Bihar Urban Infrastructure Development Corporation Ltd.

Bihar Urban Development Investment Program – BUDIP

DETAILED PROJECT REPORT

IMPROVEMENT OF WATER SUPPLY SYSTEM FOR GAYA MUNICIPAL CORPORATION-PACKAGE: GA/WS/02

VOLUME- I

Main Report

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IPE Global Pvt. Limited

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LIST OF ABBREVIATIONS

ADB	Asian Development Bank
AMR	Automatic Meter Reading
AWWA	American Water Works Association
bar	Pressure unit: 1 bar ~ 10 metres of water column
cm	Centimetre
BOD_5	Biochemical Oxygen Demand at 5 days
BUIDCo	Bihar Urban Infrastructure Development Corporation
BUDIP	Bihar Urban Development Investment Programme
CDP	City Development Plan
COD	Chemical Oxygen Demand
CPHEEO	Central Public Health and Environmental Engineering Organisation
d	Day
DBO	Design Build Operate
DCI	Ductile Cast Iron (material for pipelines and fittings)
DI	Ductile Iron (material for pipelines and fittings)
DIN	Deutsches Institut für Normung (German Institute for Norming)
DMA	District Metered Area
DPR	Detailed Project Report
DN	Nominal Diameter (refers to metallic pipelines)
DSC	Design and Supervision Consultant
EA	Executing Agency – UDHD
EIA	Environmental Impact Assessment
EMP	Environmental Management Plan
FFA	Framework Financing Agreement dated 31 January 2012 between ADB and the Borrower with respect to the MFF
Ø or Dia.	Greek letter “phi” used by engineers to abbreviate the diameter of a pipe
FP	Fully Plumbed
GLSR	Ground Level Service Reservoir
GMC	Gaya Municipal Corporation
GoB	Government of Bihar
GoI	Government of India
GWB	Gaya Water Board
h	Hour
ha or Ha	Hectare
HH	House Hold
HDPE	High Density Poly Ethylene (material for pipelines)
HP	Horse Power; 1HP = 0.7354987 kW = 735.4987 Nm/s (Newton metre / second)
HSC	House Service Connection
ID	Identification Number
IBNET	International Benchmarking Network
IFA	International Financing Agency

IFI	International Financing Institution
ISO	International Organisation for Standardisation
Kg	Kilogramme
Kg/h	Kilogramme per hour
KPI	Key Performance Indicator
km	Kilometre
kVA	Kilo Volt Ampere
kW	Kilowatt
kWh	Kilowatt hour
l	litre
L	Length
LEAP	Local Environmental Plan
LOS	Levels of Service
l/d or lpd	Litres per day
l/h or lph	Litres per hour
l/m or lpm	Litres per minute
lpcd or l/c/d	Litres per capita per day (referring to the consumption of water)
l/s or lps	Litres per second
m.a.s.l.	metres above (normal) sea level
m	metre
m^2	square metre
m^3	Cubic metre
m^3/d	cubic metres per day
m^3/h	cubic metres per hour
m^3/y	cubic metres per year
MDPE	Medium Density Polyethylene
MFF	Multi-tranche Financing Facility
mld or MLD	1 Mega l/d = 1,000,000 l/d = 1000 m^3/d
mm	Millimetre
NRW	Non-Revenue Water
NSLB	National Service Level Benchmark
NTPA	Technical Norms for Water Protection
NTU	Nephelometric Turbidity Unit
OD	Outer Diameter (refers to non-metallic pipelines)
OJT	On the Job Training
OHSR	Overhead Service Reservoir
OHT	Overhead Tank/Reservoir
OHASAS	Occupational Health and Safety Standard
O&M	Operation and Maintenance
PD	Project Director
PE	Poly Ethylene (material for pipelines and fittings)
PHED	Public Health Engineering Department
PI	Performance Indicator

PIU	Project Implementation Unit
PMC	Project Management Consultant
PMU	Programme Management Unit
PN	Nominal Pressure (normally followed by a number that represents bar)
PPTA	Project Preparatory Technical Assistance
PRV	Pressure-reducing Valve
PSP	Public Stand post
ppm	parts per million = milligrams per litre
PVC	Polyvinylchloride (material for pipelines and fittings)
RCC	Reinforced Cement Concrete
RF	Resettlement Framework
RP	Resettlement Plan
SAR	Subproject Appraisal Report
SCADA	Supervisory Control And Data Acquisition
SDR	Standard Dimension Ratio for HDPE pipes (outer diameter / pipe wall thickness)
SEIAA	State Environment Impact Assessment Authority
SPUR	Support Program for Urban Reforms
SS	Suspended Solids
STC	Shah Technical Consultants
STP	Sewage Treatment Plant (or WWTP)
TA	Technical Assistance
TC	Town Committee
ToR or TOR	Terms of Reference
TM	Transmission Main
TSS	Total Suspended Solids
UDHD	Urban Development and Housing Department
UfW	Unaccounted for Water replaced by NRW in common engineering terminology
ULB	Urban Local Body
VAT	Value Added Tax
WHO	World Health Organization
WTP	Water Treatment Plant
WWTP	Waste Water Treatment Plant
YT	Yard Tap

TABLE OF CONTENTS

LIST OF TABLES

TABLE OF FIGURES

LIST OF DRAWINGS – IN VOLUME - II

S NO.	DRAWING TITLE	DRAWING NO.
1	MAP SHOWING PROJECT AREA	BUDIP-2/GA/WS/02/01
2	LAYOUT OF EXISTING WATER SUPPLY SYSTEM	BUDIP-2/GA/WS/02/02
3	MAP SHOWING WARD & DMA BOUNDARIES PROPOSED IN PACKAGE I	BUDIP-2/GA/WS/02/03
4	MAP SHOWING PROPOSED RISING MAINS AND DISTRIBUTION MAINS IN PACKAGE I	BUDIP-2/GA/WS/02/04
5	MAP SHOWING PROPOSED WATER SUPPLY SYSTEM	BUDIP-2/GA/WS/02/05
6	GENERAL ARRANGEMENT OF CLEAR WATER RESERVOIR CUM PUMP HOUSE	BUDIP-2/GA/WS/02/06
7	GENERAL ARRANGEMENT OF GROUND LEVEL SERVICE RESERVOIR ON SHRINGHSTHAN HILLS	BUDIP-2/GA/WS/02/07
7a	REINFORCEMENT DETAILS OF GROUND LEVEL SERVICE RESERVOIR ON SHRINGHSTHAN HILLS	BUDIP-2/GA/WS/02/07a
8	PLAN OF OPERATING OFFICE CUM CUSTOMER SERVICE CENTER	BUDIP-2/GA/WS/02/08
9	TYPICAL DRAWING OF PUMP HOUSE	BUDIP-2/GA/WS/02/09
10	TYPICAL CROSS SECTIONS OF PIPE LINE TRENCH	BUDIP-2/GA/WS/02/10
11	TYPICAL DRAWING OF AIR RELEASE VALVE CHAMBER	BUDIP-2/GA/WS/02/11
12	TYPICAL DRAWING OF SLUICE VALVE CHAMBER	BUDIP-2/GA/WS/02/12
13	TYPICAL DRAWING OF BUTTERFLY VALVE CHAMBER	BUDIP-2/GA/WS/02/13

S NO.	DRAWING TITLE	DRAWING NO.
14	TYPICAL DRAWING OF SCOUR VALVE CHAMBER	BUDIP-2/GA/WS/02/14
15	TYPICAL DRAWING OF SPECIALS FOR VALVE FITTINGS	BUDIP-2/GA/WS/02/15
16	DRAWING FOR DETAILS OF THRUST BLOCK	BUDIP-2/GA/WS/02/16
17	TYPICAL DRAWING OF RAILWAY CROSSING	BUDIP-2/GA/WS/02/17
18	TYPICAL DRAWING OF NATIONAL HIGH WAY CROSSING	BUDIP-2/GA/WS/02/18
19	TYPICAL DRAWING OF PRODUCTION TUBE WELL AND OBSERVATION TUBE WELL	BUDIP-2/GA/WS/02/19

0. EXECUTIVE SUMMARY

Bihar is one of the major states in eastern India, being the third largest by population and twelfth largest by geographical area. The urban service delivery e.g. water supply, sewerage and solid waste management, etc. in the state are not adequate and are below the national and state benchmarks. The water supply lacks uniformity in improvement in terms of coverage, quantity and duration. The condition of these facilities in Gaya is not exceptional, indicating an immediate need of attention.

Due to the uncertainty related to the availability of water resources for the future the reliable hydro-geological investigation/ Resistivity survey is carried out. The Improvement of Water Supply System in Gaya had to be broken in 2 packages:

Package 1 deals with the refurbishing of the existing water production facilities, consolidation, renovation, and extension of the pipes work, augmentation of the storage capacities, introduction of tools for monitoring the production and the consumption of water, and last but not the least, the capacity building of GMC for ensuring the sustainability of the project.

Package 2 (**This Report**) deals with the determination of the capacity of the aquifer, design and implementation of additional water production capacities in case of need, and design and implementation of related transmission facilities of the additional water volumes to the town.

Additional storage capacities will be needed now at few locations. The storage capacities are normally provided for a design period of 30 years. However, in outer areas of the city it is not known at what locations they will be constructed as urban planning of that horizon is not available. Accordingly, construction of such storages has not been included in the present proposals. Such deferred reservoirs may be taken up later when urban planning of such areas is either finalised or the areas gets substantially developed.

The objective of the present DPR is to define the measures needed in Gaya for improving in a sustainable manner the water supply production to the population for additional water requirement to meet projected demand for design year 2048.

The DPR is presented in following three volumes:

Volume I:	General Report
Volume II:	Drawings
Volume III:	Confidential Cost Estimates including unit rates

0.1. EXISTING SYSTEM

The existing water supply system is not covering the entire urbanised area. DSC's investigations have shown that a large proportion of the population connected to the piped water supply system is not using it due to unreliable water quality and/or intermittent supply and prefers to use private wells.

The water sources of Gaya consist of underground water extracted by tube wells located on both sides of the River Phalgu, Manpur and Gaya main. There are 39 tube wells in the town at present of which one is meant for firefighting, one has become defunct and 2 are standby.

The existing distribution system is not in conformity with basic engineering practices. Part of it consists of Transmission Mains raising the water to 1 Over Head Tank and 7 Ground Level Reservoirs on hills. The other part is operated by pumping the Tube Wells water directly into the distribution network. For this portion no storage capacities are available.

The total existing storage capacity is of 17747 m^3.

The reservoirs constructed on Ramshila hills, Murli hills and overhead tank at Azad Park are not functional at present as these tanks are not being fed due to inadequate capacity of the pumping

plants on respective tube wells or of the transmission mains and the water is being supplied through direct pumping into the distribution network.

There is no zoning in the existing distribution system. All areas connected to one reservoir are served in one go. Similarly distribution system directly fed from TWs is also supplied simultaneously. There is practically no chlorination system for disinfection of water supplied. The chlorination system wherever provided is either not functioning or highly undependable resulting in a high health risk.

0.1.1. EXISTING LEVEL OF SERVICE

Pop.	Transmission & Distribution		Population connected to Piped Water Supply		Water Storage / connected pop.		Distribution Network	
Cap.	2013 [m]	m/cap served	%	cap	2013 m^3	m^3/cap served	2013 [m]	m/cap served
468,614	159,376	0.91	37%	174,819	17,709	0.10	147,893	0.85

0.2. DEMANDS

The water losses have been assumed by using experience based figures expressed in l/connection/day for systems that are developed randomly, without design, and are unmaintained. The result of the present Water Balance in Gaya is shown below:

Table 6: Water Balance for 2013 in Gaya

Description	2013
Domestic Demand [l/d]	23,164,400
Demand Floating Population [l/d]	8,400,000
Demand Hospitals [l/d]	84,000
Demand Schools [l/d]	803,000
Industrial Demand [l/]	1,870,000
Demand Livestock [l/d]	1,278,304
Conn. #	28,912
Specific Water loss value [l/conn/d]	700
Water Loss demand [l/d]	20,238,692
Total Demand [l/d]	55,838,396
Total Demand [MLD]	**55.84**
Total Demand [l/s]	**646.28**
Potential Water Production [MLD]	**68**
Water Loss [%] of production	**33%**
(+) Water Balance [MLD]	**12.16**

Result of Population Projections

Population Projection Method	Projected Population		
	2018	2033	2048
Exponential Graphical Method	524,297	675,237	848,200

Demand Projections

Description	2018	2021	2033	2048
Domestic Demand [l/d]	63,675,928	71,992,214	88,185,916	112,640,928
Demand Floating Population [l/d]	8,400,000	8,400,000	8,400,000	8,400,000
Demand Hospitals [l/d]	92,400	101,640	111,804	122,984
Demand Schools [l/d]	883,300	971,630	1,068,793	1,175,672
Industrial Demand [l/]	1,870,000	1,870,000	1,870,000	1,870,000
Demand Livestock [l/d]	1,278,304	1,278,304	1,278,304	1,278,304
Conn. #	87,053	120,689	147,837	188,617
Specific NRW value [l/conn/d]	150	160	170	200
NRW demand [l/d]	13,057,904	19,310,169	25,132,282	37,723,376
Total Demand [l/d]	89,257,836	103,923,957	126,047,099	163,211,264
Total Demand [MLD]	**89.26**	**103.92**	**126.05**	**163.21**
Total Demand [l/s]	**1,033.08**	**1,202.82**	**1,458.88**	**1,889.02**
Required Water Production [MLD]	**90**	**104**	**130**	**165**
NRW [%] of production	**15%**	**19%**	**19%**	**23%**
(+) Water Balance [MLD]	**0.74**	**0.08**	**3.95**	**1.79**

0.3. SCHEDULE OF IMPLEMENTATION

Proposed Schedule of Implementation

Description	Year → Month ↓	1	2	3	4	5	6	7
Contract commence date	3							
Works								
Section 1 : Water source works	18							
Section 2: Storage Reservoirs	12							
Section 3: Transmission Mains	18							
Section 4: Operator office	12							
Commissioning and Testing	3							
Operation services	48							
Contract Completion Date								

1. INTRODUCTION

Bihar is one of the major states in eastern India, being the third largest by population and twelfth largest by geographical area. The urban service delivery e.g. water supply, sewerage and solid waste management, etc. in the state are not adequate and are below the national and state benchmarks. The water supply lacks uniformity in improvement in terms of coverage, quantity and duration. The condition of these facilities in Gaya is not exceptional, indicating an immediate need of attention.

Due to the uncertainty related to the availability of water resources for the future the reliable hydro-geological investigation/ Resistivity survey is carried out. The Improvement of Water Supply System in Gaya had to be broken in 2 packages:

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Additional storage capacities will be needed now at few locations. The storage capacities are normally provided for a design period of 30 years. However, in outer areas of the city it is not known at what locations they will be constructed as urban planning of that horizon is not available. Accordingly, construction of such storages has not been included in the present proposals. Such deferred reservoirs may be taken up later when urban planning of such areas is either finalised or the areas gets substantially developed.

1.1. PROJECT BACKGROUND

To accelerate the economic growth of Bihar, it is imperative to enhance the major urban services e.g. water supply, sewerage and solid waste management to achieve better health status of the urban population in the second to the fifth largest towns (Bhagalpur, Darbhanga, Gaya and Muzaffarpur) with economic growth potential. This will empower the four towns to unceasingly play their roles as the engines of economic evolution in Bihar.

The physical investment requirements to water supply, sewerage and Solid Waste Management sub-sectors in these four towns are estimated at about Rs 21 billion, Rs 11 billion and Rs 3 billion respectively under the Roadmap. Although the urban infrastructure development scheme for small and medium towns (UIDSSMT), the National Ganga River Basin Authority (NGRBA), and other national and state budgetary allocations are available, but are not adequate to meet the entire investment requirement.

In the light of the large financial requirements for the roadmap implementation in Bihar, ADB has agreed for a multi tranche financing facility (MFF) of $200 million for the Bihar Urban Development Investment Program (BUDIP).

The objective of the Bihar Urban Development Investment Program (BUDIP) is to improve the quality, coverage, and reliability of water supply and sewerage services for an estimated 1.5 million residents living in these four towns.

Bihar Urban Development Infrastructure Corporation (BUIDCo) is the implementing agency for investment program. It will engage and supervise contractors and consultants on behalf of the municipal corporations. In line with the requirements of the investment program, BUIDCo has selected **Shah Technical Consultants Pvt. Ltd.** in association with **IPE Global Pvt. Ltd. and Cogent Training Research Development Consultant Pvt. Ltd**. as the Design Supervision Consultants.

1.2. PREVIOUS STUDIES AND SURVEYS

Few hydro-geological surveys were carried out in the past to assess the ground water potential and capability along the river Phalgu to use the river as the source of water for Gaya town. The details of these studies are as follows:

i. Central Ground Water Board (CGWB)

A study conducted by Central Ground Water Board (CGWB) in Year 1978 to assess the ground water potential and capability along the river Phalgu (in the river flood plain) recommends that tube wells in the bed of Phalgu river may be taken as a source for water supply for MES, as adequate yield of the tube wells is available in the bed. However, no detailed hydro geological study was carried out before coming to this conclusion.

ii. The WAPCOS report December 2012

UDHD, GoB awarded the work of preparation of DPR for augmentation of water supply of Gaya town in 2010 WAPCOS. In this report it was assumed that underground water available in Phalgu basin will be adequate to meet water demand of the town until 2029 but gave no reasons or justification for this assumption.

iii. M/S Kirloskar Brothers Ltd. Kolkata

PHED, GoB is executing a project to augment water supply to Gaya town on behalf of Gaya Municipal Corporation. PHED awarded the work to M/S Kirloskar Bros. Ltd in 2008. The contractor constructed 8 tube wells in 2008-2009. The results of TWs constructed are summarized below:

Table 1: Tube wells report

No.	Location	Dia (mm)	Depth (m)	Discharge (lps)	Year of Inst.	Remarks
1	Dandibagh TW 5	300	22	28	2008	Soft rock which is bed rock found at depth of 23m BGL
2	Muffassil Thana (Manpur)	450	27	82	2008	Hard rock at the depth of 27m BGL
3	Janakpur-Near Bridge (Manpur)	300	30	32	2008	-
4	Near Joda Masjid Khanjhapur road (Manpur)	450	33	78	2008	Hard rock at 33m depth BGL
5	Dandibagh TW1	450	108.23	47	2008	Hard rock at Depth of 108.23m BGL
6	Dandibagh TW2	450	22.85	47	2008	Hard rock at Depth of 22.85m BGL
7	Dandibagh TW3	450	21.95	47	2008	Hard rock at Depth of 21.95m BGL
8	Dandibagh TW4	450	22.5	47	2008	Hard rock at Depth of 22.5m BGL

Thus, there has not been any substantial study to establish the aquifer characteristics and its potential. It is essential to undertake a detailed hydro geological study to determine the extent of the basin, its characteristics and its potential to provide sustained discharge for city water supply over a long period of time.

iv. Hydro-Geosurvey Consultants Private Limited (HGCPL)

HGCPL is conducted comprehensive hydrogeological investigations, and it is concluded that there is no need of getting water from Ganga river as the Phalgu river in itself is a boon for Gaya town for meeting its water requirement of 124 MLD by considering dry weather duration of 75 days where

water requirement is 163 MLD and dry weather duration may by 4 months. The consultants also not identified the pin pointing of proposed tube wells.

