THE HASHEMITE KINGDOM OF JORDAN
MINISTRY OF WATER AND IRRIGATION (MWI)
WATER AUTHORITY OF JORDAN (WAJ)
YARMOUK WATER COMPANY (YWC)

THE STUDY FOR BASIC/ DETAILED DESIGN AND DRAFT BIDDING DOCUMENTS (COMPONENT B) UNDER THE PROJECT FOR THE STUDY ON WATER SECTOR FOR THE HOST COMMUNITIES OF SYRIAN REFUGEES IN NORTHERN GOVERNORATES IN THE HASHEMITE KINGDOM OF JORDAN

DRAFT DETAILED DESIGN DOCUMENTS

MARCH 2017

JAPAN INTERNATIONAL COOPERATION AGENCY

TEC INTERNATIONAL CO., LTD., JAPAN

IN ASSOCIATION WITH

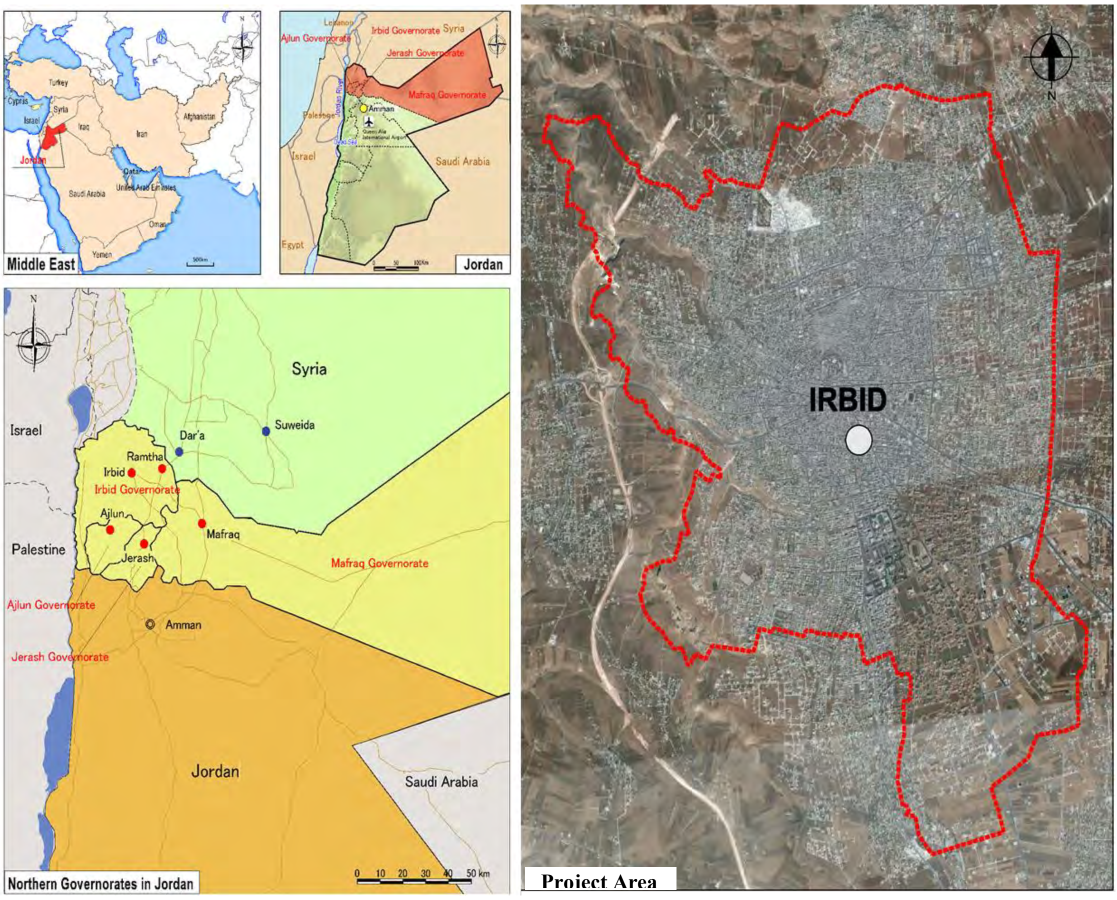
ARABTECH JARDANEH, JORDAN

EXECUTIVE SUMMARY

1. The Master Plan (MP) report prepared by JICA in January 2015 had recommended for carrying out certain priority works, called Phase 1 works, by 2020 to ease with the immediate shortage of water in the Irbid city and its suburbs. Accordingly, JICA agreed to Jordan Government to assist in preparation of Basic/ Detailed Design and Draft International Bidding Documents for a part of Phase-1 works. The JICA assigned the job to TEC International Co., Ltd, Japan who, in turn, is carrying out the works in association with Arabtech Jardaneh of Jordan.
2. The Project area consists of 4 DMAs, 3 of the gravity supply systems (GR01, GR02 and GR03) and 1 of pump supply system (P01) under Zebdat reservoir as laid out in the MP Report. But the water demand of GR-04, GR-05 and Bani Kinana district (located to the north of GR-05) of MP has also been considered for designing the Outlet pipe from Zebdat Reservoir and the Primary mains.
3. After the MP, there have been new population census carried out in 2015 and also there are some updates in the existing Pipelines in the Project area. Hence, this study was intended to do the review of MP and incorporate the updates and changes, as deemed appropriate, in the Basic and Detailed Designs.
4. Upon the review of the MP, the following main findings are obtained and accordingly changes are proposed for the Basic and Detailed Design under this study.
    a. The MP was done based on 2004 population census data and estimates for future population projections. However, now new Population census data of year 2015 is available. This is found to be higher than the figure considered in the MP for settled population. Hence, it is proposed to consider the new census data and make future projections based on the same. The population increase rates have been however kept the same as in the MP.
