justify the qualifications of "Corrosion Engineer" to the Engineer for review and approval.

The Corrosion Engineer shall design the cathodic protection system by taking into account of the followings:

D: Total surface area of the pipelines;
E: Type of coating and condition of coating at the pipelines;
F: Total bare surface area to be protected shall be assumed to be, as a minimum, 25% of the total surface area of the pipelines;
G: Minimum current density of 10 mA/m^2 to the protected surface area;
H: Chemical analysis of the raw/treated water and the resistivity expressed in ohm-cm;
I: Minimum anode design life of twenty (25) years; and
J: Economic and maintenance convenience consideration.

The design for the cathodic protection system shall be submitted to the Engineer for approval and should be the pre-requisite condition for any pipe laying work to commence.

B 8.8.2 Impressed Current Cathodic Protection (ICCP)

ICCP shall be used as the primary cathodic protection method for the pipelines under the Contract. Sacrificial anodes cathodic protection shall only be used as a supplementary cathodic protection method to be installed in conjunction with the ICCP to boost the protection locally, when it is necessary; or under scenario where ICCP is unable to work effectively at a particular pipeline installation.

The ICCP system shall utilize an external direct current electrical source that forces the direction of the current, instead of the natural galvanic cell reaction when the pipelines are buried and in contact with soil. The positive terminal from the power source is connected to the ground bed anode and the negative terminal is connected to the cathode, which shall be the pipeline. The direct current electrical source shall be derived from an alternating current sources using a rectifier to perform the ac/dc conversion. The rectifier and its associated equipment shall confirm to the requirements entered in Clause K23.

Metal oxide coated titanium anodes, platinized titanium anodes, graphite anodes or silicon iron anodes shall be used. The Contractor shall submit their design of the anodes, with justification to show that the material chosen will provide the best performance at the installed sites, for the approval by the Engineer.

(a) Graphite anodes

Maximum allowable current density for the anode surface area, in application of pipelines buried in soil, shall be 10.76A/m^2. Chemical composition of the graphite anode shall be:

Impregnant	6.5 percent maximum
Ash	1.5 percent maximum
Moisture & Volatiles	0.5 percent maximum
Water Soluble Matter	1.0 percent maximum
Graphite	Remainder

c) Mixed metal oxide coated titanium anode

Mixed metal oxide coated titanium anodes shall be provided by a firm that is regularly engaged in and has, as a minimum, 5 years experience in manufacturing and applying mixed metal oxide coatings to titanium anode substrates. The mixed metal oxide coated titanium anodes shall conform to the following requirements:

(i) Conductive Material

Titanium substrate coated with an inert, dimensionally stable, electrically conductive coating, with average composition of a 50/50 atomic percent, mixture of iridium and titanium oxides with a small amount of tantalum and ruthenium, 0.002 ohm-centimeter maximum resistivity, 50 MPa minimum adhesion or bond strength, and capable of sustaining a current density of 100 A/m^2 in an oxygen generating electrolyte at 66^0C for 20 years. Sinter the mixed metal oxide coating to the titanium surface as to remain tightly bound to the surface when bent 180^0 onto itself;

- Anode Life Test

An accelerated current capacity life test shall be performed on every lot of anode wire used to construct the anode as described. The anode wire material shall sustain current densities of 100 A/m^2 in an oxygen generating electrolyte for 20 years. The manufacturer shall certify that a representative sample taken from the same lot used to construct the anode, has been tested and meets the following criteria:

The representative sample shall be 125 mm in length and be taken from the lot of wire that is to be used for the anode;

The cell containing the anode shall be powered with a constant current power supply for the 30 day test period;

The test cell sustains a current density of 10,000 A/m^2 in a 15 weight percent sulfuric acid electrolyte at 66^0 C without an increase in anode to cathode potential of more than 1 volt.

- Adhesion or Bond Strength Test

Determine the adhesion or bond strength by epoxy bonding a 2.54 mm diameter stud to the ceramic coating and measuring the load to failure of either the epoxy or the interface between the coating and the substrate.