1.3. BASE OF THE DPR

The objective of the present DPR is to define the measures needed in Gaya for improving in a sustainable manner the water supply production to the population for additional water requirement to meet projected demand for design year 2048.

The following activities were undertaken in the process of preparing present report:

- Study of report prepared by WAPCOS;
- Study of report prepared by Hydro-Geosurvey Consultants Private Limited (HCPL)
- Study of report prepared by M. K. Soil Testing Laboratory
- Census 2011 and population projections as described further;
- Location pinpointing of existing water production and storage facilities by means of GPS;
- Recording the data of the equipment installed at the production facilities;
- Bulk Flow measurement campaign at production and storage facilities by means of ultra-sonic flow meters;
- Analysis of present level of service based on above activities and projection of future level of service;
- Definition of storage capacities for the project horizon:
- Generating the Unit Prices Data Base from enquiries, and ongoing projects in the area or elsewhere in India.
- Mapping of all collected and produced information on the geo-rectified satellite image provided by the Urban Development and Housing Department – as AutoCAD and shape file formats;
- Preparation of Standard Designs.
- Preparation of Cost Estimates per component.

1.4. SCOPE OF THE DPR

The above activities lead to the defining the scope of the DPR comprising the following:

1. To provide sustainable ground water sources and their pumping machinery;
2. Optimize the extracted volume of water from the aquifer;
3. Provide for additional service reservoir capacity to meet the projected demand for the design year 2048;
4. To achieve a NRW level less than 20% by year 2021;
5. Operate and maintain the system for a period commencing after takeover of the assets by the contractor until 4 (four) years after completion of construction work;
6. Provide conditions for implementing preventive maintenance

1.5. STRUCTURE OF THE DPR

DPR is presented in following three volumes:

Volume I: General Report

Volume II: Drawings

Volume III: Confidential Cost Estimates including unit rates

In the various chapters of the Volume I we are presenting the results according to the following logical sequence:

- background of the project,
- the sources of information used,
- the proposed measures,
- The information about the methodology used for designing the mentioned measures.

The Chapter 0 “Executive Summary” is meant for condensing the information on the input and on outcome of the present report.

2. EXISTING WATER SUPPLY SYSTEM

The piped water supply system in Gaya town was introduced in 1924 with Phalgu River as a source of water. Later in the year 1954–55, a ground water based water supply system was developed at Dandibagh, on the bank of river Phalgu due to inadequate flow in the river during summer and it's incapability to cope with the growing water demand of the town. The water supply system was extended to different parts of the town from time to time.

Government of India sanctioned a project under 12th Finance Commission program to augment water supply of the city at an estimated cost of Rs.11.94 Crores in 2007. This project involved construction of battery of Tube Wells on the bank of river Phalgu near Dandibagh and also in various parts of the city to increase water production by 16 MLD and provide distribution system for the newly developed areas like Manpur, AP Colony etc. The work on this project is being executed by Public Health Engineering Department of GoB on behalf of Gaya Municipal Corporation (GMC) and is in advanced stage of completion.

2.1. SERVICE COVERAGE

The town is located on the Banks of River Phalgu at a height of about 110 m above mean sea level (msl). The river Phalgu flows from south to north of the town stretching a width of about 900 m. According to Census 2011, the population in Gaya Municipal area was 468614 spreading over an area of 48.517 km^2.

Gaya is governed by Municipal Corporation. From administrative point of view the town has been divided in 53 wards of which ward no. 47, 48, 49, 50, 51, 52 and 53 lie in Manpur area situated on the right bank of River Phalgu.

About two thirds of the total area of 4852 ha is urbanised. The existing water supply system is not covering the entire urbanised area. DSC's investigations have shown that a large proportion of the population connected to the piped water supply system is not using it due to unreliable water quality and/or intermittent supply and prefers to use private wells.

2.2. AVAILABLE SOURCES OF WATER

The water sources of Gaya consist of underground water extracted by tube wells located on both sides of the River Phalgu, Manpur and Gaya main. There are 39 tube wells in the town at present of which one is meant for firefighting, one has become defunct and 2 are standby.

The tube wells are in 4 segments, i.e. Manpur side, Dandibagh side, Panchayati Akhara side and within the main city area. The tube wells in Manpur, Dandibagh and Panchayati Akhara area are bored in the bed/bank of river Phalgu and the other tube wells are bored at various locations in the town, away from the river bank. The tube wells constructed in Manpur side are pumping directly to distribution system in Manpur area. The tube wells constructed in Dandibagh side are used to pump water to the reservoirs located on Brahmayoni hills. Tube wells locate in Panchayati Akhara are used to pump water to the reservoirs located on Ramshila hills and Murli hills. The tube wells installed in the town area are used to pump water directly to the distribution system.

The WAPCOS report refers to the high potential of the aquifer underlying the Phalgu River upstream of Gaya, towards Bodhgaya in the south. In that area the river flows through a wide plain. At Gaya the width is reduced with rocky outcrops on both the East and West banks. Near Gaya the depth to the rock underlying the alluvial deposits is in the order of 25 to 30m only. It is possible that further upstream, and with a widening of the alluvial plain, the depth-to-rock is more, resulting in a wider and maybe deeper aquifer.

It is assumed that the wells currently installed at Dandibagh extract water from a relatively small sub-aquifer, resulting in the limited recharge as experienced at the existing wells. The relatively small distance between the existing wells may also play a role.

The Consultant has performed a flow measurement campaign at all tube wells in Gaya and the results are shown in the Table 2 hereafter. During the flow measurement campaign the pumps were working for long periods. No drop in the capacity of the wells has been reported. For this reason the total water production of the tube wells in Gaya can be considered as the sum of the yield of all wells.

Table 2: Present Water Production

ID	Name	Discharge informed by GMC m³/h	Power Availability hr	No. of Running hours	Measured Flow	
					m³/h	m³/d
1	Dandibagh No. 1#	NA	23	22	0	0
2	Dandibagh No. 2	250	23	22	225	4950
3	Dandibagh No. 3	250	23	22	172	3794
4	Dandibagh No. 4	250	23	22	186	4094
5	Dandibagh No. 5	250	23	22	4	88
6	Panchayati Akhara No. 1	68	20	20	104	2083
7	Panchayati Akhara No. 2	41	20	20	94	1888
8	Azad Park	54	20	11	52	572
9	Dhobighat	45	20	11	37	407
10	Central School	54	20	8	79	632
11	Nigam Store	54	20	5	23	115
12	Gurudwara	54	20	10	56	560
13	Fire Station	36	20	8	55	440
14	New Godown	54	20	11	50	550
15	Kharkhus	41	20	12	46	552
16	Delha	27	20	8	45	360
17	Panchayati Akhara No. 3#	68	20			0
18	Janata Colony	14	20	9	39	351
19	Janata Colony	14	20	12	18	216
20	Pilgrim Hospital	14	20	5	17	85
21	Visnupad	73	20	8	129	1032
22	Bypass	27	20	8	80	640
23	Bairagi Powerganj	32	20	6	79	474
24	Bageshwari Pachim	14	20	8	19	152
25	Pitamaheshwar	54	20	5	65	325
26	Kauvasthan	32	20	8	17	136
27	Hata Godown	54	20	8	52	416
28	Manpur	54	20	10	93	930
29	Manpur - Buniydiganj	68	20	11	65	715

ID	Name	Discharge informed by GMC m³/h	Power Availability hr	No. of Running hours	Measured Flow	
					m³/h	m³/d
30	Khadi Gramodyog Lakhibagh	54	20	20	53	1067
31	Cotton Mill ##					
						27624

#Flow could not be measured due to pump break down

TW not functional

Table 2 further shows that the existing TWs are highly underutilised both from rate of pumping as well as operational hours points of views. The present total daily production works out to 27624 m³/day only.

There are 31 TWs owned by GMC of which 30 are under operation. In addition to these, PHED has constructed 8 TWs on behalf of GMC of which 4 have been commissioned. Two TWs constructed by PHED are proposed to be used as standby tube wells. There is practically no instrumentation available at Tube Wells like electric measuring instruments (ampere meters, volt meters, energy meters, power factor meters etc.), pressure gauges, flow meters, water level measuring instruments etc. In absence of required instrumentation, the present level of production and performance level of electro-mechanical equipment is not known.

The water pumped from the tube wells is directly pumped to the service reservoirs or to the distribution system without any disinfection as no chlorination system has been provided on tube wells or on service reservoirs.

2.3. RISING MAINS

There are three Cast Iron rising mains 350 mm, 450 mm and 600 mm of 1.6 km length each from Dandibagh to Brahmayoni Hills reservoirs. One more DI rising main 450 mm of 2.3 km length has been laid recently under the augmentation project under 12th Finance Commission program from Dandibagh to Singra sthan GLSR.

2.4. EXISTING STORAGE CAPACITIES

The status of existing storage reservoirs and their health is depicted in Table 3.

Table 3: Existing Storage

ID	Location/Name	Capacity [m³]	Age	Staging	Health	Comment
6	Ramshila Hills	227	50+ years old	No	Bad	Very low capacity
8a	Murli Hills	1630	50+ years old	No	Bad	Roof and inside wall need repair
9	Azad Park	454	50+ years old	12.2 m	Workable	Needs slight repair from inside
10a	Brahmayoni	1816	70+ years old	No	Bad	Roof and inside wall in very bad condition and need replacement
10b	Brahmayoni	1816	70+ years old	No	Bad	
11	Brahmayoni	3632	50+ years old	No	Workable	Needs slight repair from inside

ID	Location/Name	Capacity [m³]	Age	Staging	Health	Comment
12	Brahmayoni	3632	50+ years old	No	Workable	
13a	Singra sthan	4540	2013	No	Workable	Although recently constructed, it leaks from various places

Note: The ID corresponds to the marking on the Drawing mentioned above.

The total existing storage capacity is of 17747 m³.

The reservoirs constructed on Ramshila hills, Murli hills and overhead tank at Azad Park are not functional at present as these tanks are not being fed due to inadequate capacity of the pumping plants on respective tube wells or of the transmission mains and the water is being supplied through direct pumping into the distribution network.

2.5. EXISTING DISTRIBUTION NETWORK

The existing distribution system is not in conformity with basic engineering practices. Part of it consists of Transmission Mains raising the water to 1 Over Head Tank and 7 Ground Level Reservoirs on hills. The other part is operated by pumping the Tube Wells water directly into the distribution network. For this portion no storage capacities are available. A layout of the existing distribution system is presented in the Drawing No.2.

There is no zoning in the existing distribution system. All areas connected to one reservoir are served in one go. Similarly distribution system directly fed from TWs is also supplied simultaneously. There is practically no chlorination system for disinfection of water supplied. The chlorination system wherever provided is either not functioning or highly undependable resulting in a high health risk.

It has to be mentioned at this stage that most of the pipelines laid by PHED have not been handed over to GMC but are presently in use.

2.5.1. CONSUMERS' CONNECTIONS

There are around 12500 registered consumers in the town. However, there is large number of unauthorised and unidentified consumers connected to the distribution system. According to the information collected from Wards Counsellors, the total number of connections is about 29000. There is no metering of water supplied to consumers and no water billing system. Water charges are levied as part of the Holding Tax on properties by the GMC.

The identified categories of existing consumer connections are the following:

i. Domestic Connections composed of House Connection considered as Fully Plumbed (FP) and Public Stand Posts (PSP);

ii. Institutional connections (Schools, Hospitals, etc.);

iii. Hostels and floating population supply points;

iv. Industries (small scale).

At present there are 1074 Public Stand Posts in the town which are being used by people not connected with individual connections for domestic purposes. Not all are functional and the number of households using them has been collected from the wards counsellors.

2.6. RECENT AND ONGOING CONSTRUCTION WORKS

Government of India sanctioned a project under 12th Finance Commission program to augment water supply of the town at an estimated cost of Rs.11.5 Crores in 2007. This project involved construction of battery of Tube Wells on the bank of river Phalgu near Dandibagh and also in various parts of the town to increase water production by 16 MLD and provide distribution system for the newly developed areas like Manpur, AP Colony, etc. The work on this project is being executed by Public Health Engineering Department of GoB on behalf of Gaya Municipal Corporation (GMC) and is in advanced stage of completion. The highlights of the works as communicated by PHED are as follows:

i. Transformers – Out of total 5 installed 3 are complete
ii. 8 nos. of tube wells – Complete
iii. 8 nos. of Pump houses on tube wells – Complete
iv. Pumps and motors – 8 nos. provided, 1 currently working
v. Rising Mains – laying of 2500m complete
vi. Gravity Mains – laying of 3433m out of total 4000m complete, the works of Sluice Valves and sluice valve chambers are 50% complete
vii. Service reservoir – Complete
viii. Distribution Network – Out of proposed total 84894 m the length laid is 47966 m. large portion of the total length laid was not handed over to GMC.

2.7. PRESENT WATER QUALITY

As part of the Environmental Assessment of Gaya water supply project-package-2, water sampling is done on 15 June 2015 and the laboratory analysis was carried out by SGS India Pvt. Ltd. Under contract with PMC. The results are shown in Table 4 and Table 5. With the results, it is concluded that the water currently abstracted from the aquifer to be used for this water supply project is safe for drinking.

Table 4 Results for production tube wells

S. No.	Parameters	Location		Standard : IS 10500:2012	
		1. Panchayati Akhara	2. Dandibagh		
	Physicochemical			Acceptable	Permissible
1	BOD (27°C for 3days) mg/L	BDL	BDL	-	-
2	COD mg/L	<5.0	<5.0	-	-
3	Calcium as Ca mg/L	56.7	26.7	75	200
4	Chloride as Cl mg/l	55.8	14.0	250	1000
5	Residual free Chlorine mg/L	BDL	BDL	0.2	1
6	Colour in Hazen unit	10	10	5	15
7	Fluoride as F mg/L	0.3	0.3	1.0	1.5
8	Total hardness as CaCo3 mg/L	210.1	99.0	200	600
9	Mg mg/L	16.7	7.9	30	100
10	Nitrate as NO3 mg/L	5.29	2.20	45	No relaxation
11	pH at 25°C	7.58	7.84	6.5-8.5	No relaxation
12	Sulphates as SO4 mg/L	9.6	6.3	200	400
13	TDS mg/L	311.2	165.6	500	2000
14	Arsenic as As mg/L	BDL	BDL	0.01	0.05
15	Total Chromium as Cr mg/L	BDL	BDL	0.05	No relaxation
16	Cu mg/L	BDL	BDL	0.05	1.5

S. No.	Parameters	Location		Standard : IS 10500:2012	
		1. Panchayati Akhara	2. Dandibagh		
	Physicochemical			Acceptable	Permissible
17	Pb mg/L	0.010	BDL	0.01	No relaxtion
18	Mn mg/L	BDL	BDL	0.1	0.3
19	Cd mg/L	BDL	BDL	0.003	-
20	Amoniacal Nitrogen as N mg/L	BDL	BDL	-	-
21	DO mg/L	3.4	4.5	-	-
22	Conductivity as 25°C µS/cm	497	266	-	-
23	Oil and Grease mg/L	BDL	BDL	-	-
24	Fe mg/L	0.06	0.07	0.3	No relaxation
25	Zn mg/L	0.02	0.02	5	15
26	Na mg/L	47.49	21.28	-	-
27	K mg/L	2.78	BDL	-	-
28	Total Phosphates as PO4 mg/L	0.37	BDL	-	-
29	TSS mg/L	BDL	BDL	-	-
30	Temperature °C	30.6	30.5	-	-
	Pesticides				
1	Methyl parathion µg/L	<0.01	<0.01	-	0.3
2	Malathion µg/L	<0.01	<0.01	-	190
3	Chlorpyriphos µg/L	<0.01	<0.01	-	30
4	DDT (o,p and p,p isomers of DDT DDE and DDD) µg/L	<0.01	<0.01	-	1
5	Gamma HCH µg/L	<0.01	<0.01	-	2

S. No.	Parameters	Location		Standard : IS 10500:2012	
		1. Panchayati Akhara	2. Dandibagh		
	Physicochemical			Acceptable	Permissible
6	Alpha HCH µg/L	<0.01	<0.01	-	0.01
7	Beta HCH µg/L	<0.01	<0.01	-	0.04
8	Delta HCH µg/L	<0.01	<0.01	-	0.04
9	Endosulfan Sulphate (Alpha Beta and sulphate) µg/L	<0.01	<0.01	-	0.4

Table 5: Results for groundwater underlying agriculture fields

S. No.	Parameters	Location		Standard : IS 10500:2012	
		3. Khiriyawa village	4. Amwan village		
	Pesticide residue			**Acceptable**	**Permissible**
1	Melthyl parathion µg/L	<0.01	<0.01	-	0.3
2	Malathion µg/L	<0.01	<0.01	-	190
3	Chlorpyriphos µg/L	<0.01	<0.01	-	30
4	DDT (o,p and p,p isomers of DDT DDE and DDD) µg/L	<0.01	<0.01	-	1
5	Gamma HCH µg/L	<0.01	<0.01	-	2
6	Alpha HCH µg/L	<0.01	<0.01	-	0.01
7	Beta HCH µg/L	<0.01	<0.01	-	0.04
8	Delta HCH µg/L	<0.01	<0.01	-	0.04
9	Endosulfan Sulphate (Alpha Beta and sulphate) µg/L	<0.01	<0.01	-	0.4

2.8. WATER BALANCE

In the sense of urban water supply engineering practice the water balance is comparing the proportion of the water produced with the proportion of water sold. The term of "Non-Revenue Water" (NRW) was introduced and replaces the term of UFW – "Unaccounted for Water" to express the volume of water that is not producing income for the water utility. The change was decided by IWA since the word "Unaccounted" leads to confusion between the non-measured water supplied or water not registered in the accounting department and sold.

The Water Balance is defining the volumes of water with the following structure:

<table>
<tr><td rowspan="7">System Input volume</td><td rowspan="3">Authorized consumption</td><td rowspan="2">Billed authorized consumption</td><td>Billed metered consumption</td><td rowspan="2">Revenue water</td></tr>
<tr><td>Billed unmetered</td></tr>
<tr><td rowspan="2">Unbilled authorized consumption</td><td>Unbilled metered</td><td rowspan="5">Non-revenue water</td></tr>
<tr><td>Unbilled unmetered</td></tr>
<tr><td rowspan="4">Water losses</td><td rowspan="2">Apearent losses</td><td>Unauthorized consumption</td></tr>
<tr><td>Metering inaccuracies</td></tr>
<tr><td rowspan="3">Real losses</td><td>Leakage on transmission and/or distribution mains</td></tr>
<tr><td>Leakage and overflows at storage</td></tr>
<tr><td>Leakage on service connection up to point of customer metering</td></tr>
</table>

In the case of Gaya, where the income for sold water generated through the payment of the property tax to GMC, its control may not be under the operator of this package. The entire System Input Volume equates the volume for Non-Revenue Water.