    b. In the MP, design population for water demand consideration was taken as Jordanian population of year 2035. Syrian refugee population was not considered. Now it is proposed to consider the refugee population also as of 2013 level without giving for any future increments.
    c. The DMAs proposed in the MP were not isolated fully, had multiple inlet and outlets and the pipes are crossing over the DMAs. Hence, new DMAs are proposed to be made by isolating them from each other.
    d. The hydraulic network model of MP reveals significant high pressure areas beyond the acceptable ranges of 7.5 bars or so. This is due to huge variations in the elevation and large sizes of DMAs. Hence, it is proposed to review on the number of DMAs including adjustment in their boundaries based on elevation ranges so as to get the acceptable range of pressures throughout the DMAs.
    e. The sequence of diameter change, increasing or decreasing, was found not in order at some places. These are proposed to be rectified.
    f. The proposed outlet gravity mains from Zebdat reservoir consists of 3 pipelines (one 1000 mm and two 800 mm) in the MP which is proposed to be made two pipelines now, a new of 1200 mm and an existing of 800 mm diameter.
    g. Some Strengthening pipes proposed in the MP were passing through the future planned roads which are not yet opened on the ground. Hence alignments of such pipelines are proposed to be re-routed.
    h. Updating hydraulic network models based on new water demand calculations
5. Basic Planning and Design of Network is made as follows.
    a. New Population census data of year 2015 are found 26.4% higher than the figure considered in the MP for settled population (except Syrian refugee). Hence, the population data of the study area has been updated and future projections have been made based on the same.
    b. Water demand has been calculated based on new population data and projections.
    c. The DMA boundaries have been adjusted and the number of DMAs increased based on elevation ranges and pressure equalization concepts. The original 3 DMAs (as per MP) in the gravity zone have been now re-organized into 8 DMAs. Similarly, original pump DMA P01 (in MP) has been now split into 2 DMAs.