B 8.8.3 Sacrificial anodes cathodic protection system

Sacrificial anodes cathodic protection (SACP) shall only be used as a supplementary cathodic protection method to be installed in conjunction with the ICCP to boost the protection locally, when it is necessary; or under scenario where ICCP is unable to work effectively at a particular pipeline installation.

The SACP shall be done by using sacrificial anodes in form of extruded magnesium ribbon anode laid in the pipe trench parallel to pipeline as shown in the drawing No: STD/PL/020/TA and STD/PL/021/TA. The length of ribbon at hot spot shall be length of hot spot pocket + 10.0 m on each side of pocket but not less than 100 m. The ribbon anode shall be connected the pipeline by means of tail cable with thermit welded joint.

Extruded magnesium ribbon anode shall be of the specifications that are stated in the following. Contractor shall furnish test certificate of chemical composition, dimensions and weight.

Material Composition:

• Element	% by Weight
• Zinc	0.01 max
• Aluminium	0.01 max
• Manganese	0.5 – 1.3
• Copper	0.02 max
• Iron	0.03 max
• Nickel	0.001 max
• Others (metal)	0.05 max each 0.30 max total
• Magnesium	Balance

Open circuit Potential	:	1.6 V with respect to saturated copper – copper sulphate reference cell
Consumption rate	:	kg per Amp – Year
Size	:	3/8'' x 3/8'' cross section
Insert	:	Continuous 1/8'' iron wire core
Weight	:	0.24 lbs per foot or 0.357 kg per m
Anode tail cable	:	1C x 25 sq.mm PE insulated PVC sheathed high conductivity stranded unarmored copper conductor cable.
Heat shrinkable sleeve	:	Heat shrinkable sleeve of suitable size to shrink on anode and anode tail cable to seal the cable to anode core joint.
Job Description	:	The magnesium ribbon anodes wherever required shall be installed prior to backfilling of trench as follows;

The length of Magnesium ribbon anode equal to length of pipeline in soil resistivity < 100 ohm – m + 20 m shall be cut from spool.

The ribbon anode shall be laid in cable trench starting 10 m before and ending 10 m after chainage of pipeline to be provided with cathodic protection at each location as shown in tender Drawing.

The core at extreme ends of the ribbon anode shall be exposed and cleaned thoroughly.

1 C x 6 sq.mm copper conductor each 5 m long shall be soldered to the core at both ends using silver solder (EUTEC ROD 157).

The soldered cable to anode core shall be directly thermit welded to the pipeline. The procedure of thermit welding and encapsulation of pipe to cable joint is given in the tender Drawing.

Soft soil shall be backfilled around anode before pipeline trench is backfilled.

- **Initial Investigation**

The Contractor shall carry out soil resistivity surveys at 1000 m intervals, on ROW (Right or Way) for buried pipeline under procedure given below to identify hot spots.

Soil resistivity survey shall be carried out by 4 Pin Wenner technique at pin spacings of 1.5 m and 2 m.

Additional readings shall be taken at following location or positions

At nalla, river, marshy areas etc i.e. where burried pipeline is close to water bodies.

Location/position where initial ERT survey show low value in proximity of 100 ohm – m or drastic change in resistivity value from adjoining reading.

If the ratios of two consecutive readings is greater than 2 and lower of the two readings is less than 200 ohm – m, additional reading shall be taken at mid point.

If the ratio of additional reading to reading on either side is also greater than 2, another reading shall be taken between the mid point and the reading which is differing by ratio of 2. This procedure shall be followed, but minimum gap between readings shall be 100 m.

- Based on the soil resistivity readings, the length of pipeline [to the nearest 100 m] in soil resistivity less than 100 ohm – m shall be identified.

Based on the soil resistivity survey, the contractor shall prepare a detailed report with schematic drawing showing the soil resistivity on ROW clearly highlighting the chainage where the soil resistivity is less than <100 ohm – m.

- Final locations

The results of the survey shall be furnished to the Engineer, who shall determine the locations and extents of sacrificial anodes to be installed. The Contractor shall install all such anodes in the trenches during laying of the pipeline.

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B 8.9 Master balancing reservoir at MADAM

B 8.9.1 Scope

This section covers particular requirements applicable to the civil and building aspects of the works. The specifications for Plant, materials and workmanship appear elsewhere.