The water losses have been assumed by using experience based figures expressed in l/connection/day for systems that are developed randomly, without design, and are unmaintained. The result of the present Water Balance in Gaya is shown below:

Table 6: Water Balance for 2013 in Gaya

Description	2013
Domestic Demand [l/d]	23,164,400
Demand Floating Population [l/d]	8,400,000
Demand Hospitals [l/d]	84,000
Demand Schools [l/d]	803,000
Industrial Demand [l/]	1,870,000
Demand Livestock [l/d]	1,278,304
Conn. #	28,912
Specific Water loss value [l/conn/d]	700
Water Loss demand [l/d]	20,238,692
Total Demand [l/d]	55,838,396
Total Demand [MLD]	**55.84**
Total Demand [l/s]	**646.28**
Potential Water Production [MLD]	**68**
Water Loss [%] of production	**33%**
(+) Water Balance [MLD]	**12.16**

3. POPULATION PROJECTIONS

The following methods were used for population projections.

1. Arithmetic method
2. Geometric increase method
3. Incremental increase method
4. Exponential graphical method
5. Linear graphical method
6. Decadal growth method

With above methods population was estimated for the year 2011 based on census populations from 1921 to 2001 and compared with the census population.

Table 7: Establishing the Population Projection Method

Sl. No	Population Projection Method	Census population	Projected Population
		Year- 2011	Year- 2011
1	Arithmetic Increase Method	468,614	433,753
2	Geometric Increase Method	468,614	478,850
3	Incremental Increase Method	468,614	441,126
4	Graphical Method (Linear Increase)	468,614	369,299
5	Graphical Method (Exponential)	468,614	463,099
6	Decadal growth increase	468,614	485,400

The Exponential Graphical Method and Geometric Increase Method are the closest to real figures. We are adopting the exponential graphical method.

The resulting population projections adopted for different horizon years are shown in Table 8 below.

Table 8: Result of Population Projections

Population Projection Method	Projected Population		
	2018	2033	2048
Exponential Graphical Method	524,297	675,237	848,200

For central wards where the population density is already high a ceiling has been defined and no further increase in population number is expected. The Ward wise population projections have been placed in the Designs Section of the present document.

3.1. DEMAND PROJECTIONS

The future demands based on the above population projections and on the data collected in the field are given below. Detailed

Table 9: Demand Projections

Description	2018	2021	2033	2048
Domestic Demand [l/d]	63,675,928	71,992,214	88,185,916	112,640,928
Demand Floating Population [l/d]	8,400,000	8,400,000	8,400,000	8,400,000
Demand Hospitals [l/d]	92,400	101,640	111,804	122,984
Demand Schools [l/d]	883,300	971,630	1,068,793	1,175,672
Industrial Demand [l/]	1,870,000	1,870,000	1,870,000	1,870,000
Demand Livestock [l/d]	1,278,304	1,278,304	1,278,304	1,278,304
Conn. #	87,053	120,689	147,837	188,617
Specific NRW value [l/conn/d]	150	160	170	200
NRW demand [l/d]	13,057,904	19,310,169	25,132,282	37,723,376
Total Demand [l/d]	89,257,836	103,923,957	126,047,099	163,211,264
Total Demand [MLD]	**89.26**	**103.92**	**126.05**	**163.21**
Total Demand [l/s]	**1,033.08**	**1,202.82**	**1,458.88**	**1,889.02**
Required Water Production [MLD]	**90**	**104**	**130**	**165**
NRW [%] of production	**15%**	**19%**	**19%**	**23%**
(+) Water Balance [MLD]	**0.74**	**0.08**	**3.95**	**1.79**

In the above table the figures in the row containing the "**Water Production**" are based on the assumption that **water sources** are or **will be made available** for the respective target year. Producing (pumping) higher volumes of water will result in the increase of the NRW.

The term **"NRW"** was used in the above table to show that for all target years it is expected the Water Utility to be operated according to commercial principles.

The specific value for NRW was chosen according to statistics for a **well operated** water utility.

4. OUTLINE FOR PHASE 2 WORKS

The population of Gaya town as per 2011 census is 468,614. Population projections and water demand projections have been made as per standard procedures prescribed in CPHEEO Manual of Water Supply. The projected populations and water demand for key years are given in the Table 10 below:

Table 10: Steps of Implementation

No.	Year	Event	Population	Demand (MLD)
1	2018	Completion of Phase I works	524,297	89.26
2	2021	Target year of Loan Agreement	552,723	103.92
3	2033	Mid design year	675,237	126.05
4	2048	Design Year	848,200	163.21

The present supply of water to the town from various sources has been determined at 27.62 MLD as per Table 2 showing much underutilisation of potential of installed facilities due to improper planning, power interruptions and frequent need for repairs.

The feasibility of carrying out rehabilitation of existing sources and pumping system has been done to utilise the existing sources to their optimum level. It is estimated that by carrying out this exercise and undertaking related works it will be possible to increase the production from existing sources to a level of 68 MLD.

The works of Phase I of this project is expected to be completed by 2018. Thus it is evident that there will be a shortfall of nearly 22 MLD of water in 2018.

Based on the recommendations of Geophysical (Resistivity) & Geo-hydrogeological survey and Investigation, following options are possible:

i. There is adequate ground water available in the aquifer to meet the designed demand of 163 MLD in 2048 on sustained basis. In such a case, balance demand of water can be met by construction of additional Tube Wells, related pumping system and transmission system.

ii. The availability of ground water is limited but can be increased by construction of a barrier across river Phalgu such that demand for 2048 is met on sustained basis. In this case also, action as per (i) above can be taken together with construction of required structure across river Phalgu.

iii. The availability of ground water can be increased by constructing the barrier across the river but even improved availability will be able to partially meet the projected demand. In such a case we can determine as to for which year water demand can be met with this improved water availability. For the remaining demand for the design year 2048, we shall be required to look for alternative ground water or surface water source.

As mentioned earlier in this report, proposals under Phase I of the project included in this DPR will consider Redevelopment of existing TWs and repair/new pump rooms on them, Rehabilitation/Replacement of existing electro-mechanical equipment on Tube Wells, construction of additional Service Reservoirs to meet the projected requirement of 2048, rehabilitation of the existing distribution pipe lines to ensure reduction in NRW level to 20% and extension of the distribution network to all uncovered areas to achieve coverage of 95% population by 2021, formation of adequate number of DMAs to facilitate monitor and help achieve NRW below norms prescribed under loan agreement, rehabilitation of service connections, release of new connections and providing water meters to all existing and future consumers.

The scope of work in Gaya Water Supply Phase II will be to develop new source(s) of water and related treatment and transmission system up to all existing and new Service Reservoirs to meet the projected demand of water for design year 2048. Work of service reservoirs deferred during

Phase I are proposed to be included in Phase II. A SCADA system is also proposed to be provided in Phase II for the system going to be developed in Phase II as well as the system developed in Phase I so that the total system is operated and maintained optimally and efficiently.

In case an Urban Development Plan will be available by the beginning of the design for Phase II where future streets will be shown, the distribution network for future extensions will be designed.

5. OUT LINE DETAILS OF PACKAGE-1

5.1. PROPOSED REHABILITATION OF TUBE WELLS & ELECTRO-MECHANICAL EQUIPMENT

5.1.1. REDEVELOPMENT OF TUBE WELLS

The 29 tube wells being operated by GMC are old ranging from 6 to 50 years range. These tube wells have not been developed or flushed after their commissioning even once as per information obtained from local staff. This shows that the tube wells are presently not working with full efficiency and with full capacity. Non-development of tube wells regularly results in sand pumping, incrustation and clogging of slots of well screen. It is recommended that tube wells are redeveloped every five years. It is therefore proposed to redevelop all the 29 tube wells by first putting chemicals like Sodium hexametaphosphate and then with compressed air so that all loose sand particles and clogging in the screen slots and incrustation in filter media are removed. As depth of tube wells is quite less, development for a period of 10 hours on an average looks to be adequate. It is further proposed to undertake pump test of each TW with a higher capacity pump to determine the actual yield to facilitate installation of right capacity pump and make use of TW optimally.

5.1.2. TUBE WELL WATER PUMPING

There are 31 tube wells of GMC. The condition of Tube Wells of GMC is not very good as they are quite old (ranging from 6 years to 50 years). It would be appropriate to undertake redevelopment of these tube wells. This is likely to improve the discharge and efficiency of tube wells and also make their discharge sand free.

There are 8 tube wells constructed by PHED under 12th Finance Commission project for GMC between 2009 and 2011, of which 2 are proposed to work as stand by TWs. These are new tube wells and are in the process of commissioning. Two Tube Wells have so far been commissioned. These TWs have not been handed over to GMC so far but production from the operating TWs is used for water distribution.

The pumping machinery installed on GMC tube wells is generally old and undergoes frequent breakdowns. There are no flow meters, pressure gauges, depth gauges and Non Return Valves installed in delivery pipe lines. As will be evident from Table 2, many of the TWs are operated for much less period than availability of power on account of such TWs being connected directly to distribution system. It would be appropriate to connect all TWs to some service reservoir so that they are optimally utilised.

It has also been noticed that yield of TWs is not optimally used on account of lower capacity of pumps installed or discharge of pumping sets having got reduced due to passage of time or frequent repairs. One such example is TWs at Dandibagh well field. Whereas all the five TWs are constructed in the same aquifer within small area and are of same size, are giving different production. It is therefore proposed to rationalise the proposed pumping rate form the TWs to make optimum use of TW capacities.

One of the important issues is average quantum of water supplied daily, which is much less than the quantity of water produced daily worked out in Table 2. This is on account of various factors like frequent breakdown of electro-mechanical system due poor condition of electrical system, no protections provided in electrical system, absence of valves in pump delivery system, non-availability of pressure gauges and level sensors making it difficult to determine/monitor performance level of TW etc.

It is therefore proposed to replace pumping sets on existing 29 out of total 31 tube wells of GMC (One TW is proposed to be left for use for firefighting and one has become defunct) with following duty conditions:

Table 11: Proposed duty condition for TW refurbishment

ID	Name	Discharge	Head	Motor	Operating	Daily Production	Remarks
		m³/h	m	HP	Hours	MLD	
1	Dandibagh No. 1	220	85	105	23	5.06	
2	Dandibagh No. 2	220	85	105	23	5.06	
3	Dandibagh No. 3	220	85	105	23	5.06	
4	Dandibagh No. 4	220	85	105	23	5.06	
5	Dandibagh No. 5	220	85	105	23	5.06	
6	Panchayati Akhara No. 1	100	65	40	20	2.00	
7	Panchayati Akhara No. 2	100	65	40	20	2.00	
8	Azad Park	55	49	25	20	1.10	
9	Dhobighat	40	69	20	20	0.80	
10	Central School	75	71	35	20	1.50	
11	Nigam Store	20	71	10	20	0.40	
12	Gurudwara	55	71	25	20	1.10	
13	Fire Station	-	-	-			Used for Fire fighting
14	New Godown	55	71	25	20	1.10	
15	Kharkhus	40	53	15	20	0.80	
16	Delha	40	53	15	20	0.80	
17	Panchayati Akhara No. 3	100	65	40	20	2.00	
18	Janata Colony 1	40	71	20	20	0.80	
19	Janata Colony 2	20	71	10	20	0.40	
20	Pilgrim Hospital	20	49	7.5	20	0.40	
21	Visnupad	130	95	70	20	2.60	
22	Bypass	75	95	45	20	1.50	
23	Bairagi Powerganj	55	71	25	20	1.10	
24	Bageshwari Pachim	20	69	10	20	0.40	
25	Pitamaheshwar	75	71	35	20	1.50	
26	Kauvasthan	20	49	7.5	20	0.40	
27	Hata Godown	55	71	25	20	1.10	
28	Manpur	100	69	40	20	2.00	
29	Manpur - Buniydiganj	75	43	20	20	1.50	
30	Khadigramodyog Lakhibagh	55	47	15	20	1.10	
31	Cotton Mill	-	-	-	-	-	Non-functional
32	Krilosker-1	150	129.1	85	0	0	No Replacement proposed
33	Krilosker-2	170	129.1	100	20	3.4	- Do -
34	Krilosker-3	75	129.1	35	20	1.5	- Do -
35	Krilosker-4	170	129.1	100	23	3.91	- Do -
36	Krilosker-5	170	129.1	100	23	3.91	- Do -
37	Krilosker-6	170	129.1	100	0	0	- Do -
38	Kirlosker-7	170	129.1	100	0	0	- Do -
39	Krilosker-8	75	76	35	20	1.5	- Do -
					Total	**67.92**	**say 68 MLD**

It is proposed to provide 3 submersible pump sets as standby to facilitate keep down time minimum.

The other 8 TWs constructed by PHED are yet to be handed over to GMC and are of recent origin and hence replacement of pumps is not proposed.

It is proposed to provide one Electro-Magnetic type flow meter with AMR facility in the delivery pipe of each Tube Well for flow measurement along with one pressure gauge, one Non Return Valve, and Butterfly Valve. A sensor to measure water level in the Tube Well is also proposed to be installed. The sizes of flow meters and valves on each Tube Well are mentioned in the Drawing No.2.

5.1.3. ELECTRICAL SYSTEMS

The condition of electrical system on the tube wells is still bad. There is practically no protection provided in electrical system against single phasing, over load, earth fault etc. There are no meters installed like ampere meters, volt meters, energy meters, power factor meters etc. on these tube wells. It is therefore proposed to provide a new Electric panel in each Tube Well pump room with an air break Star Delta starter with necessary protection relay, meters and level indicating meter. The electrical system is proposed to be properly earthed as per rules. A Single Line Diagram for a typical electrical system of a Tube Well is given in drawing section in the Drawing No. 3 of package1.

There are 5 TWs in Dandibagh campus with substantial discharge. The condition of 11/0415 KV substation of (300+250+100) KVA is not good. The transformers are old and have not undergone maintenance for long and need replacement. Protection for the Transformers either on HT side or on LT side is not available. It is proposed to renovate the substation by providing two 1000 KVA 11/0.415 KV transformers (1Working+1Stand by) with necessary protections through 11 KV VCB, LAs and ACB on LT side with proper cabling. A Single Line Diagram for the arrangement of substation is placed in Drawing No. 4 of package-1.

It is also proposed to construct a control room at Dandibagh campus for housing all switchgear and panels for centralised operation of all the 5 Tube Wells. This will reduce requirement of manpower for operation and also more effective control and supervision. Push button stations shall also be provided on each TW. A layout plan of substation, control room and tube wells at Dandibagh are placed in the drawing section in the Drawing No. 5 of package-1. No intervention is proposed at the new PHED constructed wells.

The above interventions at Dandibagh campus are likely to provide sustained and dependable power supply to TWs located here. A 33 KV electric substation exists just outside Dandibagh campus connected to 132KV GSS. Thus we can safely assume that at least 23hours daily power supply will be available on sustained basis. Similarly, it has been informed that at TWs located elsewhere in the town power supply availability is 20 hours daily in general and the same has been adopted.

5.1.4. DISINFECTION SYSTEM FOR TUBE WELLS

At present water supply from the Tube Wells is made either directly to distribution network or through reservoirs. However, there is no disinfection arrangement for the water supplied.

It is therefore proposed to provide one Electro Chlorinator at each Tube Well capable of producing 1kg/hour chlorine. The raw material required in these chlorinators will be common salt. Provision has been made in the electrical panel proposed at each TW for power supply required for the electro chlorinator.

5.1.5. REHABILITATION OF PUMP ROOMS ON TUBE WELLS

The condition of Pump Rooms constructed on TWs is not good in many cases. The internal wiring is generally in precarious condition, doors and windows and in bad condition. It is therefore, proposed to construct new pump rooms at 6 locations and rehabilitate pump rooms by repair of

civil construction, replacement of doors and windows wherever required and electric wiring for illumination at remaining 23 locations.

5.2. PROPOSED WATER SUPPLY SYSTEM LAYOUT

The proposed water supply system of Gaya will be divided in District Metered Areas. The water from the tube wells will be pumped through dedicated rising mains to the respective service storage capacities. As described below in Section 5.4, Table 13, 10 new service reservoirs are proposed and will be operated along with the 8 existing ones detailed above in the status of existing storage reservoirs and their health is depicted in Table 3.

From these reservoirs, the water will flow by gravity through transmission mains and distributed to each of the proposed 30 District Metered Areas connected to the transmission main through a Flow and Pressure Monitoring Station. The larger Reservoirs (Existing GLSRs) will supply several DMAs whereas for DMAS where no storage was until now available one Over Head Tanks will be provided, for each DMA. No other connection will be allowed to the Transmission Mains from Storage to DMAs.

All pipelines laid by PHED with a length of about 72 km of Ductile Iron are proposed to be kept in operation, in spite of the fact that a large portion of them has not yet been handed over to GMC. All other existing pipe lines which are reported to be of Cast Iron and laid prior to 1982 will be decommissioned and replaced as the same have become very old and unsuitable for rehabilitation.

The decommissioning of the old pipelines is an important item to be considered in the Capital Works Contract to be laid as result of works of package-1.

The length of new pipes to be laid is estimated at about 446 km. The pipe materials will be Ductile Iron for diameters 350 mm and above and HDPE for sizes up to 300 mm. This is based on the prevailing practice in most of the utilities in India as both HDPE and DI pipe provide excellent service for distribution system. However, looking to cost economy HDPE pipes for 110 mm dia and DI pipe in sizes 150 mm & above have been adopted.

In the frame of the activity related to the installation of customers' meters, also the old service connections will be renewed.

A drawing showing location of all existing and proposed service reservoirs, tube wells and existing and proposed transmission pipe lines is placed in the Drawing No. 2.

5.3. PROPOSED TRANSMISSION AND STORAGE SYSTEM

5.3.1. PROPOSED PUMPING MAINS

The existing tube wells at Dandibagh are already connected through three pumping mains to Brahmayoni SRs and accordingly no new transmission pipe line is proposed for them. Similarly, new tube wells constructed by PHED at Dandibagh are also connected by a separate pumping main to Singra sthan GLSR by a new transmission main and accordingly no new pumping main will be required for these tube wells.

All remaining tube wells are presently pumping water to the distribution system. However, in order to have equitable distribution of water in a sustained manner and use the production capacity of TW optimally, it is proposed to supply water through OHSRs or GLSRs on Hills. Table 12 details the lengths and sizes of pipe lines proposed to be provided to connect tube wells to respective Service Reservoirs. All pipes for pumping mains will be of Ductile Iron K9. The pipe sizes have been worked out in the design section based on the TW discharge capacity based on most techno-economic consideration over a period of 30 years.