   d. Hydraulic network model has been updated including new water demands, new DMA boundaries and other changes occurred in the network.
   e. The following are the major features of the new designed network
      i. DMAs are created based on elevation ranges so as to get uniform range of pressures in each DMA.
      ii. All DMAs are fully isolated and there is either single or very few primary mains feeding the proposed DMAs.
      iii. Consistency in the diameter changes have been maintained in each DMA
      iv. All new pipelines pass through the accessible and planned road
      v. The Hofa-Bait Ras transmission pipeline that is scheduled to be operational in early 2017 has been utilized as an existing pipeline in the network.
      vi. Two outlet gravity mains from the Zebdat reservoir are proposed: new 1200 mm diameter pipeline and an existing 800 mm diameter pipeline.
      vii. Three pump mains are proposed for each of 3 pump DMAs.
   f. Hydraulic analysis has been done for the two scenarios, maximum flow and minimum flow. In addition, the networks have been checked for the rationing of water supply situation as well so as to ensure that it doesn't behave poorly in such an eventual situation. For rationing situation, the entire area have been divided into three blocks supplying water to each twice a week.
   g. Hydraulic analysis of the designed network reveals that more than 91% of the junction pressures fall in the desired pressure ranges of 2.5 bars to 7.5 bars for both the gravity and pump zones (over 96%). In addition, the minimum pressure of above 1 bar is maintained everywhere.
   h. Based on the network analysis, the total length of Pipelines selected for strengthening in gravity and pump zones are as follows
      i. Gravity Zone = 52.8 km
      ii. Pump Zone = 21.4km
6. Major Design Criteria followed in the design are as follows
   a. Design Horizon is set as year 2035 for Jordanian Population and a fixed number of Syrian refugees as of 2013 level.
   b. Water demand for fire hydrants has not been considered separately as the service area population is more than 100,000.
   c. Pipes to be used are Ductile Iron (DI) pipe; Class C25, C30 and C40 for 150 mm and above diameters. The pipes are lined internally with cement mortar and externally coated with an alloy of Zinc and Aluminium (85% Zinc and 15% Aluminium). The pipes below 150 mm will be HDPE of 16 bar pressure but the same is out of the scope of this study.
   d. Hazen-William Equation has been used for distribution network analysis considering C-value as 110 for both the new as well as existing pipes.
   e. Desirable pressure in the pipeline is set in between 2.5 to 7.5 bars
   f. Trench depth and sizes for pipeline will be fixed as per WAJ specification and requirements of Municipality and MoPWH.
   g. Pipe Appurtenances including Air valves, Control Valves etc. shall be provided as per the prevailing engineering practice in design works.
7. The Project area includes different category of roads maintained by MoPWH and Irbid Municipality wherein proposed strengthening pipes have to be laid. The WAJ/YWC shall be required to take necessary approvals for laying of pipes. Roads are congested and Traffic high in the core city areas for which appropriate construction methodology shall be proposed.
8. Trenchless technology namely Pipe Jacking method has been proposed for MoPWH road crossings at 3 locations along Irbid Amman Road.
9. The study team shall provide inputs from the MP Study for preparing document for Environmental Clearance from the relevant authority. Similarly in order to mitigate the Environmental impacts during construction stage, Environmental management plan are provided.

10. Major component of the project is the supply and installation of Pipelines including pipe appurtenances and ancillary works coming along the same. The pipeline works shall have a single comprehensive rate per unit length which shall include the cost of all associated works.
11. The overall project cost is tentatively estimated at JD 16.9 million.
12. For Construction purposes, the entire works are proposed to be split into 3 contract packages.



Location Map

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Abbreviations

BoQ	Bill of Quantities
DMA	District Meter Area
DoS	Department of Statistics
HWL	High Water Level
JICA	Japan International Cooperation Agency
KoM	Kickoff Meeting
lpcd	Liter per capita per day
PEA	Project Executing Agency
PMU	Program Management Unit
MCM	Million Cubic Meter
MoEnv	Ministry of Environment
MWI	Ministry of Water and Irrigation
MoPWH	Ministry of Public Works and Housing
MP	Master Plan
TOR	Term of Reference
TC	Technical Committee
WAJ	Water Authority of Jordan
YWC	Yarmouk Water Company

1 GENERAL

1.1 Background of the Study

1.1.1 Background of the Study

The phase 1 works have been recommended in the Master Plan (MP) report submitted in January 2015. About the proposed phase 1 works that should be carried out by 2020 in the above-mentioned MP, Japan International Cooperation Agency (hereinafter referred to as "JICA") agreed to the Government of Jordan to prepare the basic/detailed design and draft international bidding documents for reference in order to promote implementation of the priority project by other funding agencies. Accordingly, this study for basic/detailed design and draft bidding documents for the part of the recommended Phase 1 works (hereinafter referred to as "the BD/DD Study") has been undertaken.