B 8.9.2 Scope of the works

The activities include:

- Construction of the master balancing reservoir;
- Construction of chambers for flowmeters (Two nos. One no. of chamber for DN1000 flowmeter and one no. of chamber for DN1500 flowmeter), inlet isolating valves (Two nos. Each no. of chamber shall be used to install DN1500 valve) and outlet isolating valves (2 nos. for DN1000 valves and 2 nos. for DN1500 valves),
- Construction of small concrete and brick Telemetry and Power House,
- Construction of chamber for washout valve,
- Supply and installation of valves and pipework to connect to the reservoir ancillary pipework,
- Ducting and cable draw pits,
- Laying site roads,
- Fencing, landscaping and drainage;
- Road lighting;
- Lighting for the master balancing reservoir;
- Staff houses;
- Supply and install pipelines (DN1000 and DN1500) to 1m outside the compound wall of the Plant, for connection to pipelines by contractor of Package II and Package V respectively, as detailed in B8.9.8.

B 8.9.3 General requirement to the works

(a) The master balancing reservoir shall be covered by reinforced concrete covers. The effective storage capacity of the reservoir shall be 24 million litres. The reservoir shall be provided with a division wall to provide two equal capacity compartments, so that a compartment may be drained down for maintenance, whilst the other compartment remaining operational. Each compartment of the reservoir shall be designed to ensure through circulation of water in the reservoir.

The minimum freeboard of the main balancing reservoir shall be 500mm and 150mm during normal operation and during overflow at the maximum rate respectively.

The floor of the reservoir shall be sloped for drainage at a minimum fall of 1 in 200, either directly to the drainage sump or indirectly via drainage channels in the floor.

(b) Each compartment shall be provided with one no. of DN1500 inlet valve. Each reservoir compartment shall be provided one nos of DN1000 outlet valve and one no. of DN1500 outlet isolating valve. Each compartment shall be provided with drainage and overflow to the site drainage system and water level transmitters. Each compartment of the master balancing reservoir shall be provided with an overflow.

(c) Two nos. of flowmeter chambers shall be constructed at the discharge side of the master balancing reservoir. One no. of DN1000 electromagnetic flowmeter and one no of DN1000 isolating valve shall be installed at one of these two flowmeter chambers. At the other flowmeter chamber, one no. of DN1500 electromagnetic flowmeter and one no of DN1500 isolating valve shall be installed.

(d) At each compartment of the master balancing reservoir, two sets of access ladders being located at two different positions shall be installed for operation and maintenance staff to access to the top of the reservoir. An access opening at the concrete cover of the reservoir, not smaller than 1.2m x 1.2m, shall be provided at the immediate end of the abovementioned access ladders. The openings shall be covered by stainless steel plate hinged at one end. Access covers shall be sealed and lockable and shall be installed on concrete upstands 150mm above the roof slab. Underneath each opening, a concrete stairway shall be provided for operation and maintenance staff to access the bottom of the reservoir compartment. Aluminium handrailings and toeboards shall be provided for all access ladders and stairways.

(e) The reservoir shall be provided with all pipework, valves, washout and overflow pipework and all necessary fittings and fixings.

(f) Two sets of ultrasonic level measuring meters, in a duty/standby configuration, shall be installed in each compartment of the master balancing reservoir. Two resistivity type level electrodes shall be installed at each compartment to detect the high-high and low-low levels inside the compartment;

B 8.9.4 Staff housing

Staff housing shall be provided for the operators, helpers and watchers. One nos. type A and four nos. type B accommodation units shall be located at the master balancing reservoir at MADAM, as typically shown on the Drawings. The layout of the houses shall be generally as shown on the standard drawings. Each staff house shall conform to the requirements as entered in Clause B8.2.18.

B 8.9.5 Telemetry and power house

The Contractor shall construct the telemetry and power house that shall be located at the position indicated on the Drawings, or as otherwise agreed with the Engineer.