Table 12: Details of Proposed Rising Mains

ID	Name of tube wells	Discharge m³/h	Rising main Length [m]	Size of Rising main [mm]
1	Dandibagh TW 1	220	300	300
4	Dandibagh TW 4	220	200	250
5	Dandibagh TW 5	220	300	250
	Combined Discharge 1,4 &5	660	3000	600
2	Dandibagh TW 2	220	50	200
		220	3000	350
3	Dandibagh TW 3	220	100	250
		220	3000	500
21	Visnupad	130	50	250
22	Bypass	75	50	200
	Combined Discharge of 1&2	205	5500	350
6	Panchayati Akhara No. 1	100	50	200
7	Panchayati Akhara No. 2	100	50	200
17	Panchayati Akhara No. 3	100	50	200
	Combined Discharge of 1,2,3	300	1500	350
9	Dhobighat	40	50	150
24	Bageshwari Pachim	20	1000	125
	Combined Discharge of 5 nos.	360	500	350
28	Manpur	100	2500	250
30	Khadigramodyog Lakhibagh	55	30	150
	Combined Discharge of 2 (Nos.)	155	900	250
34	Kirl 3, Near Bridge	75	1200	200
33	Kirl 2, Maffassil Thana	170	100	250
29	Manpur - Buniydiganj	75	1500	200
32	Kirl 1, Joda Masjid	150	150	250
18	Janata Colony 1	40	50	150
19	Janata Colony 2	20	50	125
	Combined Discharge of 1&2	60	1000	200
10	Central School	75	500	200
14	New Godown	55	50	200
	Combined Discharge of 1&2	130	1000	250
12	Gurudwara	55	50	200
11	Nigam Store	20	50	125
23	Bairagi Powerganj	55	1000	200
25	Pitamaheshwar	75	50	250

ID	Name of tube wells	Discharge m³/h	Rising main Length [m]	Size of Rising main [mm]
27	Hata Godown	55	50	200
	Combined Discharge of 5	260	1000	350
26	Kauvasthan	20	900	125
8	Azad Park	55	50	200
20	Pilgrim Hospital	20	300	125
	Combined Discharge of 3	95	200	250
15	Kharkhura	40	50	150
16	Delha	40	500	150
	Combined Discharge of 2	80	1500	200

5.4. PROPOSED STORAGE CAPACITIES

5.4.1. LOCATION OF THE STORAGE CAPACITIES

The location of all existing Service Reservoirs is shown in the Drawing No. 16 of package-1. This drawing also shows the location of proposed new reservoirs.

5.4.2. CAPACITY OF OVER HEAD TANKS

The water distribution system has been designed with formation of DMAs. The DMAs are connected to nearest SRs. An examination of existing capacities of reservoirs and water demand to be met has been done in the design section. Accordingly, in Phase I 9 new SRs are proposed, among them 6 No's are OHT and 1 GLSR are to be newly constructed & 2 existing GLSRs are to be demolished and two new GLSRs of proposed capacities are to be constructed at the same locations. All newly proposed OHSRs will have a staging of 21m and same has been incorporated in network design. Table 13 shows the location, the capacity, the DMAs served and the water demand of served DMAs. It is also proposed that 2 OHTs may be constructed after project period as the same are not immediately required due to less population density in these DMAs.

Table 13: Proposed Service Storages details

ID.	Reservoir Location	ML	Land required	DMAs connected	DMAs Demand (MLD)		TW
			(m x m)		2048	2018	Connected
1	Joda Maszid	2.15	30 x 30	2, 3	12.71	7.39	29, 32
2	Patan Toli (Phase-II)	*1.0					
3	Budhva Mahadev	1	30 x 30	1	2.25	1.18	New T/W proposed
4	Mastalipur	2	24 x 37.5	4, 5	7.587	3.8	28, 33
5	Bhusanda Mela	2.15	30 x 30	6, 7	8.592	4.45	34,30
6 &7	Ramshila Hill GLSR	#0.22+ 2.6	24 x 40	8, 9	10.248	5.31	6, 7, 9, 17, 24,31
8	Murli Hills GLSR	#1.630		10	5.326	3.58	10, 11, 12, 14, 18, 19, 23, 25, 27
9	Azad Park	#0.45		Ward 15, DMA 13	2.324	1.25	8, 20, 26
10c	Brahmayoni Hills GLSR	4.64	45 x 90	11, 12, 13, 14, 17,	68.763	41.44	1, 2, 3, 4, 5

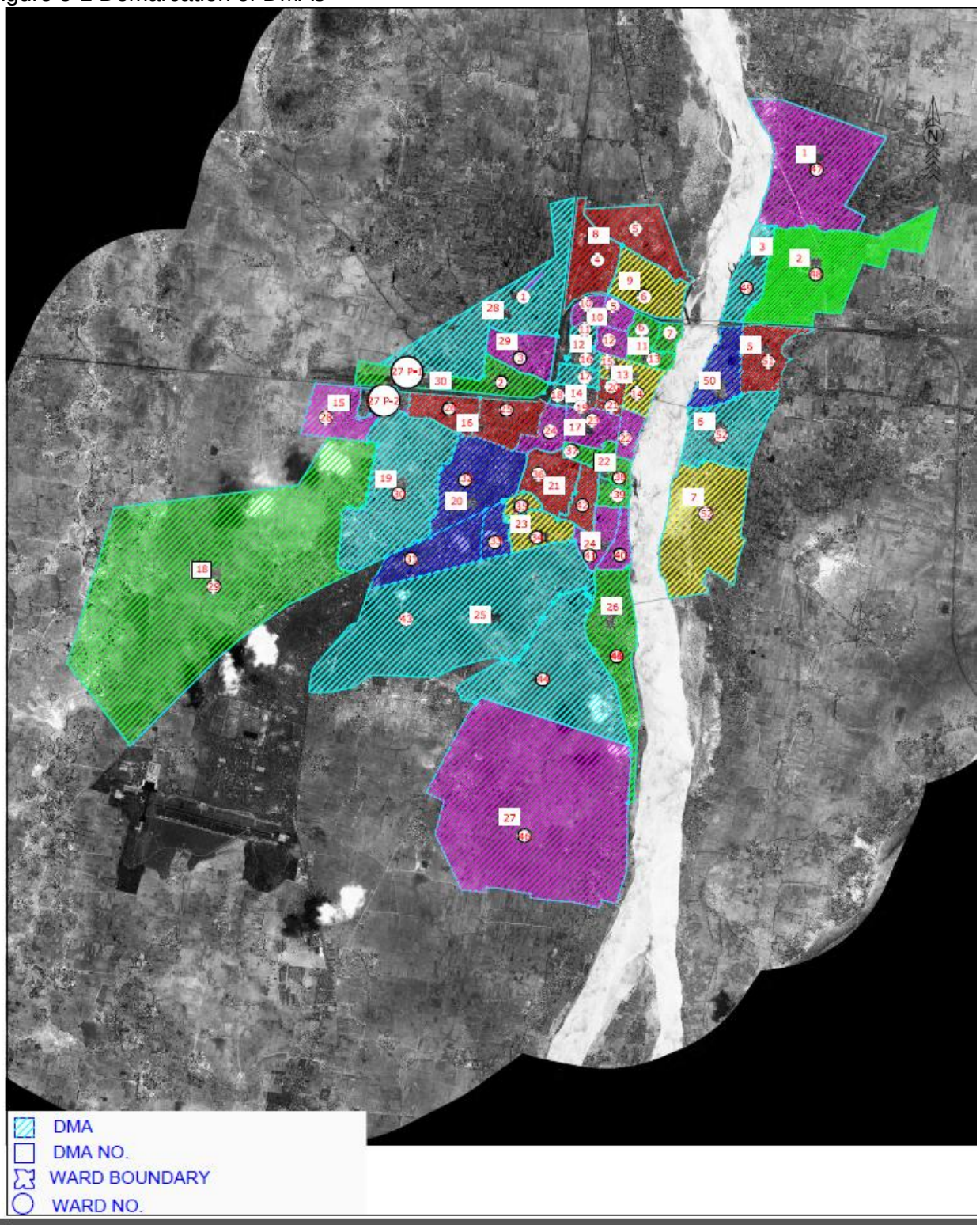
ID.	Reservoir Location	ML	Land required (m x m)	DMAs connected	DMAs Demand (MLD)		TW
					2048	2018	Connected
10d	Brahmayoni Hills GLSR	4.64		21, 22, 23, 24, 25, 26, 27			
10a	Brahmayoni Hills GLSR	#1.816					
10b	Brahmayoni Hills GLSR	#1.816					
11	Brahmayoni Hills GLSR	#3.632					
12	Brahmayoni Hills GLSR	#3.632					
13a+13b	Singra Sthan	#4.54 & 3.7		15, 16, 18, 19, 20	32.698	14.59	35, 36, 37, 38, 39
14	Behind Delha PS 1A	1.5	30 x 30	29	5.546	2.77	15, 16
16	Behind Delha PS 1	2.15	26 x 34.6	28, 30	7.27	3.5	21, 22

Existing Reservoirs: * *Reservoirs proposed in Phase II*

5.5. PROPOSED DISTRIBUTION SYSTEM

5.5.1. DEMARCATION OF DMAS

Figure 5-1 Demarcation of DMAs



The District Meter Area serve to better manage the distribution network, based on the pressure patterns control and on the water flows monitoring. A DMA is fed from few monitored input pipe lines and supply and consumption can be easily compared.

A DMA of the distribution system for Gaya town is covering 6 to 40 km of water supply pipelines and up to 4,000 and up to 7000 service connections in 2018 and 2048 respectively according to the present design. However further DMAs will be necessary as the network develops to the streets configuration at a certain target year. The DMAs have 1 to 3 monitored connections to transmission mains used to calculate and derive the water balance in that DMA.

Gaya will be divided in to 30 DMAs. Each DMA will be supplied with water from the storage tank with a dedicated feeder main. All DMAs are having separate monitoring stations at taping point from feeder mains.

The Detailed representation of DMA with municipal ward boundaries are shown in the Drawing No.18 of package-1 DPR.

The demarcation and details of DMAs like storage tanks, contributing municipal wards and length of pipes are shown below.

Table 14: Details of DMAs in Gaya

DMA No.	Population					No. of Connections for Year 2021	Length (m)	Tank ID
	Ward	2018	2021	2033	2048			
1	47	8922	9405	11490	14433	1649	19,631	1
2	48	15128	15948	19483	24473	4729	10,497	2
3	49	17322	18261	22308	28023	5281	12,078	3
4	50	17439	18385	22460	28213	3646	14,545	4
5	51	9495	10010	12229	15362	2119	9,753	
6	52	12276	12941	15810	19860	3838	20,847	5
7	53	13010	13715	16755	21047	2947	18,561	
8	5	4178	4404	5380	6759	1236	14,858	6 & 7
	4	14562	15351	18754	23557	2716		
9	6	15413	16249	19850	24935	3841	8,825	
10	9	6423	6771	8272	10391	261	14,852	8
	10	9196	9694	11843	14877	1989		
	12	11777	12415	15167	19052	3422		
13 (Pt-1)	15	8144	8585	10488	13175	2126	2,876	9
12	11	7585	7996	9768	12270	1958	9,805	10a+ 10b
	16	7721	8140	9944	12491	2083		
	17	7185	7575	9254	11624	1809		
11	7	9707	10233	12501	15704	1208	13,831	
	8	11987	12637	15438	19393	3747		
	13	4625	4876	5957	7483	793		
13 (Pt-2)	14	11719	12354	15092	18958	2736	4,555	
14	18	4884	5148	6290	7901	1389	10,947	
	19	5750	6061	7405	9302	1258		
	20	5120	5397	6594	8283	1295		
	21	3021	3185	3890	4887	1412		

DMA No.	Population					No. of Connections for Year 2021	Length (m)	Tank ID
	Ward	2018	2021	2033	2048			
15	28	11930	12577	15365	19300	2435	13,987	13
	27 (pt-2)	17883	17910	18425	19288	2573		
16	26	7835	8260	10091	12676	1913	22,072	
	25	11575	12203	14908	18726	2320		
18	29	9406	9916	12114	15217	4146	40,970	
19	30	17880	18849	23027	28926	4639	38,109	
20	31	9850	10384	12686	15935	1171	29,472	
	32	8282	8731	10666	13398	1464		
	33	5812	6127	7486	9403	1593		
21	36	14076	14839	18128	22772	2315	19,149	11
	42	8278	8727	10661	13392	1369		
22	37	4115	4338	5300	6657	1085	10,819	
	38	11830	12472	15236	19139	1869		
	39	6193	6528	7976	10018	1407		
23	34	12156	12815	15656	19666	2577	14,351	
	35	5583	5886	7190	9032	1165		
24	40	9604	10125	12369	15537	1920	11,171	12
	41	7549	7958	9722	12212	1458		
25	43	11384	12001	14661	18417	2035	33,739	
	44	6489	6841	8357	10498	1277		
26	45	13986	14745	18013	22627	2801	13,996	
27	46	10454	11021	13464	16913	2515	17,799	
17	24	7425	7827	9562	12011	1389	17,389	
	23	8041	8477	10356	13009	1579		
	22	9923	10461	12780	16053	1982		
28	1	10515	11085	13542	17011	3313	21,160	14
29	3	14412	15193	18561	23315	4788	10,366	15
30	2	9246	9747	11908	14958	2026	12,264	16
	27part-1		943	4606	9644	135		
Totals		**524297**	**552723**	**675237**	**848200**	**120747**	**513274**	

5.5.2. HYDRAULIC MODELING

The basic objective of the distribution system is to provide equitable distribution of water throughout the network with acceptable pressure. However, due to the addition of new localities and continuous growth of population the infrastructural setup needs to be upgraded periodically to meet the additional demand.

The distribution system is modelled and simulated with actual flow conditions. The process of simulation and model build is called as modelling. On built up of such model, improvements / additions are easy to perform.

5.5.3. PROPOSED DISTRIBUTION PIPELINES

The future Distribution Network will be composed of the pipeline and diameters shown below in the Table 15.

Table 15: Details of Proposed Distribution Network Pipes

Diameter (mm)	*Existing DI pipe lengths laid by Kirloskar Bros. for PHED*										
	100	150	200	250	300	350	400	450			
Total [m]	30755	14598	15492	2053	1246	1720	4319	2272	**72455**		
Diameter (mm)	*Proposed HDPE (PN 6) pipe lengths*										
	110										
Total [m]	3,01,002										
Diameter (mm)	*Proposed DI K-7 pipe lengths*										
	150	200	250	300	350	400	450	500	600	700	
Total [m]	62354	29631	18919	9131	6321	5077	5376	2226	4897	2141	**447075**

The total length to be laid is 446475 m.

All existing pipelines laid before 1982, which are mostly of Cast Iron are proposed to be replaced. Special attention shall be given to their decommissioning.

The above length of 72.4 Km PHED pipe lines is based on GIS map prepared based on pipe lines marked in software, connected with proposed DMAS and designed with the help of M/S Kirloskar representative. However, actual length will be known only when the assets are handed over to GMC along with 'As Built Drawings' as agreed during a meeting in BUIDCO on 29th April 2014 by EE PHED Gaya.

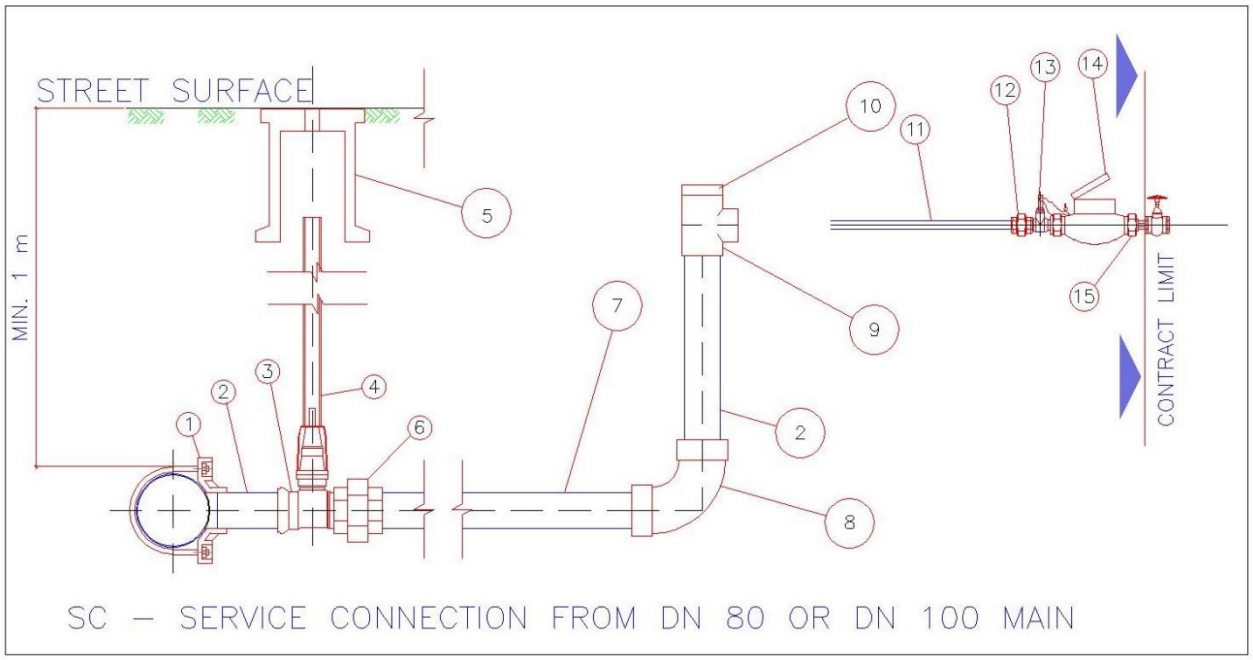
It is assumed that before the start of the capital investment works all the existing PHED pipelines laid by Kirloskar Brothers will be properly tested and commissioned and will be taken over by GMC. However, provision is made in the confidential cost estimate for replacement of 5% of pipes laid through PHED which are found to be leaking/un-repairable during execution/operation.

Details of the above DMA wise designs are placed in the Design section of the present report and shown in the drawings.

5.6. SERVICE CONNECTIONS AND METERING

All service connections shall be provided with water meter and shall consist of an arrangement similar to the one shown in the Figure 5-2 below.

Figure 5-2:Service Connections arrangement recommandations



Legend

1	Drilling Saddle for DN 80 and 100	9	T-Piece
2	Pipe Nipple, Dia.100, L=100 mm	10	Plug
3	Service Gate Valve (with brass union)	11	Pipe Nipple, Dia. 40, L=100mm
4	PVC Valve protection Bell and Pipe	12	Reduction or T-piece 100-40
5	Valve surface box	13	Anti-Fraud system stop cock
6	Union	14	Water Meter complete with brass union
7	MDPE Pipe,	15	Brass Coupling
8	Compression joints		

The main characteristic of the above recommendation is that the tapping either as above realised through a drilling saddle in existing pipes or by T-piece in new pipes, shall not be at the top of the distribution pipe barrel, but horizontally or at 1/8 of the circumference. This system will reduce the possibility that the meter would measure volumes of air.

The T-piece no. 10 in the above figure is suggesting that similar arrangement to the one composed of items 11 through 15 should be repeated for multi-stories buildings where no convention for a single bulk meter exists.

In case one single connection is to be installed, with reference to the above figure, the nipple 11 shall be joined to the union piece 6.

The shown configuration is recommended for the situation when the meter can be located in-house. If this is not possible, the meter shall be provided with housing (box or chamber).

All materials of pipes, fittings, and any appurtenances are to be adapted to the technical specifications.

6. UNDER GROUND WATER DEVELOPMENT

6.1. REVIEW OF EARLIER WORK

Few hydro-geological surveys were carried out in the past to assess the ground water potential and capability along the river Phalgu to use the river as the source of water for Gaya town. The details of previous studies are as follows:

1. Central Ground Water Board (CGWB)

A study conducted by Central Ground Water Board (CGW B) in Year 1978 to assess the ground water potential and capability along the river Phalgu (in the river flood plain) recommended tube wells in the bed of Phalgu river as a source for water supply for MES, since the yield in the tube wells are adequate due to high potential available in the bed. However, no detailed hydro geological study was carried out before coming to this conclusion.

2. The WAPCOS report:

UDHD, GoB awarded the work of preparation of DPR for augmentation of water supply of Gaya town in 2010 WAPCOS. In this report it was assumed that underground water available in Phalgu basin will be adequate to meet water demand of the town until 2029. But they gave no reasons or justification for this assumption.