Since the armed conflict erupted in Syria in 2011, the influx of Syrian refugees has further deteriorated the condition of water supply services in Jordan and particularly in the northern governorates which already suffers from limited water resources, small amount of water supply per capita, high non-revenue water (NRW) and so on.

The MP was undertaken to identify the required improvements and priority to mitigate the poor water supply services in Irbid and its suburbs where the Syrian refugees have been largely settled in the largest urban area in the northern governorates. The MP presents a water supply development plan meeting the year 2035 demand scenario of Jordanian population, which is equivalent to the year 2028 demand combining the Jordanian population and the 2013 level of Syrian refugees.

Since even before the influx of Syrian refugees, Water Authority of Jordan (WAJ) has been implementing the construction of transmission facilities in order to convey the Disi fossil groundwater nationwide. WAJ has accelerated construction of the transmission facilities terminating at Hofa reservoir in Irbid suburbs (so-called the Eastern Transmission Mains) to narrow down the gap between the increasing demand and supply. These facilities are expected to be completed by 2019 and consequently the total amount of water available for the northern governorates is expected to increase to 91 Million Cubic Meters (MCM)/year from current level of 72 MCM/year.

However, supplying 91 MCM of water/year in the northern governorates will not satisfy the demand of 2017 and beyond. Therefore, WAJ has already started development of additional 30 MCM/year water source, thus totaling to a supply of 121 MCM/year water. This additional amount will be conveyed through the so-called Western Transmission Mains terminating at Zebdat reservoir in Irbid city and the increased water supply amount would be able to meet the year 2028 demand of Jordanian and Syrian refugees combined provided that the latter's population remains at the same level as in 2013. The BD/DD study proposes the strengthening measures of distribution pipes to supply the increased water for Irbid.

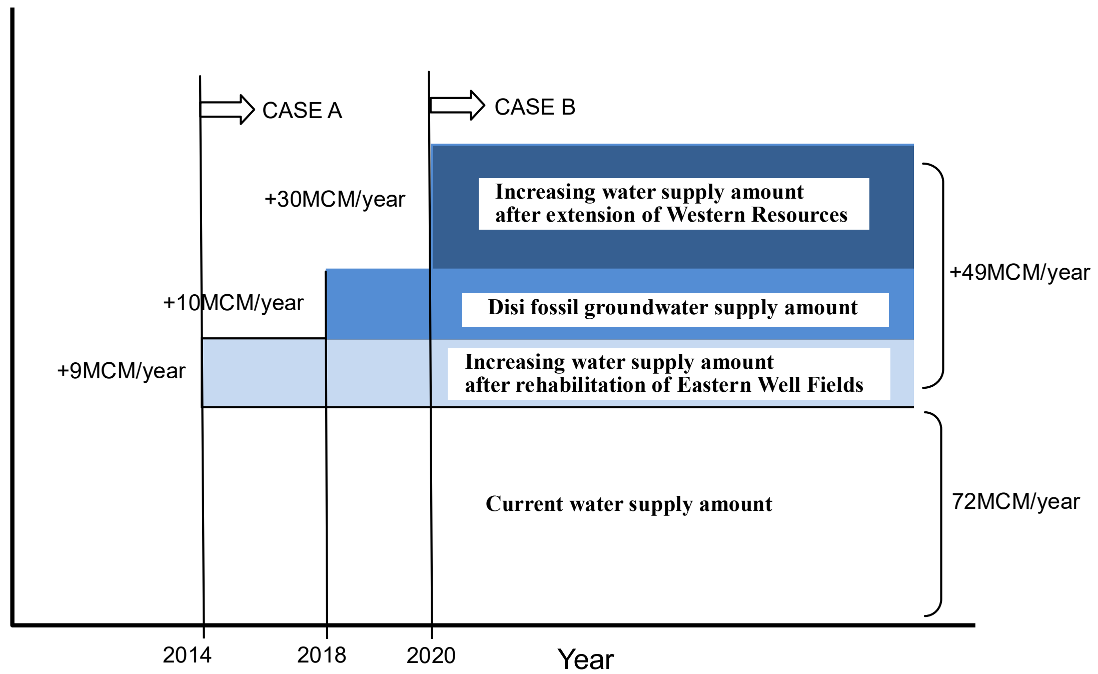


Figure 1-1 Water Source in the Northern Governorates

1.1.2 Outline of MP

The MP intends to identify the required facilities in order to distribute the available water to Irbid and its suburbs and the following measures are proposed:

- Strengthening and restructuring of distribution system,
- Rezoning of reservoir zones,
- Strengthening of network including increase in pipe size and addition of mains,
- Rehabilitation of inferior pipes (galvanized iron and old pipes),
- Distribution management for equitable supply,
- Establishment of District Metered Area (DMA),

Supervisory Control and Data Acquisition (SCADA),

The proposed facilities are to be implemented in 4 phases and target values for the Irbid and its suburbs are set as shown below.

Table 1-1 Target Values for Improvement of Service in Irbid and Its Suburbs

Indicators for improvement		Current (2013)	Target values in 2035	Required main measures
Number of "No water" complaints (equitable supply)		20,801	1,000	・ Distribution management for equitable supply ・ All measures below
Water supply pressure		0 – more than 7.5 bar	2.5 – 7.5 bar	・ Strengthening and restructuring of distribution main system ・ Distribution management
Per capita supply (liter)		82	123	・ Strengthening of distribution main system
Per capita consumption (liter)		65	104	・ Strengthening of distribution main system ・ Leakage reduction measures
Leakage ratio	Assumption	20 %	15 %	・ Replacement of inferior pipes
Leakage	Complaints	4,439	1,000	
Service population		498,800	790,200	・ Distribution management for equitable supply

The proposed facilities that are to be implemented in Phase 1, between 2016 and 2020, in Irbid city and its suburbs are as shown in Figure 1-2 and Table 1-2 and part of the Phase 1 works are selected for this study.

Table 1-2 Proposed Facilities by DMAs in Phase 1 (2016-2020) in Irbid City and Its Suburbs

Package	Description			Quantity	Unit
1	Zebdat Transmission Pumps		Q = 732 m^3/h, H=180 m	2	Sets
2	Transmission pipes (from Zebdat to Hofa)		DI 500 mm,	3,700	m
3	Zebdat Distribution Pumps		1,206 m^3/h, H=80 m	2	Sets
4	Distribution pipes (Strengthening)	Zebdat Gravity 01	DI 200 -800mm	10,139	m
5		Zebdat Gravity 02	HDPE 150,DI 200-1000 mm	26,390	m
6		Zebdat Gravity 03	DI 200 -800 mm	13,245	m
7		Zebdat Gravity 04	HDPE 150,DI 200-800 mm	24,069	m
8		Zebdat Gravity 05	HDPE 150,DI 200-800 mm	27,673	m
9		Zebdat Pump 01	HDPE 150,DI 200-600 mm	11,375	m
10		Zebdat Pump 02	HDPE 150,DI 200-300 mm	6,965	m
11		Hofa Gravity 01	HDPE 150,DI 200-800 mm	3,063	m
12		Hofa Gravity 02	HDPE 150,DI 200-400 mm	12,814	m
13		Hofa Gravity 03	DI 300 mm	347	m
		Sub-total		136,080	m
14	Service pipes & House connections			10,100	Num.
15	SCADA	SCADA center		1	LS
	DMA			10	Place
	Remote Station	Zebdat, Hofa		2	Place
	Sub-total				

Note: For defined DMAs and its boundary, refer to Figure 1-2.

DI: Ductile Iron

HDPE: High Density Polyethylene Pipe

[grey box] : Scope of the BD/DD Study

The BD/DD Study was conducted for the part of the recommended phase 1 works, and the following effects are expected after the implementation of these works:

- Reduction in the number of "No water" complaints (equitable supply)
- Equalization of water supply pressure in the distribution system
- Increase in the per capita supply and consumption
- The beneficiary population is projected to about 302,000 in 2020.