The telemetry and power house is for the installation of the following equipments:

a) The incoming mccb/fuseswich panel for terminating of the 400V power supply cable from the switchboard at the Pennagaram Union booster pumping station, to be provided by the contractor of Package II. The Contractor has to review the design, determine the current rating of the feeder and advise the contractor of Package II, to enable them to furnish the design of the switchboard. As a minimum, the contractor of Package II will provide one three phases and neutral, 400Vac 200A supplies. At the Pennagaram Union booster pumping station, a changeover panel will be installed such that the abovementioned 400Vac 200A supplies will be able to changeover from the failure supply to the healthy supply there. The contractor of Package II will make the application on behalf of the Employer from TNEB for the power supply to the switchboard at the Pennagaram booster pumping station;

b) Wall-mounted mccb distribution panel. One incomer mccb shall be installed to accept the power from the outgoing circuit of the incoming mccb/fuseswitch that is fed from the Pennagaram Union booster pumping station switchboard. Seven outgoing mccb shall also be installed in this panel. One outgoing mccb shall be connected to a mcb board for the 'small power and lighting' of the works and the second outgoing mccb shall be connected to another mcb board for the instrument supply. Both these two mcb boards shall be installed inside the telemetry and power house. The remaining five outgoing mccb shall each be connected to the consumer incoming unit at each staff house;

c) 'Instrument supply mcb board' shall be installed for providing power to the electromagnetic flowmeter transmitter, the ultrasonic level transmitters, the Local Control Panel as described in sub-paragraph (e) below and the level electrode controllers. 'Small power and lighting mcb board' shall be installed for providing power supply to the road lightings, the lightings for the

d) master balancing reservoir and the building services electrical equipment at the 'telemetry and power house'. The Contractor has to provide and install two 1.5m T5 fluorescent lighting and two 230Vac 13A socket outlets in the 'telemetry and power house';

e) The road lighting control panel with overriding switch and the master balancing reservoir lighting control panel with overriding switch;

f) The Local Control Panel for the PLC, I/Os and the associated telemetry equipment. The electromagnetic, the ultrasonic level transmitters, the electrode level signals for the main balancing reservoir at MADAM and the control/signal cables from the Pennagaram booster pumping station (to be provided by the contractor of Package II) shall be wired back to this panel and these signals be transmitted to the Control Centre Room (CCR) at the filter building of the Water Treatment Plant.

B 8.9.6 Access roads and pathways

Access roads and pathways shall be laid in accordance with the Drawings. All roads and parking areas shall be surfaced with water-bound macadam overlain by a 20mm carpet of bituminous macadam.

All pathways shall be hard surfaced with textured concrete flags. Flags shall be soundly laid on a 50mm bed of 6:1 sand: cement and joints pointed with mortar.

B 8.9.7 Landscaping

The Contractor shall reinstate all the disturbed land to the levels shown on the Drawings, or as agreed with the Engineer. The Contractor shall reinstate the land with approved topsoil, which shall be properly tilled and seeded with an approved grass mixture. The Contractor shall also plant such trees and shrubs as directed by the Engineer. The lump sum in the bill of quantities for landscaping shall be deemed to cover all such items. The Contractor shall tend the landscaping, by watering and cutting as necessary, until it is well established. This shall be for a period of no less than three months, or until the Engineer is satisfied that the landscaping is properly established.

B 8.9.8 Interface with other contractor

The following works has to be supplied and installed by the Contractor for future use by the contractor of Package II:

(a) One (1) no. of 1.5m mild steel pipe connecting the outlet side of the master balancing reservoir to an access point, about 1m, from the compound boundary wall of this Plant for future connection by the contractor of Package II. The exact setting-out of this pipe shall be determined by the Engineer on site;

(b) One DN1500 standard tee shall be installed at the inlet pipelines to the compartment 2 of the master balancing reservoir. One DN1500 to DN 600 with flange end at this side shall be connected to the standard tee as mentioned above. A blind flange shall be installed to temporarily cover the DN600 end of the reducer;

(c) All cable ducting and draw pits that are necessary to connect the Pennagaram booster pumping station to the Telemetry and Power House, as mentioned in Clause B8.9.5. The cable ducting are used for laying of the power supply cables from the Pennagaram booster pumping station switchboard, the control/signal cables from the devices in the Pennagaram booster pumping station to the Local Control Panel in the Telemetry and Power House.