3. M/S Kirloskar Brothers Ltd. Kolkata report

PHED, GoB has executed a project to augment water supply to Gaya town, M/S Kirloskar constructed 8 successful tube wells in 2008-2009. These tube wells are drilled along Phalgu River bank for a depth ranging from (22 to 30) m and they discharging around (28 to 82) lps

4. Hydro-Geo Survey Consultants Private Limited (HCPL)

DPR furnished by WAPCO was studied by the UD&HD, Govt. of Bihar and by Gaya Municipal Corporation (GMC) and Public Health Engineering Department (PHED). From its observation it was concluded that the information given in it was found inconsistent. For getting long term assured water supply to Gaya town for next 30 years Bihar Urban Development Investment Program, (BUDIP), BUDIP authority appointed Haskoning DHV Nederland BV in association with Tata Consulting Engineers (TCE) and PSP Financial Consultants as Program Management Consultant (PMC)

PMC had entrusted the work for conducting Comprehensive Hydro Geological Investigations to Hydro-Geo Survey Consultants Private Limited (HCPL) which includes comprehensive hydro geological investigations, comprising remote sensing for locating the most promising area on the bank of Phalgu river, detailed geo electrical resistivity surveys for locating sites having maximum aquifer thickness, long duration pump tests to find out aquifer parameters, ground water quality analysis and to assess the long term assured availability of water of 127.25 MLD for the projected population of Gaya city in the mid-year 2033.

- The report is more informative and elaborative and focused particularly on the river bed aquifer area. Identification of four promising areas confined along both the bank of river Phalgu is mentioned in this report
- But pinpointing the location of probable feasible sites for exploratory cum production tube wells with expected drilling depth, yield and quality were not carried out in that study.

DSC had prepared detailed ToR and eventually contracted work for conducting the resistivity survey. The main objective of the survey & investigation is to pinpoint the Tube well locations using Geophysical (Resistivity) and Geo hydrological survey & investigation. And the study is conducted along both banks of River Phalgu and in Gaya Municipal Corporation.

6.2. HYDROLOGY

6.2.1. PHALGU RIVER

Phalgu River has historical importance as Gaya is located on the bank of this river. The Phalgu is formed by the junction, some three kilometres below Bodh Gaya, of the *Lilajan* (also called *Niranjan* or *Nilanjan*) and the *Mohana*, two large hill streams each of which is over 300 yards wide. The *Phalgu* is also known as *Niranjan*. The united stream flows on to the north past the town of Gaya, where it attains a breadth of over 900 yards. The Phalgu here passes by a high rocky bank, on the steep sides of which are many paved stairs leading down to the river bed, while high above are the Vishnupad Mandir, with many minor shrines around it. It then runs in a north-easterly direction for about 27 km, and opposite the Barabar hills it again takes the name of Mohana, and divides into two branches which eventually flow into a branch of the Punpun.

Phalgu is rain fed river and almost dry in summer season. The river is simply a vast stretch of sand dunes, wide, flat and generally dry. But the mass of water is available below the sand dunes. If one digs even a meter, the water seeps out and a small crater full of water is formed Fig 6.1

Figure 6-1 Small pit showing shallow water table on the left bank of River Phalgu near I.T.I. Ghugritand during month of Feb-2014

The *Lilajan* begins its journey north of Simaria in Chatra district on the Hazaribagh plateau, the western portion of which constitutes a broad watershed between the Damodar drainage on the south and the *Lilajan* (also called Niranjan) and *Mohana* rivers on the north. It flows through a deep and rocky channel until it reaches the neighbourhood of Jori. There the hills begin to recede and the stream flows sluggishly over a wide sandy bed. From this point to the Gaya border beyond Hunterganj the river is a sandy one dry in summer but disastrous during the rains. Six miles south of Gaya it unites with the Mohana River to form Phalgu River.

The *Mohana* originates on Korambe Pahar on the Hazaribagh plateau near Bendi village, 19.3 kilometres from Hazaribagh. The *Mohana* then runs north past Itkhori, descends into the Gaya Plains, and crosses the Grand Trunk Road / NH 2 at the foot of the Danua pass. Near Itkhori it intersects the Chatra-Chauparan Road with its wide and sandy channel. 3.2 km below Bodh Gaya it

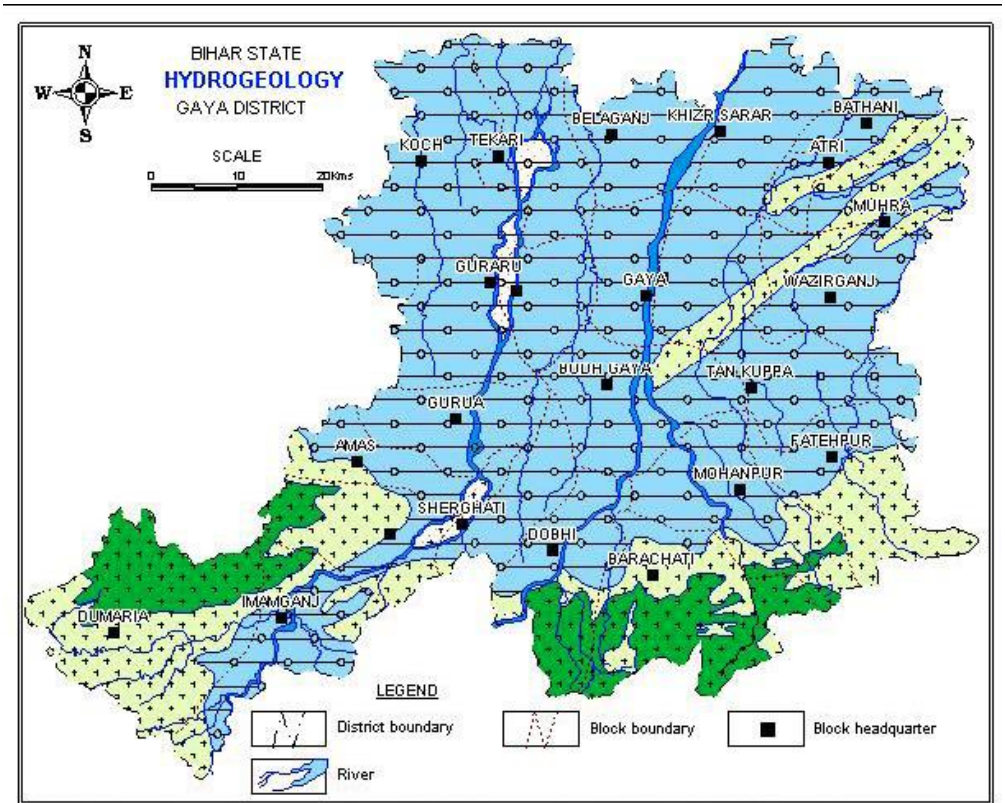
unites with the Lilajan (Niranjana) to form the Phalgu. When it goes past the Barabar Hills, it again takes the name of *Mohana*, and divides into two branches.

6.2.2. PHALGU RIVER SUB-BASIN, ITS HYDROLOGY AND PHYSIOGARPHY

The study area lies in the southern part of the Bihar state and covers the district of Gaya and lies in Phalgu river sub-basin, a tributary of Harohar River (a major tributary of Ganga River). The study area drains northwards. The principle river of the study area is Phalgu.

The catchment area of Phalgu river sub-basin up to Dandibagh well field is located between latitude N 23° 59' 33.1'' – N 24° 46' 47.7'' and Longitude 84° 39' 01.7'' – 85° 18' 40.4'' and covers an area of 3398 km^2 up to Dandibagh well field. The surface water resources of Phalgu River and its tributaries have been harnessed in about 10% of the catchment area of Phalgu river sub-basin at some locations by constructing minor irrigation projects. So, free catchment area of Phalgu river sub-basin is taken as 3058 km^2 up to Dandibagh well field. The elevation within Phalgu river sub-basin varies from 540-645 m AMSL in south to 100 - 110 m AMSL near Dandibagh well field.

The area is traversed by river Phalgu. A number of streams originate in the catchment area and merge with larger streams and rivers which are tributaries of the river Phalgu. These tributaries dissect the study area and finally deposit their sediment load into the river. The drainage pattern of Gaya District is shown in below Fig 6.2.



FORMATION	AGE GROUP	LITHOLOGY	SYMBOL	GROUND WATER POTENTIAL
Unconsolidated	Quaternary	Recent alluvium, clay, silt, sand, gravel etc.		Moderate yield 50 - 108 cu.m./hr.
Consolidated	Pre- cambrian	Quartzite / Mica schist Granite gneiss		Poor yield prospect 20 - 50 cu.m./hr.

Figure 6-2 Bihar State Hydrogeology Gaya District

Data Source: *Ground Water Information Booklet, Gaya District, Bihar State Central Ground Water Board Mid-Eastern Region Patna, September 2013*

6.3. GROUND WATER OCCURRENCE

The Ground water occur in this project area in (i) Fissured formations (ii) Porous formation.

6.3.1. FISSURED FORMATIONS

The Ground water occur under unconfined condition is weathered zone which acts as a good repository of groundwater. The thickness of weathered zone varies from 2.0 m to 10.0 m in the low lying valley area.

The ground water occurs under semi- confined condition in the fractures underlying the weathered formation.

The movement of ground water is controlled by joints, fissures and other planes of structural weakness and is depended on the extent, size, opening, continuity and interconnections of fractures.

They form potential repositories of groundwater in the fissured rocks consisting of granite gneisses, mica-schist, quartzite and other associated rock of Pre-Cambrian area. The range of Aquifer Parameter Depth yield.

6.3.2. POROUS FORMATION

The Quaternary alluvium occurring in the central valley (Dhobi- Gaya terrace) as well as Sone-Ganga plain constitute this **Hydrogeological Unit.** It consists of alluvial sediments, made up of gravels, sands, silt and clays. The gravel and medium to coarse-grained sand layers are good groundwater repositories. The thickness of the alluvium deposit is nearly 30-50 m, but the actual thickness of the aquifer varies from 15 to 20 m. In the alluvium the groundwater is under water-table condition. If can sustain a yield of 25 m^3/hr. to 40m^3/hr. on an average.

The exploratory drilling in Gaya district is confined to hard rock areas.

Shallow bore wells of 50 m depth with 10-15 m^3/hr yield of fresh ground water. The deeper bore wells of 100 m depth may of 15-30 m^3/hr. of fresh ground water.

In order to assess the temporal and spatial behaviour of ground water levels over the years, 10 ground water monitoring wells are monitored during pre- and post-monsoon periods in the year 2011. From the study of depth of water level map, it is evident that ground water level during monsoon period varies 5-10 m below ground level. Near Gaya deeper ground water levels exceed (>10m) were observed.

Ground water level during post monsoon period mainly varies between 2-5 m below ground water level. Near Gaya ground water levels (5-10 m) were observed over a small patch.

There is paucity of reliable site specific information of these wells like Lithological logs of the wells, well pipe assembly lowered indicating the zone screened, Depth to water level , Depth to pumping water level, Draw down, Discharge, the depth of pump lowering, Capacity of pump lowered, also the information about aquifer parameters like specific capacity, transmissivity. Field permeability, Radius of influence etc. are not available.

6.4. GEO HYDROLOGICAL AND GEOPHYSICAL (RESISTIVITY) SURVEY & INVESTIGATIONS

During the resistivity survey, the information about existing ground water structures in and around the Vertical Electrical Sounding (VES) points/areas was collected, studied and used in interpreting the resistivity survey data.

Geo-electrical resistivity survey is carried out in, and around Gaya city to study the variation in sub surface lithology, ground water quality and feasible points for ground water exploration by tube well. The investigation was conducted in government lands only.

6.4.1. GEO-ELECTRICAL RESISTIVITY SURVEY

Resistivity Survey technique is proved to be one of the most effective method for groundwater investigation. However it should be used in conjunction with other methods.

Resistivity Survey does give some positive indication about the soil salinity and aquifer water quality. However, this technique has got some limitations.

The presence of water and its chemical character are the principal controls on the flow of electric current because most rock particles offer high resistance to electrical flow.

In case of interpretation care must be taken not to overvalue a resistivity reading for a particular depth. Each value represents an average resistivity for a 10 or 20 feet (3 to 6m) vertical section of the formation. This value may indicate more than one combination of geologic material & water and Experience must be called upon to make a correct interpretation.

Resistivity method is not, however, without limitations.

The Resistivity of a rock is Not Unique to it and that there is considerable overlapping of resistivity range of several rock types depending on Clay Content, Water Saturation, Quality of Water and Porosity.

During Resistivity Survey in Gaya Municipal Area, 36 vertical electrical sounding using Schlumberger configurations is conducted in and around Gaya city area. The investigated areas are 1. ITI Polytechnic campus 2. Kendui Ghat 3.Kendua 4. Delha, 5. Kharkhura, 6.Budhava Mahadev 7. Bhusanda, 8. Mastalipur and 9. Haridas Inter College premises in Gaya city. Out of total 36 VES , 4 VES (4A , 4 B and 5 A , 5 B in ITI Polytechnic campus, VES 20 A, 20 B at Budhva Mahadev and VES 22 A ,22 B at Bhusanda area) are conducted at same pin point with perpendicular orientation to each other to study the ground water flow direction in that part. It is pertinent to mention that it was not possible to take more perpendicular VES due to non-availability of necessary spreading area. Furthermore it was tried to take maximum available VES spreading at all VES point.

Longitude and latitude of each VES point are shown below table 16.

Table 16 Latitude and Longitude of VES points

VES No.	Latitude (N)	Longitude (E)	VES No.	Latitude (N)	Longitude (E)
1	24°45'48.239"	85°0'38.264"	17	24° 48' 18.093"	84° 59' 22.598"
2	24°45'50.31"	85°0'37.555"	18	24° 49' 52.799"	85° 1' 44.304"
3	24° 45' 49.549"	85° 0' 38.991"	19	24° 49' 50.732"	85° 1' 42.77"
4 A / 4 B	24° 45' 50.096"	85° 0' 36.135"	20A/20 B	24° 49' 57.152"	85° 1' 41.635"
5 A / 5 B	24° 45' 50.609"	85° 0' 33.208"	21	24° 47' 4.234"	85° 0' 56.098"
6	24° 45' 50.041"	85° 0' 36.918"	22A/22 B	24° 47' 2.195"	85° 0' 56.772"
7	24° 45' 47.689"	85° 0' 35.995"	23	24° 47' 1.016"	85° 0' 56.078"
8	24° 45' 44.826"	85° 0' 38.212"	24	24° 47' 44.782"	85° 1' 54.269"
9	24° 45' 42.029"	85° 0' 38.043"	25	24° 47' 44.522"	85° 1' 56.73"
10	24° 45' 37.557"	85° 0' 39.075"	26	24° 47' 44.253"	85° 1' 58.479"
11	24° 45' 26.563"	85° 0' 43.272"	27	24° 47' 8.008"	84° 59' 50.57"
12	24° 44' 44.822"	85° 0' 39.986"	28	24° 47' 9.712"	84° 59' 51.611"
13	24° 44' 43.924"	85° 0' 38.47"	29	24° 47' 9.036"	84° 59' 49.664"
14	24° 48' 16.089"	84° 59' 4.151"	30	24° 44' 46.864"	85° 0' 39.633"
15	24° 48' 12.22"	84° 59' 4.036"	31	24° 44' 48.082"	85° 0' 40.788"
16	24° 48' 9.095"	84° 59' 6.009"	32	24° 44' 47.173"	85° 0' 38.383"

6.4.2. THEORY ON GEO-ELECTRICAL RESISTIVITY SURVEY:

In general the resistivity of a geological formation may be considered as a function of its moisture content and salinity.

Resistivity survey is a quick and relatively inexpensive method compared to drilling and 3D seismic survey for acquiring quantitative information of the sub-surface with respect to its lithology and hydrogeology such as depth of bedrock, groundwater occurrence & its distribution, weathered and fracture zone and salinity of the saturated zones.

Resistivity sounding is a process by which depth investigation is made. In this, the centre of the configuration is kept fixed and the measurement is made by successively increasing electrode spacing on either side. The apparent resistance values obtained with increasing values of electrode separations are used to estimate the thickness and resistivity of the subsurface formations.

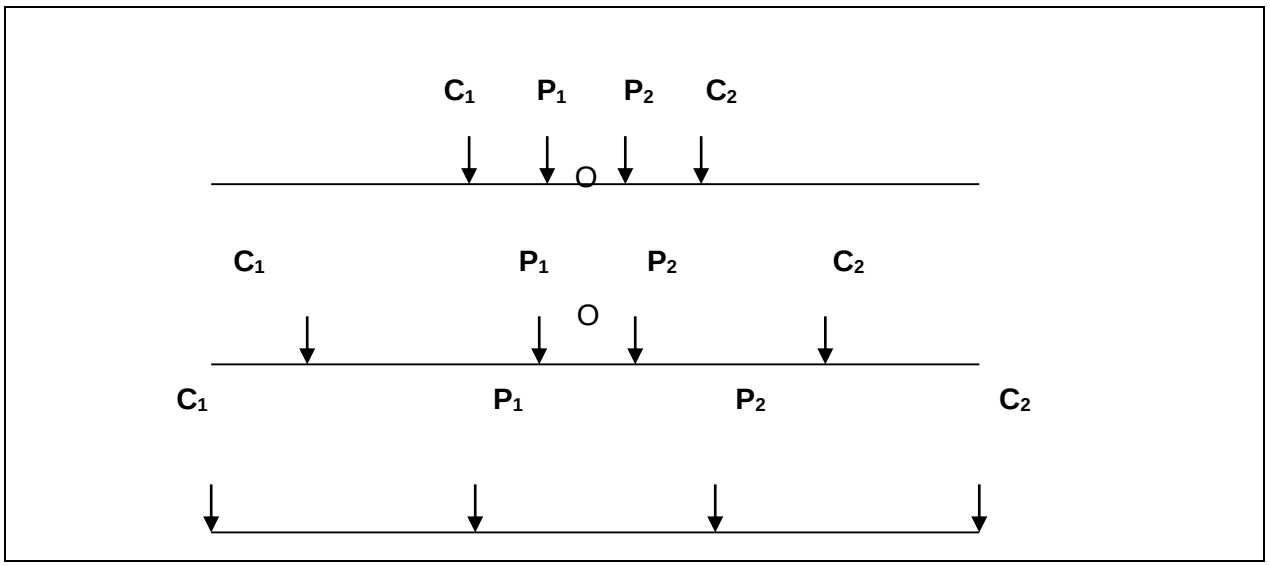


Figure 6-3 Successive positions of electrodes during sounding

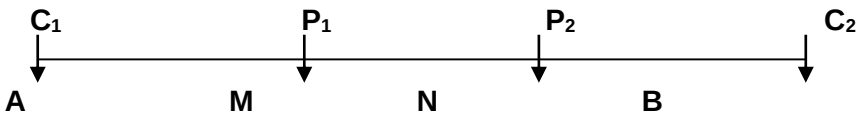
In Schlumberger array all the four electrodes are kept in a line on either side of the fixed centre point 'O' where the two inner electrodes (Potential electrodes P1 & P2) are kept closer. For increasing depth of investigation the current electrodes C1 and C2 are moved apart symmetrically about the centre point 'O', keeping the potential electrodes fixed and changing their distances only when the potential deference becomes low. The apparent Resistivity for each current electrode separation is calculated by multiplying the resistance value by Schlumberger configuration factor.