Water distribution system in Irbid and its suburbs gives slightly different scenarios depending on water amount conveyed and locations of terminal reservoirs. The scenarios together with water allocation in the northern governorates are attached in Appendix 6.1. In case of availability of 91 MCM/year, water will be distributed by gravity from both the Zebdat (received from the western transmission mains) and Hofa reservoirs (received from the eastern transmission mains) except the use of one Zebdat pump zone.

In case of availability of 121 MCM/year, all the water requirements of Irbid are to be obtained from the western transmission mains to Zebdat reservoir, from where most part of Zebdat command area will be supplied by gravity except in case of one Zebdat pump zone. Three high areas are proposed to be supplied water from Hofa reservoir through gravity. Summary of the water allocation in the northern governorates are presented in Appendix 6.2.

1.2 Objective of the Study

The objective of the BD/DD Study is to assist WAJ in preparation of the basic/detailed design and draft bidding documents for the part of recommended Phase 1 works. Any drawings and documents formulated by the BD/DD Study will be utilized by WAJ only as a reference documents for the procurement of the works.

1.3 Study Area and Project Area

The map of the Study Area and Project Area is shown in Figure 1-2.

The Study Area is Irbid city and its suburbs as considered in the MP. This is larger than the Project Area and includes 5 DMAs (GR-01 to GR-05) and Bani Kinana district to the north of GR-05 in the gravity zone and 2 DMAs (P-01 and P-02) in the pump zone under the supply from Zebdat reservoir.

The Project Area, on the other hand, is limited to the 3 DMAs (GR-01, GR-02 and GR-03) in the gravity zone and 1 DMA (P-01) under pump zone under the supply from Zebdat reservoir.

The water demand in the study area including GR-04, GR-05 and Bani Kinana district to the north of GR-05 was considered while designing the pipe sizes for primary mains in the Project Area coming out of Zebdat reservoir.