The contractor of Package II is to construct: “Treated water trunk mains from Master Balancing Reservoir at MADAM to Uthangarai Unions, branch pipelines, union reservoirs, panchayat reservoirs, sumps, overhead tanks, chlorination stations, booster pumping stations, instrumentation, electrical and mechanical works for Pennagaram, Nallampalli, Dharmarpuri, Mathur & Uthangarai Unions”. The Engineer will arrange meetings among himself, the Contractor and the project manager for the contractor of Packages II to agree a programme for the connection of their necessary pipelines to the master balancing reservoir. The Contractor shall allow the contractor of Package II to access the site area of the master balancing reservoir during the Contract period, to enable them to conduct their works.

The Contractor shall coordinate with this contractor so that hydraulic pressure test including the length of pipeline being supplied and installed by the Contractor can be done with the pipelines of this contractor after the connection has been done.

B 8.9.9 The master balancing reservoir and the staff houses shall be fenced off from the exterior by compound walling of, not less than, 2m height. A double leaf access door, the main gate, for vehicles and a single leaf access door, the side gate, for operation personnel shall be provided at the compound wall. The main gate and the side gate shall be positioned adjacently. Compound walling shall be rendered brickwork with painted finish in accordance with the standard detail drawings. The main and side gates shall be anti-intruder painted steel gates.

B 8.10 Inlet Sump to Booster Pumping Station

B 8.10.1 Scope

This section covers particular requirements applicable to the civil aspects of the works. The specifications for Plant, materials and workmanship appear elsewhere.

B 8.10.2 Scope of the works

The activities include:

(a) Construction of the inlet sump to Booster Pumping Station;
(b) Construction of chamber for washout valve,
(c) Supply and installation of valves and pipework to connect to the reservoir ancillary pipework;
(d) Fencing, landscaping and drainage;
(e) Lighting for the inlet sump of the Booster Pumping Station;
(f) Compound wall to fence off the inlet sump of the Booster Pumping Station from the exterior.

The works shall be provided as shown on the Drawings.

B 8.10.3 General requirements to the works

(a) The inlet sump shall be covered by reinforced concrete covers. The effective storage capacity of the reservoir shall be around 3.5 million litres. The reservoir shall be provided with a division wall to provide two equal capacity compartments, so that a compartment may be drained down for maintenance, whilst the other compartment remaining operational. Each compartment of the reservoir shall be designed to ensure through circulation of water in the reservoir.

The minimum freeboard of the main balancing reservoir shall be 500mm and 150mm during normal operation and during overflow at the maximum rate respectively.

The floor of the reservoir shall be sloped for drainage at a minimum fall of 1 in 200, either directly to the drainage sump or indirectly via drainage channels in the floor.

(b) Each compartment shall be provided with inlet and outlet isolating valves, drainage and overflow to the site drainage system. Each compartment of the inlet sump shall be provided with an overflow.

(c) At each compartment of the inlet sump, two sets of access ladders being located at two different positions shall be installed for operation and maintenance staff to access to the top of the tank. An access opening at the concrete cover of the reservoir, not smaller than 1.2m x 1.2m, shall be provided at the immediate end of the abovementioned access ladders. The openings shall be covered by stainless steel plate hinged at one end. Access covers shall be sealed and lockable and shall be installed on concrete upstands 150mm above the roof slab. Underneath each opening, a concrete stairway shall be provided for operation and maintenance staff to access the bottom of the tank compartment. Aluminium handrailings and toeboards shall be provided for all access ladders and stairways.

(d) The tank shall be provided with all pipework, valves, washout and overflow pipework and all necessary fittings and fixings.

B 8.10.4 The inlet sump shall be fenced off from the exterior by compound walling of, not less than, 2m height. A double leaf access door, the main gate, for vehicles and a single leaf access door, the side gate, for operation personnel shall be provided at the compound wall. The main gate and the side gate shall be positioned adjacently. Compound walling shall be rendered brickwork with painted finish in accordance with the standard detail drawings. The main and side gates shall be anti-intruder painted steel gates.