The configuration factor for the Schlumberger array is

$$K = \frac{[AB/2]^2 - [MN/2]^2}{MN} \times л$$

And the apparent resistivity is obtained with the formula

$$p_a = K \times (V / I)$$



As per basic stipulation of Schlumberger configuration, in order to contain the measurement error within 5 %, MN/2 (Half of Potential electrode distance) should be always kept < or = 1/5 (AB/2 i.e. Half of Current electrode distance).

Instruments used for Survey:

The signal stacking Resistivity meter, model no. SSR-MP-AT, designed by IGIS, Hyderabad is used for present survey. It contains microprocessor based measuring unit. Measuring unit measures the current and potential values, calculates the resistance, apparent resistivity and longitudinal conductance values , stores in the memory and gives the output through the display/directly sends the values to PC.

During present survey at many places interruption for current penetration in to the ground was observed, which may be due to clayey or saline nature of the subsurface formations.

Interpretation of Resistivity Data:

The present study has been intended to the identification of the geological condition and potential of the aquifer at depths from the surface using deep geophysical soundings. In the study, resistivity values have been used to interpret the thickness and lithological character of the layers along with the salinity of the aquifers.

The interpretation of resistivity data is done in two stages

a. Processing of data to get the physical parameters in term of resistivity and depths, IX 1D software is used for the interpretation of the data and

b. Using these parameters inferring the nature of subsurface formations on the basis of geological knowledge and correlative studies.

Quantitative Interpretation:

Quantitative interpretation of the field resistivity data indicates the occurrence of alluvium deposit (over burden) of varying nature with moderate thickness (7 m. to 44m.), followed by rock. Correlating the analysed resistivity values with different nature of alluvium and rock formation, following resistivity ranges can be assigned.

Inferred resistivity ranges of Formation

Formation	Inferred resistivity ranges
Alluvium (unsaturated)	5.9 - 6909 Ohm m
Alluvium (saturated)	6.1 - 56 Ohm m
Weathered rock	< 50 Ohm m.
Semi weathered rock	50 - 500 Ohm m.
Massive rock	> 500 Ohm m.

The interpreted field curves with inferred geological units and recommendations for each VES conducted in different part of investigated area are presented in report and submitted separately. A sample of field curve and VES recommendations are shown below figure and table.

Table 17 Resistivity Survey (Schlumberger configuration) Data Sheet

VES NO: 1		**DATE: 26-04-2015**		
LOCATION		**Govt. ITI and Polytechnic College premises**		
LATITUDE (N)		**24º 45'48.239"**		
LONGITUDE (E),		**85º 0'38.264"**		
ORIENTATION		**N 20 W / S 20 E**		
S.N.	**AB/2 (m)**	**MN/2 (m)**	**Rho (ohm-m)**	**Remarks**
1	1.5	0.5	675	
2	2	0.5	452.5	
3	3	0.5	206.5	
4	4	0.5	100.9	
5	4	1.0	121.9	
6	6	1.0	44.5	
7	8	1.0	23.8	
8	10	1.0	16.9	
9	10	2	18.1	
10	15	2	14.9	
11	20	2	16	
12	20	5	15.6	
13	25	5	17.1	
14	30	5	20.5	

15	35	5	22.5	
16	40	5	27.7	
17	45	5	31.5	
18	50	5	35.5	
19	50	10	36.8	
20	60	10	43.9	
21	70	10	49.5	
22	80	10	60.2	
23	90	10		
24	100	10		
25	100	20		
26	120	20		

The sample at Govt. ITI & Polytechnic Campus: VES-1

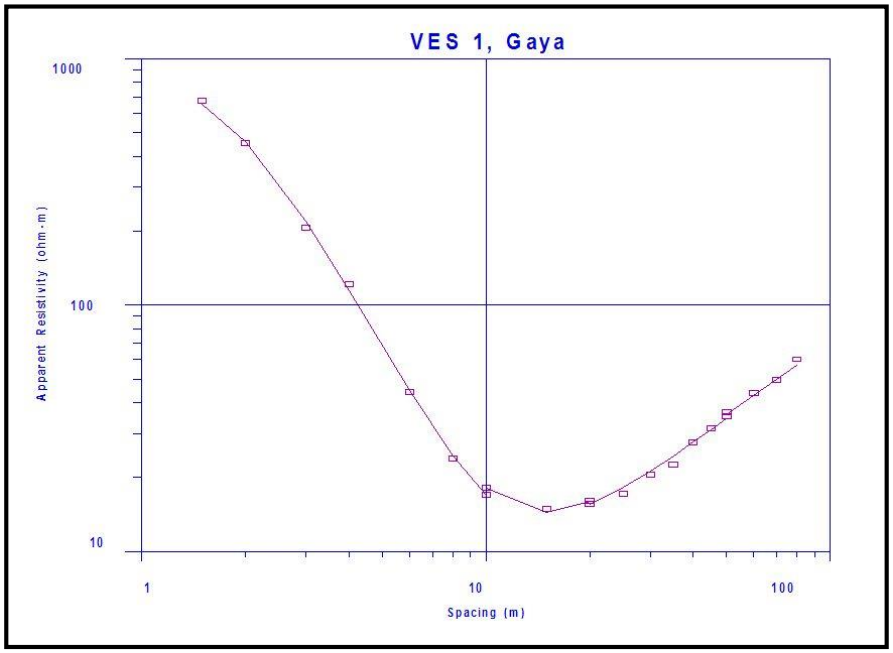


Figure 6-4 Interpreted field curve

Table 18 Interpreted Resistivity Results

VES NO. 1							
Layers	Resistivity (Ohm. m.)	Layer Thickness (m)	Depth (m)	Expected Formation	Depth of Investigation (m)	Error %	Recommendation
1st layer	1135	0.89	0.89	Top Soil	80.0	3.71	T/W of @20 m.
2nd layer	112.9	2.00	2.89	Alluvium (Unsaturated)			
3rd layer	11.9	15.10	17.99	Alluvium (Saturated)			
4th layer	2504	-		Massive rock			

6.5. RECOMMENDATIONS ON GROUND WATER SOURCE

- The Major Geological Formation in and around Gaya Municipal Corporation Area is Granitic Gneisses and Alluvium. The Ground water occur in this area in (i) Fissured formations (ii) Porous formation.
- The Ground water occur under unconfined in weathered and semi- confined condition occur in fractures underlying the weathered formation. Thickness of weathered zone is ranging from 2 to 10 m.
- The Quaternary alluvium occurring in this area consists of alluvial sediments, made up of gravels, sands, silt and clays. The gravel and medium to coarse-grained sand layers are good groundwater repositories. The thickness of the alluvium deposit is nearly 30-50 m, it can sustain for an average yield of 25 m^3/hr. to 40m^3/hr.
- Depth To Water Level during monsoon period mainly varies between 5-10 m below ground level but near Gaya deeper ground water levels exceed (>10m) were observed. And, ground water level during post monsoon period mainly varies between 2-5 m below ground water level, Near Gaya ground water levels (5-10 m) were observed over a small patch.
- Sources of water for Gaya consist of underground water extracted by tube wells located on both sides of river Phalgu, Manpur and Gaya main. There are 39 Tube wells in the town. Quantitative interpretation of the field resistivity data indicates that alluvium (over burden) with fresh ground water quality and of appreciable thickness is deposited in the project area.
- Alluvium formation is of more sandy in nature in the area close to Phalgu River where as in inland area it is of clayey nature resulting in weak aquifer system.
- Quantitative analysis indicates that alluvium formation thickness ranges in between 7 m to 44 m in the investigated areas.
- At Kendua and Budhva Mahadev alluvium of sandy nature has thickness in general more than 30 m. At ITI Polytechnic premises, Bhusanda and Mastalipur; alluvium of sandy nature has thickness in between 15 m. to 30 m.
- At Dhela, Kharkhura and Haridas Inter college premises alluvium thickness is in between 20 m. to 30 m. but its nature seems to be of more clayey thus yield may become low.
- In general in the investigated areas alluvium (over burden) is followed by rock. In general rock is of massive nature where recorded resistivity is more than 500 ohm. m. At places semi

weathered nature of rock (recorded resistivity 50 ohm. m. to 500 ohm .m.) is also indicated. Only a few VES point weathered rock (recorded resistivity <50 ohm. m.) is indicated.

- Two VES taken right angles to each other for precise estimation of ground water flow directions and nature of river, appears to be insufficient. However, it gives fairly good idea.
  Broadly speaking river Phalgu is influent in nature.

7. PROPOSED WATER SUPPLY SYSTEM

7.1. PROPOSED TUBE WELLS

The present water production of 27 MLD is to be increased 68 MLD after refurbishment of tube wells in package-1 against the total requirement of 126 MLD of water demand for Year- 2033. And the total water demand for Year-2048 is 163 MLD. The tube well in this package are designed for horizon year-2033.

After review of earlier work done and Hydrogeological survey & Investigation on ground water source, the consultants have come to concluded the availability of sustainable ground water source for Gaya water supply project.

There are seven potential zones are identified based on resistivity survey and Hydrogeological investigation results. Keeping in view of long run of tube well and acceptable discharge of tube well, all these potential zones are proposed in the river bed on both banks of the Phalgu river. Except at River bed near Budhva Mahadev Mandir, at all other six locations a battery of tube wells are proposed.

Table 19 Ground water potential zones and connecting reservoirs

S. No.	Tube well locations / Potential zones	Proposed TW ID No.	Tank ID.	Tank Location	Tank capacity ML	Land required (m x m)	DMA No.	Demand (MLD) 2033
1	River bed near School at Gauri Shankar Mandir	40, 41,42,43	1	Joda Maszid	2.15	Package-1	2, 3	8.0
			2	Patan Toli (Phase-II)	*1.0	Phase-2		
2	River bed near Budhva Mahadev Mandir	44	3	Budhva Mahadev	1	Package-1	1	2.0
3	River bed near Bhusanda Mela	45,46	5	Bhusanda Mela	2.15	Package-1	6, 7	4.0
4	River bed near Dharamshala	60, 61, 62, 63	14	Behind Delha PS 1A	1.5	Package-1	29	8.0
			16	Behind Delha PS 1	2.15	Package-1	28, 30	
5	Govt. Polytechnic College	47,48,49	17	CWR	4.00	90 X 60	11, 12, 13 part-2, 14 to 27	39
6	Kendui	50,51,52						
7	Kendua	53, 54, 55, 56, 57, 58, 59						

The additional required water demand for horizon year 2033 is 58 MLD. Resistivity survey results produce the different discharges of 100 m³/hr, 130 m³/hr at different potential zones. The total 24 number of tube wells are proposed battery wise in this package to meet 58 MLD of water demand for horizon year 2033. In each battery of tube wells there are 1, 2, 3, 4 & 7 tube well are proposed as per the requirement.

Table 20 Proposed tube wells and water demand & supply gap

Proposed Discharge of Tube well		No of Tube wells pumping @ 20 hr		Reservoir	Reservoir Location	Total Demand at reservoir (MLD)		Supply from package 1&2 (MLD)		Supply and Demand Gap for Year (MLD)		Remarks on Tube wells
(m3/hr)	MLD	Y-2033	Y-2048	ID No.		Y-2033	Y-2048	(After P-1)	(After P-2)	Y-2033	Y-2048	
100	2.0	1	0	3	Budhva Mahadev	1.711	2.250	0.0	2.0	-1.71	-0.25	One TW can be drilled after Year 2033
100	2.0	4	1	1	Joda Maszid	10.106	12.709	1.5	9.5	-8.61	-3.21	Presently 1 TW required. And later 1
100	2.0	-	1	4	Mastalipur	5.675	7.587	5.4	5.4	-0.27	-2.19	TW are Not required now
100	2.0	2	1	5	Bhusanda	6.497	8.592	2.6	6.6	-3.90	-1.99	Presently two and one later
100	2.0	-	1	6&7	Ramshila Hill GLSR	7.770	10.248	7.9	7.9	0.15	-2.33	One TW can be drilled after Year 2033
50	1.0	-	-	8a	Murli Hills GLSR	4.547	5.326	9.0	9.0	4.45	3.67	Surplus but some of the TWs are ancient
75	1.5	-	-	9	Azad Park	1.889	2.324	1.9	1.9	0.01	-0.42	Surplus but some of the TWs are ancient
130	2.6	3	3	13a	Singra Sthan	23.263	32.698	9.3	24.3	-13.94	-8.43	Presently 13 TW required. And later 8
130	2.6	1	1	12	Brahmayoni Hills	18.143	21.438	16.7	16.7	-1.46	-4.76	
130	2.6	5	2	10a+10b	Brahmayoni Hills	18.611	23.921	5.1	20	-13.55	-3.91	
130	2.6	4	2	11	Brahmayoni Hills	18.120	23.404	7.7	16.6	-10.46	-6.77	
100	2.0	1	1	14	Behind Delha PS 1A	4.260	5.546	1.6	3.6	-2.66	-1.95	Presently 4 TW required. And later 2
100	2.0	3	1	16	Behind Delha PS 1	5.512	7.270		6.0	-5.51	-1.27	
Total	**37.3**	**24**	**14**			**126.104**	**163.3**	**68**	**129**	**-58**	**-34**	

For supplying required water demand to overhead tank near Budhva Mahadev Mandir one Tube well is proposed, and likewise for OHT at Joda Masjid a battery of 4 tube wells, for OHT at Bhusanda a battery of 2 tube wells are proposed. Batteries of tube wells with 3 at ITI College, 3 at Kendui and 7 at Kendua are proposed to meet water demand of GLSRs on Brahmayoni hills and Singra sthan hills. All these three batteries of tube wells will pump water to proposed clear water reservoir of 4 ML capacity at Govt. ITI College. From this CWR water will further pump to GLSRs on Brahmayoni hills and Singra sthan hills.

7.1.1. CONSTRUCTION METHODOLOGY FOR PRODUCTION TUBE WELL

- Drilling work of pilot hole is to be taken up and completed up to recommend depth at respective point
- After the completion of pilot hole drilling, it is to be electrically logged, in order to identify the promising aquifers for screening it. On the basis of the Physical Observation of formation material (drill cuttings) and the Electro logging Test Results, corrected lithological log is to be prepared for recommending lowering of well pipe Assembly. On the basis of the study of Mechanical Analysis of Aquifer material for grain size distribution, the slot size & gravel size should be selected and recommended.
- On confirmation of well pipe Assembly, Pilot hole is to be reamed (enlarged) to 500 mm diameter for lowering 250 mm pipe diameter or hole diameter of 600 mm for lowering 300 mm pipe diameter, as the case may be, up to the total recommended depth of tube well.
- On lowering the pipe assembly into the enlarged hole, space between the (slotted & blank) pipe and enlarged hole should be packed with proper size gravel from the bottom of well up to the bottom of clay packing below ground level.
- From the top of the gravel packing, up to the ground level, perfect clay packing between Pipe and Hole is to be provided, for sanitary as well as water quality protection of well.
- Well is to be developed through backwashing prior to +compressor development test.
- Production tube well is to be developed zone wise using Airline/Education pipe by using appropriate capacity of compressor for getting sand free discharge (or Well is to be developed at least for 40 to 50 hours whichever is less).Water samples should be collected for analysing chemical and biological parameters.
- Production tube well is to be developed (10 to 15 hours depending on the observation of sand free discharge it is indicative) through over pumping before conducting Pump Test. Thereafter Pump Test is to be conducted for yield test (5 to 6 hour continuous pumping) to recommend appropriate size & capacity of pump to be installed before putting the well. Water samples should be collected for analyzing chemical and biological parameters. Drawing 19 shows the typical drawing for production tube well and observation well.

7.1.2. CONSTRUCTION METHODOLOGY FOR OBSERVATION TUBE WELL

At every potential zone one observation well is proposed.

- Drilling work of pilot hole is to be taken up and completed up to recommend depth at respective point.
- After the completion of pilot hole drilling, it is to be electrically logged, in order to identify the promising aquifers for screening it. On the basis of the Physical Observation of formation material (Drill Cuttings) and the Electro logging Test Results, corrected lithological log is to be prepared for recommending lowering of well pipe assembly. On the basis of the study of Mechanical Analysis of Aquifer material for grain size distribution, the slot size & gravel size should be selected and recommended.
- On confirmation of well pipe Assembly, Pilot hole is to be reamed (enlarged) to 300 mm diameter for lowering 150 mm pipe diameter.
- On lowering the pipe assembly into the enlarged hole, space between the (Slotted & Blank) pipe and enlarged hole should be packed with proper size gravel from the bottom of well up to the bottom of clay packing below ground level.

- From the top of the gravel packing, up to the ground level, perfect clay packing between Pipe and Hole is to be provided, for sanitary as well as water quality protection of well.
- Well is to be developed through backwashing prior to +compressor development test.
- Production tube well is to be developed zone wise using Airline/Education pipe by using appropriate capacity of compressor for getting sand free discharge (Well is to be developed at least for 40 to 50 hours).Water samples should be collected for analysing chemical and biological parameters
- Production tube well is to be developed (6 to 10 Hours) through over pumping before conducting Pump Test. Thereafter Pump Test is to be conducted for yield test (5 to 6 hour continuous pumping) to recommend appropriate size & capacity of pump to be installed before putting the well. Water samples should be collected for analyzing chemical and biological parameters. Drawing 19 shows the typical drawing for production tube well and observation well.

7.2. PROPOSED RISING MAINS

It is proposed to supply water through OHTs or GLSRs on Hills. Table 1221 below details the lengths and sizes of pipe lines proposed to be provided to connect tube wells to respective Service Reservoirs. All pipes for pumping mains will be of Ductile Iron K9. The pipe sizes have been worked out on TW discharge capacity based on most techno-economic consideration over a period of 30 years. Inlet pipe to every reservoir is designed for water demand of year 2048. Details are shown in Drawing 5 in volume II.

Table 21 Proposed rising main details

S. No.	Diameter of Pipe (mm)	Length (m)
1	200	1417
2	250	217
3	300	351
4	350	8086
5	400	21
6	450	157
7	500	89
8	600	4100
9	800	329
10	1000	2284
	Total	**17051**

7.3. PROPOSED STORAGE CAPACITIES

In addition to the existing storage capacities and the storage reservoirs proposed in package-1, there is a ground level reservoir is proposed on Singra Sthan hills to meet the required storage capacities. A break pressure tank or clear water reservoir is proposed in Govt. ITI college campus. The pumping mains from tube wells at ITI College, Kendui and Kendua are connecting to Clear water reservoir of 4.0 ML capacity. The proposed reservoir details are shown in Table 22 and in Drawing 5.

Table 22 Proposed reservoir details

Reservoir location	Capacity ML	Land required (m x m)	Connected water source TW No.	Connected DMA No.
Clear water Reservoir (CWR) at Govt. ITI	4.0	90 X 60	47,48,49,50,51,52,53,54,55,56,57,58,59	11, 12, 13 (part-2) 14, 17, 21, 22, 23,24, 25, 26, 27,
GLSR on Singra Sthan hills	3.7	45 X 45		15, 16, 18, 19, 20

7.4. OFFICE FOR WATER UTILITY OPERATOR

Existing office facility in Gaya is now limited to one room of the engineer in charge at the GMC premises. It is proposed to construction and furnishing of an office for the water utility operator in this Water Supply Project. 60 people shall be accommodated in this office. This office can be also provided with customer affairs cell. General arrangement drawing of operator office is provided in the Volume-II of this package. One operator office is proposed at Dandibagh area, with in GMC Campus. And other office shall be constructed in Manpur side. The appropriate location for operator office in Manpur side shall be finalize by contractor later after the contract is awarded. The plan of operator office cum customer service center are shown in drawing no 8.

7.4.1. CIVIL STRUCTURE DETAILS

- Area of building 14 X 11 M
- About 60 people shall be accommodated in the Utility Office.
- In the future the number will/may increase, also with sewerage-related staff.
- The building is to be constructed in 2 stages:
  - Stage 1 - 60 people,
  - Stage 2 - 30 people. (later after this package)
- This is to be realized by planning a 3-storey building, with the ground and first floor to be constructed in Stage 1. The first stage of 60 people includes both Contractor's and GMC operating staff.

7.4.2. PROPOSED FUNCTIONAL REQUIREMENTS

The following Staff details shown in below table 23 are to be accommodated in the office.

Table 23 Staff requirement details

Description	Managers	Senior staff	Other staff	Total
Director office	1	3	9	13
Technical operations	1	2	23	26
Financial operations	1	2	9	12
Customer affairs	1	0	8	9
Total	4	7	49	60

- Managers shall have separate offices with attached washroom.
- Senior and other staff shall be accommodated in shared offices with 5 to 10 staff per room.
- A conference room for at least 30 persons, Visitor's reception area and customer desk
- Accommodation for field staff visiting the office regularly (10 persons)
- Small kitchen / pantry / canteen, Library, archive and store room
- Lobby, corridors, staircase, Toilet facilities as per requirements, Backup power supply

It is also proposed to have a separate entrance from main road, Parking space for visitors and Parking space for staff.

8. PROPOSED TUBE WELLS & ELECTRO-MECHANICAL EQUIPMENT

8.1. OUTLINE OF PACKAGE-1 WORKS

At present 39 tube wells operated which includes 31 of GMC and 8 of PHED. Out of 39 tube wells 29 tube wells are proposed to rehabilitee the electromechanical equipment's to meet out the 2018 demand by providing new pump sets and electrical system.

8.2. PROPOSED MECHANICAL WORK FOR NEW TUBE WELL.

To meet out the design period demand it is proposed to provide 24 new tube wells in additional to the existing 39 tube wells. The proposed 24 tube well will be fitted with submersible pump set ranging from 15kW to 26 kW with different discharge capacity ranging from 100m³/hr to 130m³/hr as per the details in the table 27.

Each tube well will be fitted with one number of Electromagnetic flow meter and one ultrasonic level transmitter for better monitoring and maintenance of the tube wells.

A clear water reservoir is proposed nearby Gaya Government polytechnic which will be fitted with 6 numbers of 132kW vertical pump set (4W + 2S) to feed water from ground reservoir to Brahmayoni reservoir. The Clear water reservoir will be fed by 13 tube wells out of 24 tube wells. The remaining 11 tube wells will feed water directly to the distribution reservoir. The proposed duty condition of tube wells are produced in the designs (Section 11).

8.3. ELECTRICAL SYSTEMS

It is proposed to provide an Electric panel in each Tube Well pump room with an air break Star Delta starter with necessary protection relay, meters and level indicating meter. An electrical panel is proposed in the clear water reservoir station with soft stator with necessary protection relay, meters and level indicating meter. The electrical system is proposed to be properly earthed as per rules.

It is proposed to provide a dedicated 11kV power supply with 11/0.415kV transformers (1Working+1Stand by) with necessary protections through 11 kV VCB, LAs and ACB on LT side with bus coupler and proper cabling for the following locations with transformer capacity as below.

1. Clear water Reservoir – 1000kVA
2. Phalgu River bed opposite to Budhva Mahadev (4 tube wells) – 200kVA
3. Kendui (Kiriawa) (7 tube wells) – 250kVA
4. Phalgu River near by Joda Mazjid (4 tube wells) – 250kVA

Thus we can safely assume that at least 23hours daily power supply will be available on sustained basis for 15 tube wells and 1 clear water pump house by providing 11KV dedicated power supply of above mentioned capacity. Similarly, it has been informed that at the remaining 9 Tube Wells located in

1. Phalgu River near to Budhva Mahadev (1 tube well)
2. Phalgu River near to Bhusanda (2 tube wells)
3. ITI (3 tube wells)
4. Kendua (3 tube wells)

Will be provided with 433V power supply directly from Electricity Board as it cannot be grouped to provide a dedicated power supply.

It is also proposed to construct a control room for housing all switchgear and panels for centralised operation of the Tube Wells in the following locations:

1. Clear water Reservoir.
2. Phalgu River bed opposite to Budhva Mahadev (4 tube wells)
3. Kendui (Kiriawa) (7 tube wells)
4. Phalgu River near by Joda Mazjid (4 tube wells)

This will reduce requirement of manpower for operation and also more effective control and supervision. Push button stations shall also be provided on each TW. All tube wells and control room shall be electrified.

8.4. DISINFECTION SYSTEM FOR TUBE WELLS

It is proposed to provide one Electro Chlorinator at each Tube Well capable of producing the required quantity chlorine ranging from 1kg/hr to 1.5kg/hr to maintain 10ppm at the delivery pipe line. The raw material required in these chlorinators will be common salt. Provision has been made in the electrical panel proposed at each TW for power supply required for the electro chlorinator.

9. PROPOSED IMPLIMENTATION STRATEGY

9.1. APPROVAL OF DPR AND TENDERING ACTIVITY

The technical approval of detailed project Report is likely to take 3 months duration from the date of submission of DPR i.e. by the end of October 2015, the DPR will be finalized. It is proposed to take up the Bid document preparation by August 2015.The approval of Bid document may take another one month time. The tender process may be commenced.

After awarding the work to the contractor, the following implementation schedule will be followed. The schematic diagram for implementation schedule is shown in fig 9.1.

9.2. CONTRACTOR PREPARATION PERIOD

Three months' time will be allowed for the contractor to commence the work from the award of contract. During this preparation period, the contractor shall visit the project area and he shall collect all the required Data to commence the work. During this period, the contractor shall undertake soil investigation, Underground utility survey, architectural design for operator office, etc. and other related surveys which are mentioned in the Bid document.

9.3. WATER SOURCE WORKS

New tube wells 24 Nos are to be drilled in the bank of river Phalgu and the locations were already pin pointed. The contractor shall drill the tube wells in the specified locations within the period of 18 months. During this period, the required observation wells are also to be drilled to monitor the water level in the proposed area. Connected pump houses, pumping plants procurement and erection shall be completed within this period. After the tube wells, one Clear water Reservoir and connected pump house and pumping plant procurement and erection shall be completed within the specified period. The pumping plants shall be designed after the ascertaining the yield in the respective tube wells. Entire activity will start within 90 days from the commencement and will be completed in 810 days.

9.4. STORAGE RESERVOIRS

The construction of Reservoir at Singra sthan will take 12 months. The work will start after180 days from the commencement date and will be completed in 12 months.

9.5. TRANSMISSION MAIN

The rising main from the respective source to Service Reservoir site/ Clear water Reservoir site and from clear water reservoir to Service Reservoirs will be taken after 180 days from the commencement date and it will be completed in 18 months.

9.6. OPERATOR OFFICE

During preparation period, the architectural design and structural design for the operator office will be completed. The construction work will start after 270 days from the commencement date and it will be completed by 12 months.

9.7. COMMISSIONING AND TESTING

All the components created and all the pumping plants erected will be commissioned simultaneously as soon as the Tube wells, concerned pump house, rising main and pumping plant works are completed. There are 24 Tube wells and one clear water pump house are proposed in this DPR. Connected pumping mains, pumping plants, Service Reservoirs, Clear water reservoirs, all the pump houses are to be commissioned during this period. The work will commence after 365 days from the commencement date and it will be fully completed by 90 days.

9.8. MAINTENANCE PERIOD

The assets created in this package shall have to be maintained by the contractor for 36 months from the completion date of commissioning and testing. At the end of maintenance period, the entire assets shall be handed over to the Local body for further maintenance.

Figure 9-1 Proposed Schedule of Implementation

Description	Year → Month ↓	1	2	3	4	5	6	7
Contract commence date	3							
Works								
Section 1 : Water source works	18							
Section 2: Storage Reservoirs	12							
Section 3: Transmission Mains	18							
Section 4: Operator office	12							
Commissioning and Testing	3							
Operation services	48							
Contract Completion Date								

10. DESIGN PARAMETERS AND CRITERIA

10.1. KEY TARGETS AND PLANNING HORIZONS

As suggested by the ADB key targets for the cities of Bihar under the investment program by 2021 are:

(i) Water supply coverage at 95% of the population;

(ii) Water supply quantity at 135 litres per capita per day;

(iii) Water supply duration for 24 hours on 7 days per week;

(iv) Non-Revenue (NRW) water at less than 20% of the total water produced;

Additional targets referring to wastewater and solid waste do not apply to this project.

The starting of the capital works is foreseen for 2014 and their finalisation for 2018. The design life of the pipelines supposed to be in place by the end of the project is of 30 years. Therefore the target year is 2048 and the intermediary stages considered in our projections are as following:

- Stage 1 of projections - year 2014 to 2018;
- Stage 2 of projections – year 2021 for meeting the agreement between ADB and GOB;
- Stage 3 of projections – year 2033 for the verification of intermediary results;
- Stage 4 of projections – year 2048 for meeting the useful life of the assets.

10.2. PRODUCTION TUBE WELL CONSTRUCTION

The specifications for construction of production tube well given in below table 24.

Table 24 Specifications for construction of production tube well

S. No.	Parameters	Particulars for Tube Well Drilling
1	Diameter of Pilot hole	250 mm
2	Diameter of enlarged hole	In case for lowering 250 mm pipe diameter, 500 mm diameter of pilot hole. In case for lowering 300 mm pipe diameter 600 mm diameter of pilot hole.
I	Diameter of tube well	250 or 300
4	Expected depth to be drilled (depends on location of site)	(35 to 50) m below ground level.
5	Expected depth of clay packing	From the top of gravel packing below ground level up to ground level.
6	Tentative length of housing pipe	Nearly 70 percent of total depth in m
7	Tentative length of slotted pipe	Nearly 30 percent of total depth in m
8	Provision of Gravel packing	The annular space between the pipe and hole is to be packed with pea size gravel from the bottom of well (i.e. from the bottom of total depth drilled) up to the base of the recommended depth of clay packing

S. No.	Parameters	Particulars for Tube Well Drilling
9	Provision of Clay packing	The annular space between the pipe and hole is to be packed with impervious clay from the top of the recommended depth of gravel packing up to the ground level
10	Slot Size	3.17 mm i.e. 3.00 mm (1/8 inch) to3.17 mm i.e. 3.00 mm i.e. (1/16 inch)
11	Expected Yield	100 to 130 m^3/hr

10.3. OBSERVATION TUBE WELL CONSTRUCTION

Specifications of construction of observation tube well shown in below table 25

Table 25 Specifications for construction of observation tube well

S. No.	Parameters	Particulars for Production Tube Well Drilling
1	Diameter of Pilot hole	250 mm
2	Diameter of enlarged hole	In case for lowering 150mm pipe diameter, 300mm diameter of pilot hole
3	Diameter of tube well	150 mm
4	Expected depth to be drilled (depends on location of site)	35 to 50 m below ground level.
5	Expected depth of clay packing	From the top of gravel packing below ground level up to ground level.
6	Tentative length of housing pipe	Nearly 70 percent of total depth in m
7	Tentative length of slotted pipe	Nearly 30 percent of total depth in m
8	Provision of Gravel packing	The annular space between the pipe and hole is to be packed with pea size gravel from the bottom of well (i.e. from the bottom of total depth drilled) up to the base of the recommended depth of clay packing
9	Provision of Clay packing	The annular space between the pipe and hole is to be packed with impervious clay from the top of the recommended depth of gravel packing up to the ground level
10	Slot Size	3.17 mm i.e. 3.00 mm (1/8 inch) to 3.17 mm i.e. 3.00 mm i.e. (1/16 inch)
11	Expected Yield	100 to 130 m^3/hr

10.4. HYDRAULIC CRITERIA FOR PUMPS

- Suction velocity in the order of 1.6 m/s
- Pump discharge in the order of 3 m/s
- General isolating suction valve in the case of a station composed of several pumps with positive suction conditions.
- Non return valve for the delivery of each pump
- Isolation valve for each pump discharge (possible butterfly)
- Delivery manometer (possibly with electrical contacts)
- Dismantling joints necessary for proper maintenance
- General delivery collector with butterfly isolating valve
- Volumetric counter with pulse head (to calculate the flow)
- Protection device against transitory phenomena, wherever appropriate
- Washouts for flushing and cleaning of the rising pipelines will be provided at each pumping station.

Storage capacity: Capacity of the service reservoir is calculated as 25% of total water demand

Rising mains :

Pipe material: DI K-9

Designed period: 30 Years, Horizon year 2048.

Hazen Williams's coefficient: 140

11. DESIGNS

11.1. POPULATION PROJECTIONS

The development of a town depends upon natural, physical and socio-economic factors. Among these factors, the population assumes significance in determining the future pattern of progress and development.

Gaya is expected to undergo many changes in its economy and demography in the coming years. The continuous exodus of rural population to urban areas has contributed to the exponential growth resulting in severe strain on the existing infrastructure. There has been considerable increase in developmental activities, which is causing a growth in urbanization. In addition to the resident population a good number of tourists flock to Gaya for religious reasons.

The design population is estimated with due regard to all factors governing the future growth and development of the project area in the industrial, commercial, educational, social and administrative spheres. Special factors causing sudden migration or influx of population has also been foreseen to the extent possible.

The forecasted population of Gaya is arrived at based on the methods laid down in the Manual on Water Supply and Treatment, published by the Ministry of Urban Development, Govt. of India, which are as follows:

- Arithmetical increase method
- Geometrical increase method
- Incremental increase method
- Exponential graphical method
- Linear increase graphical method
- Decadal growth increase method

The population projection has been carried out for 30 years from year 2018 to 2048. The base year for works identified and designed under this project has been considered as 2018. Detailed population projections by various methods are therefore made for the base year 2018, mid-design year 2033 and design year 2048, which is presented as follows:

Table 26: Population projections by various methods

Population projection for the years 2018, 2033 & 2048 based on census data from year 1921 to 2011			
Census Population for year 1961 to 2001			
Year	**Census population**	**Increment X**	**Increment Y**
1921	67,562		
1931	88,005	20,443	
1941	1,05,223	17,218	3,225
1951	1,33,700	28,477	11,259
1961	1,51,105	17,405	11,072
1971	1,79,884	28,779	11,374
1981	2,47,075	67,191	38,412
1991	2,91,675	44,600	22,591
2001	3,89,192	97,517	52,917
2011	4,68,614	79,422	18,095

	Average	**44,561**	**7,372**
1. Arithmetic increase method			
Increase per decade			44,561
Pop. in n^{th} year		=Pop. in $(n-1)^{th}$ decade + Increase for n decade	Projected Pop.
Population in 2011 based on 2001			4,33,753
Population in 2018 based on 2011			4,99,807
Population in 2033 based on 2011			5,66,649
Population in 2048 based on 2011			6,33,491
2. Geometrical increase method			**rg**
Rate of growth (r) between 1931 & 1921			0.3026
Rate of growth (r) between 1941 & 1931			0.1956
Rate of growth (r) between 1951 & 1941			0.2706
Rate of growth (r) between 1961 & 1951			0.1302
Rate of growth (r) between 1971 & 1961			0.1905
Rate of growth (r) between 1981 & 1971			0.3735
Rate of growth (r) between 1991 & 1981			0.1805
Rate of growth (r) between 2001 & 1991			0.3343
Rate of growth (r) between 2011 & 2001			0.2041
Rg=	Geometric mean	=power(product (rg),1/n))	0.2304
Pop. in nth year		=Pop.in $(n-1)^{th}$ year*power((1+rg),n)	**Projected Population**
Population in 2011 based on 2001			4,78,850
Population in 2018 based on 2011			5,41,801
Population in 2033 based on 2011			7,39,424
Population in 2048 based on 2011			10,09,129
3. Incremental increase method			
Pop. in n^{th} year		=Pop.in $(n-1)^{th}$ year +n*X+(n(n+1)*Y)/2	**Projected Population.**
Population in 2011 based on 2001			4,41,126
Population in 2018 based on 2011			5,04,193
Population in 2033 based on 2011			5,92,600
Population in 2048 based on 2011			6,97,592

4. Exponential Graphical Method			
Year	**X-axis Years**	**Census Population**	**Interpolated population 2nd degree**
1921	0	67,562	80,245
1931	10	88,005	83,140
1941	20	1,05,223	95,945
1951	30	1,33,700	1,18,662
1961	40	1,51,105	1,51,290
1971	50	1,79,884	1,93,830
1981	60	2,47,075	2,46,280
1991	70	2,91,675	3,08,642
2001	80	3,89,192	3,80,915
2011	90	4,68,614	4,63,099
2018	97		5,24,297
2033	112		6,75,237
2048	127		8,48,200
5. Linear Graphical Method			
Year	**X-axis Years**	**Census Population**	**Projected Population.**
1921	0	67562	20,778
1931	10	88005	63,317
1941	20	105223	1,05,856
1951	30	133700	1,48,395
1961	40	151105	1,90,934
1971	50	179884	2,33,473
1981	60	247075	2,76,012
1991	70	291675	3,18,551
2001	80	389192	3,61,090
2011	90	468614	4,03,629
2018	97		4,33,406
2033	112		4,97,215
2048	127		5,61,023
6. Decadal growth rate method			
Census Year	**Census Population**	**Decadal Increase**	**Decadal Growth Rate in %**
1921	67562		
1931	88005	20443	30.26
1941	105223	17218	19.56
1951	133700	28477	27.06
1961	151105	17405	13.02

1971	179884	28779	19.05
1981	247075	67191	37.35
1991	291675	44600	18.05
2001	389192	97517	33.43
2011	468614	79422	20.41
Total		401052	
Average		44561	
Average			**24.2**
S. No.	**Year**	**Population**	**Projected Population.**
1	1921	67562	
2	1931	88005	
3	1941	105223	
4	1951	133700	
5	1961	151105	
6	1971	179884	
7	1981	247075	
8	1991	291675	
9	2001	389192	
10	2011	468614	483532
11	2018		548128
13	2033		718516
14	2048		888905

The census population for 2011 is available as an authentic basis for comparison. Therefore, the projected populations carried out by various methods for Year 2011 have been cross checked with the census population of 2011, which is given in the Table 27 below:

Table 27: Variation comparison by various methods

No.	Population Projection Method	Projected Population	Census Population	Variation
		2011	**2011**	%
1	Arithmetic Increase Method	4,33,753	4,68,614	7.44
2	Geometric Increase Method	4,78,850	4,68,614	-2.18
3	Incremental Increase Method	4,41,126	4,68,614	5.87
4	**Exponential Graphical Method**	**4,63,099**	**4,68,614**	**1.18**
5	Linear Increase Graphical Method	4,03,629	4,68,614	13.87
6	Decadal growth increase	4,83,532	4,68,614	-3.18

It is evident from the table above that the percentage variation of population projected by Exponential Graphical Method is the least (1.18) as compared to that by other methods. Therefore Exponential Graphical Method has been recommended and used for water demand assessments for Gaya. The projected population for Gaya, therefore, is as follows:

Horizon Years	Projected Population
Base Year (2018)	5,24,297
Mid-Design Year (2033)	6,75,237
Design Year (2048)	8,48,200

11.2. PUMP SET CAPACITIES

The capacity of proposed pumping sets & head has been arrived at based on actual physical measurement of tube well discharge & also capacity of aquifer tapped all around. The pumping set installed at the existing tube well locations is proposed to be replaced and delivery pipe and flow meters to be provided as per Table 28 below:

Table 28 Proposed pump sets

S. No	Location of the Tube wells	Name of the SR to be served by the Tube well	Tube well No	BHP	KW	Discharge (m^3/hr)	Total Head (m)
i	Phalgu River near by Joda mazjid	Joda mazjid OHT	40	35	26.11	100	65
			41	35	26.11	100	65
			42	35	26.11	100	65
			43	35	26.11	100	65
			Total Load		104.44		
ii	Phalgu River near to Budhva Mahadev	Budhva Mahadev	44	40	29.84	111.6	66
iii	Phalgu River near to Bhusanda	Bhusanda OHT	45	30	22.38	100	58
			46	30	22.38	100	58
			Total Load		44.76		
iv	ITI	Brahmayoni & Singra Sthan GLSRs	47	20	14.92	130	30
			48	20	14.92	130	30
			49	20	14.92	130	30
			Total load		44.76		
v	Kendve		50	25	18.65	130	34
			51	25	18.65	130	34
			52	25	18.65	130	34
			Total load		55.95		
					0		
vi	Kendui (Khiriawa)		53	20	14.92	130	29
			54	20	14.92	130	29
			55	20	14.92	130	29
			56	20	14.92	130	29
			57	20	14.92	130	29

S. No	Location of the Tube wells	Name of the SR to be served by the Tube well	Tube well No	BHP	KW	Discharge (m^3/hr)	Total Head (m)
			58	20	14.92	130	29
			59	20	14.92	130	29
			Total load		104.44		
vii	Phalgu River bed opp to Budhva Mahadev	Behind Delha PS 1&1A	60	35	26.11	100	60
			61	35	26.11	100	60
			62	35	26.11	100	60
			63	35	26.11	100	60
			Total load		104.44		
CWR	Polytechnic college campus	34.4	MLD				
	For one pump set	8.6	MLD	ADD 10% for parallel pumping			9.46
		500	m^3/hr			say	10
	Head	64	m				
	BHP required	164.6090535	HP				
	Available HP	175	HP				
	kW	130.55	kW				
	Provide 175 HP Turbine Pump set having duty of 500 m^3/hr x 64 m head - 4 Nos and 2 Nos standby						

11.3. RISING MAIN PIPE LINES

The rising mains to ground level / overhead service reservoirs located at various places of the Gaya town have been designed based on proposed pumping rate from the TW and most techno-economical system over a period of 30 years has been proposed. The details of the rising mains and their connection details are presented in Table 29 and Table 30

Table 29: Details of rising mains pipe line sizes

ID.	Reservoir Location	Proposed Rising Main Dia. (mm)		Proposed Tube wells Connected	Package-1		DMAs connected
					Dia (mm)	Tube wells Connected	
1	Joda Mazjid	450		40, 41,42,43	250	32	2,3
2	Patan Toli (Phase-II)						
3	Budhva Mahadev Mandir	200		44	250	29	3
4	Mastalipur				200	33,34	4, 5
5	Bhusanda Mela	300		45, 46	200	28,30	6, 7
6&7	Ramshila Hill GLSR				350	6, 7, 9, 17, 24	8, 9
8a	Murli Hills GLSR				350	10, 11, 12, 14, 18, 19, 23, 25, 27	10, 12
9	Azad Park				250	8, 20, 26	Ward 15, DMA 13
10a	Brahmayoni Hills GLSR	300		Centrifugal pumps (4W+2S) Clear Water reservoir at Govt. ITI College	350	1, 2, 3, 4, 5,22	11, 13, 14, 17,21,22,23 , 24,25,26,27
10b	Brahmayoni Hills GLSR						
11	Brahmayoni Hills GLSR	10c	500		450		
12	Brahmayoni Hills GLSR	10d	500		600		
13	Singra Sthan	13a	600			35, 36, 37, 38, 39	15, 16, 18, 19, 20
14	Behind Delha PS 1A	300		60, 61,62,63	250	15, 16	29,
16	Behind Delha PS 1	300					28, 30
17	CWR at ITI College	400		47,48,49			
		350		50,51,52			
		600		53,54,55,56,57,58,59			

Note: Combined pipe which is connecting from CWR to tanks ID number 10c, 10d, & 13a size is 1000 mm.

Table 30: Sample of a design for economic size of rising main

Discharge at Ultimate Stage 2048	**lps**	**lpm**	**m^3/hr**	**m^3/s**					
	47.22	**2833**	**170.0**	**0.05**					
Physical Data									
Length of rising main (m)	1000								
Maximum velocity (m/sec)	3								
Minimum velocity (m/sec)	0.6								
Relative density of water to be pumped	1								
Overall efficiency of pumping plant	72%								
Cost of electrical energy per unit (Rs.)	6								
Pump Equipment cost per KW (Rs.)	40000.00								
Type of pipe to be used	DI K9								
Manning constant 'C'	100								
Velocity Head (m) / Terminal Head	2.00								
Frictional loss in PH (m)	2.00								
Interest rate of Loan (%)	10								
Life cycle period of project (yrs)	15								
Capital recovery factor	0.13147								
RL of minimum water level (m)									
RL of discharge point(m)									
Total static head (m)	**60.17**								

Cost of electrical energy consumed per meter head									
Total days per year for pumping	365								
Hours of flow	24								
Discharge to be pumped (lps)	47.22								
Quantity of water pumped (Kg/sec)	47.22								
Electrical energy input (KW/m)	0.643								
No. of units consumed per year (KWH/m)	5633								
Cost of electrical energy per year per meter head (Rs.)	33796.30								
Calculation for economic size of DI, K9 rising main									
Rate	908	1084	1316	1804	2503	3029	3793	4414	5245
Diameter of pipe	100	125	150	200	250	300	350	400	450
Per meter cost of pipeline including taxes, laying etc.	1271.2	1517.6	1842.4	2525.6	3504.2	4240.6	5310.2	6179.6	7343
Cost of pipe line for total length (Rs. In Lacs)	12.712	15.176	18.424	25.256	35.042	42.406	53.102	61.796	73.43
Cost of Pump including 25% Stand by (Rs. In Lacs)	80.6	42.5	29.8	22.3	20.5	19.8	19.6	19.5	19.4
Capital cost (Line & Pump) (Rs. In Lacs)	93.3	57.6	48.2	47.6	55.5	62.3	72.7	81.3	92.9
Total annual capitalized (Rs. In Lacs)	12.273	7.578	6.335	6.253	7.297	8.185	9.558	10.687	12.21
Total frictional losses including 10% extra for bends etc.	190.651	71.902	32.413	9.220	3.477	1.568	0.799	0.446	0.267
Total Head including static head at Discharge 2047	250.816	132.067	92.578	69.385	63.642	61.733	60.964	60.611	60.43
Annual energy consumption (Rs. In Lacs) at Discharge 2047	84.77	44.63	31.29	23.45	21.51	20.86	20.60	20.48	20.42
Total annualised cost (Rs. In Lacs)	**97.04**	**52.21**	**37.62**	**29.70**	**28.81**	**29.05**	**30.16**	**31.17**	**32.63**

Velocity (m/sec)	6.010	3.846	2.671	1.503	0.962	0.668	0.491	0.376	0.297
Considering the velocity criteria and the capitalized cost, the economic diameter as					250				
Discharge in m^3/sec	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
Diameter in m	0.10	0.13	0.15	0.20	0.25	0.30	0.35	0.40	0.45
Length of line in m	1000	1000	1000	1000	1000	1000	1000	1000.	1000.
$h=[10.674 \times Q^{1.852} \times L]/[C^{1.852} \times D^{4.87}]$	173.32	65.37	29.47	8.38	3.16	1.43	0.73	0.41	0.24
h – frictional head loss m, L – length in m, D – Internal dia in m, Q – Discharge in m^3/sec, C – Pipe roughness coefficient									
Recommended size of rising main	**250**	**mm**							

The rising main design and static head calculations for economic size design are shown in below table Table 31 Pumping main designs and head calculations.

11.4. PUMPING MAIN DESIGNS AND HEAD CALCULATIONS

Table 31 Pumping main designs and head calculations

Tank ID No.	Location of Tank	TW ID. No.	Location of Tubewell and No.	Point of Delivery (OHT / GLSR)	No. of TW Proposed	Discharge (MLD)	Discharge (m^3/sec)	Discharge (m^3/hr)	Proposed Size of Rising Main (mm)	Length (m)	GL of TW	GL of Tank/ Junction	Diff between GL of TW & Tank (m)	Staging of OHT (m)	Ht of container of OHT/GLSR (m)	Total level diff. for pumping (m)	Depth of Pump (m)	Static Head H_s (m)
1	**Joda Masjid OHT**	40	TW 40	Y-Junction 1			0.028	100	200	84.56	104	104.5	0.5		6.87	7.37	25	61.37
		41	TW 41	Y-Junction 1			0.028	100	200	63.68	104	104.5	0.5		6.87	7.37	25	61.37
			Y-Junction 1	**Y-Junction 3**			**0.056**	**200**	250	**61.58**	**104**	**104.5**	**0.5**			**0.5**		**29.00**
		42	TW 42	Y-Junction 2			0.028	100	200	57.05	104	104.5	0.5		6.87	7.37	25	60.87
		43	TW 43	Y-Junction 2			0.028	100	200	76.90	104	104.5	0.5		6.87	7.37	25	60.87
			Y-Junction 2	**Y-Junction 3**			**0.056**	**200**	250	**52.90**	**104.5**	**104.5**	**0**			**0**		**28.5**
			Y-Junction 3	**Junction of Package-1**			**0.111**	**400**	350	**467.28**	**104.5**	**113**	**8.5**			**8.5**		**28.5**
			Junction of Package-1	**Tank 1**	**4**	**12.709**	**0.177**	**635**	450	**71.95**	**113**	**112**	**-1**	**21**		**20**		**20**
3	**Budhva Mahadev OHT**	44	Budhva Mahadev-44	**Tank 3**	**1**	**2.250**	0.031	100	200	152.70	106	111	5	21	5.82	31.82	25	56.82
5	**Bhusunda OHT**	45	Bhusunda - 45	Y-Junction 4			0.028	100	200	70.72	108	109	1		6.87	7.87	25	57.87
		46	Bhusunda - 46	Y-Junction 4			0.028	100	200	27.60	108	109	1		6.87	7.87	25	57.87
			Y-Junction 4	**Junction of Package-1**			**0.056**	**200**	250	**26.68**	**109**	**111**	**2**			**2**		**25.00**
			Combined Line (Junction of Package-1)	**Tank 5**	**2**	**8.592**	**0.119**	**430**	350	**26.68**	**109**	**111**	**2**	**21**		**23**		**23.00**
10c, 10d, 11, 12, 13 & 13a	**Brahmayoni & Shringrasthan**	47	Govt. ITI College-47	Y-Junction 5			0.036	130	200	94.98	118	119	1		4	5	25.0	29.4
		48	Govt. ITI College-48	Y-Junction 5			0.036	130	200	57.92	118	119	1		4	5	25.0	29.4
			Y-Junction 5	**Y-Junction 6**			**0.072**	**260**	300	**54.90**	**119**	**119**	**0**			**0**		**-0.7**
		49	Govt. ITI College-49	Y-Junction 6			0.036	130	200	50.72	118	119	1		4	5	25.0	29.4
			Combined Line (Y-Junction 6)	**CWR**	**3**	**8.970**	**0.108**	**390**	350	**465.48**	**119**	**117**	**-2**		**1.35**	**-0.65**		**-0.65**
		50	Kendua -50	Y-Junction 7			0.036	130	200	48.88	114	115	1		4	5	25.0	32.5
		51	Kendua -51	Y-Junction 7			0.036	130	200	29.95	114	115	1		4	5	25.0	32.5
			Y-Junction 7	**Y-Junction 8**			**0.072**	**260**	300	**17.70**	**115**	**115**	**0**			**0**		**4.9**
		52	Kendua -52	Y-Junction 8			0.036	130	200	67.80	114	115	1		4	5	25.0	32.5
			Combined Line (Y-Junction 8)	**CWR**	**3**	**8.970**	**0.108**	**390**	350	**1837.95**	**115**	**117.45**	**2.45**			**2.45**		**2.5**
		53	Kendui-53	Y-Junction 9			0.036	130	200	74.48	120	121	1		4	5	25.0	26.5

Tank ID No.	Location of Tank	TW ID. No.	Location of Tubewell and No.	Point of Delivery (OHT / GLSR)	No. of TW Proposed	Discharge (MLD)	Discharge (m^3/sec)	Discharge (m^3/hr)	Proposed Size of Rising Main (mm)	Length (m)	GL of TW	GL of Tank/ Junction	Diff between GL of TW & Tank (m)	Staging of OHT (m)	Ht of container of OHT/GLSR (m)	Total level diff. for pumping (m)	Depth of Pump (m)	Static Head H_s (m)
		54	Kendui-54	Y-Junction 9			0.036	130	200	32.82	120	121	1		4	5	25.0	26.5
			Y-Junction 9	**Y-Junction 11**			**0.072**	**260**	300	**107.45**	**121**	**121**	**0**			**0**		**-3.6**
		55	Kendui-55	Y-Junction 10			0.036	130	200	69.05	120	121	1		4	5	25.0	26.5
		56	Kendui-56	Y-Junction 10			0.036	130	200	23.70	120	121	1		4	5	25.0	26.5
			Y-Junction 10	**Y-Junction 11**			**0.072**	**260**	300	**11.48**	**121**	**121**	**0**			**0**		**-3.6**
			Y-Junction 11	**Y-Junction 14**			**0.144**	**520**	450	**23.02**	**121**	**121**	**0**			**0**		**-3.6**
		58	Kendui-58	Y-Junction 13			0.036	130	200	26.78	120	121	1		4	5	25.0	26.5
		59	Kendui-59	Y-Junction 13			0.036	130	200	70.05	120	121	1		4	5	25.0	26.5
			Y-Junction 13	**Y-Junction 12**			**0.072**	**260**	300	**39.05**	**121**	**121**	**0**			**0**		**-3.6**
		57	Kendui-57	Y-Junction 12			0.036	130	200	28.25	120	121	1		4	5	25.0	26.5
			Y-Junction 12	**Y-Junction 14**			**0.108**	**390**	400	**20.75**	**121**	**121**	**0**			**0**		**-3.6**
			Y-Junction 14	**CWR**	**7**	**20.930**	**0.253**	**910**	600	**2983.90**	**121**	**117.45**	**-3.55**			**-3.55**		**-3.6**
			CWR	Junction at Akshyawat Temple		**62.741**	0.871	3137	1000	2284.45	113.5	119	5.55			5.55	3.0	63.6
			Junction at Akshyawat Temple	**Junction on Brahmayoni**		**39.363**	**0.547**	1968	800	**329.03**	**119**	**149**	**30**			**30**		**85.0**
10c	**Brahmayoni**		Junction on Brahmayoni	**Tank 10c**		4.371	0.061	219	300	58.10	149	152	3			3		58.0
10d	**Brahmayoni**		Junction on Brahmayoni	**Tank 10d**		4.371	0.061	219	300	61.88	149	152	3			3		58.0
11	**Brahmayoni**		Junction on Brahmayoni	**Tank 11**		15.744	0.219	787	500	34.78	149	157	8			8		63.0
12	**Brahmayoni**		Junction on Brahmayoni	**Tank 12**		14.878	0.207	744	500	54.05	149	157	8			8		63.0
			Junction at Akshyawat Temple	**Junction on Shringrasthan**		**23.378**	**0.325**	1169	600	**1116.95**	**119**	**168**	**49**		**6**	**55**		**55.0**
13	**Shringrasthan**		Junction on Shringrasthan	**Tank 13**		11.689	0.162	584	450	26.30	168	168	0			0		0.0
13a	**Shringrasthan**		Junction on Shringrasthan	**Tank 13a**		**11.689**	**0.162**	584	450	35.36	168	168	0			0		0.0
14 & 16	**Kharkhura Raja kothi and Delha**	60	Near Manpur bridge-60	Y-Junction 15	4		0.028	100	200	76.25	112	113	1		5.674	6.674	25	69.67
		61	Near Manpur bridge-61	Y-Junction 15			0.028	100	200	40.68	112	113	1		5.674	6.674	25	69.67
			Y-Junction 15	**Y-Junction 16**			**0.056**	**200**	250	**41.25**	**113**	**113**	**0**			**0**		**38**
		62	Near Manpur bridge-62	Y-Junction 17			0.028	100	200	42.05	112	113	1		6.870	7.87	25	70.87

Tank ID No.	Location of Tank	TW ID. No.	Location of Tubewell and No.	Point of Delivery (OHT / GLSR)	No. of TW Proposed	Discharge (MLD)	Discharge (m^3/sec)	Discharge (m^3/hr)	Proposed Size of Rising Main (mm)	Length (m)	GL of TW	GL of Tank/ Junction	Diff between GL of TW & Tank (m)	Staging of OHT (m)	Ht of container of OHT/GLSR (m)	Total level diff. for pumping (m)	Depth of Pump (m)	Static Head H_s (m)
		63	Near Manpur bridge-63	Y-Junction 17			0.028	100	s	49.05	112	113	1		6.870	7.87	25	70.87
			Y-Junction 17	**Y-Junction 16**			**0.056**	**200**	250	**25.00**	**113**	**113**	**0**			**0**		**23**
			Y-Junction 16	Junction at Tanks (Delha 1 & 1A)			**0.111**	**400**	350	5273.4	113	115	2			2		**23**
14	**Karkhura (Delha 1A)**		Junction at Tanks (Delha 1 & 1A)	**Tank 14 Delha1A**		**2.660**	**0.048**	**173**	250	10.00	112	112	0	21		21		**21**
16	**Delha 1**		Junction at Tanks (Delha 1 & 1A)	**Tank 16 Delha**		**7.270**	**0.101**	**364**	350	14.76	115	109	-6	21		15		**15**
Total					**24**					**17051**								

11.5. GROUND LEVEL SERVICE RESERVOIR CAPACITIES

The capacities of the ground level and overhead service reservoirs have been calculated based on the water demand of the DMAs to be served and has been determined as 25% of daily water demand of DMAs served for the design year 2048 and are given below Table 32: Details of designed storage capacities

Table 32: Details of designed storage capacities

Reservoir location	Capacity ML	Type	Connected water source	Connected
			TW No.	DMA No.
Govt. ITI College	4.0	Clear water Reservoir (CWR)	47,48,49,50,51,52,53,54,55,56,57,58,59	11, 12, 13 (part-2) 14, 17, 21, 22, 23,24, 25, 26, 27
Singra Sthan hills	3.7	GLSR		15, 16, 18, 19, 20