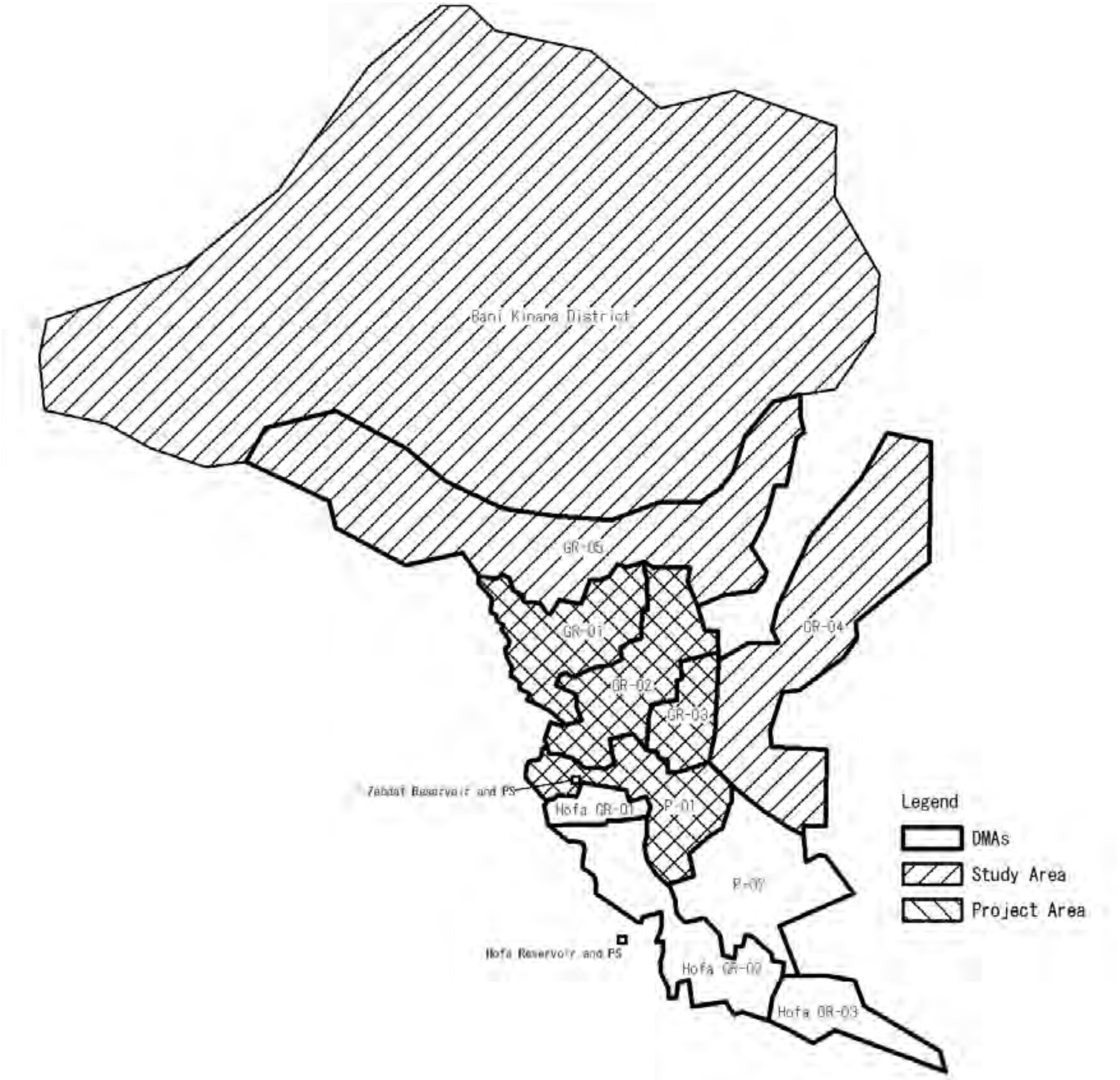


Figure 1-2 Project Area and Study Area

Note: Name of DMA is based on the Master Plan.

Table 1-3 DMAs in the Study Area and Project Area

DMA in the MP	Study Area	Project Area	Note
GR-01	○	○	
GR-02	○	○	
GR-03	○	○	
GR-04	○	X	Water is supplied partly from Zebdat reservoir. Primary mains are designed to convey this water amount.
GR-05	○	X	
Bani Kinana District	○	X	
P-01	○	○	Water is independently pumped from Zebdat.
P-02	X	X	Water is independently pumped from Zebdat.
Hofa GR-01	X	X	
Hofa GR-02	X	X	
Hofa GR-03	X	X	

Figure 1-3 Project Area

1.4 Target Year

The target year is set as 2035, about 20 years ahead of now, for Jordanian Population in the MP.

1.5 Scope of Works under the study

Strengthening of distribution pipes in the 4 District Metered Areas (DMAs) is selected for the scope of the BD/DD Study. The important works to be carried out are as below.

1. Discussions with Relevant Organizations such as WAJ and YWC

2. Investigation

- Site survey
- Collection of data
- Study of natural conditions

- Checking public and private lands
- Study of existing pipes
- Public relations works

3. Basic Design

- Organization and Setting out of design conditions
- Preparation of basic design plan
- Hydraulic network analysis

4. Detailed Design

- Design of plan and longitudinal sections
- Design of pipeline structures
- Design of temporary structures
- Quantity calculations of work components
- Preparation of documents and data for discussion with relevant organizations
- Preparation of documents and data for cost estimation
- Preparation of draft bidding documents

1.6 Environmental Considerations

1.6.1 Overview

The study/project area is located within Irbid city and its suburbs in Irbid Governorate. This area is occupied by government organization's facilities, educational institutions, medical institutions, commercial zones in addition to residential areas. The pipelines and water supply networks is planned to be installed along the existing public roads.

Based on the MP, the Environmental and social impacts during the construction activities are not expected to be significant. These impacts can be mitigated by implementation of appropriate environmental management measures and monitoring program during construction.

It is worth noting that the project area is located far away from any sensitive environmental areas, the nearest natural reserve area at a distance of more than 10 km.

1.6.2 Project Environmental Clearance

The Jordanian Environmental Protection Law No. 52 of the year 2006 has introduced a system of an environmental "pre-emptive" assessment of all economic and developmental projects to be established in Jordan. This process is known as the Environmental Impact Assessment (EIA) wherein all kinds of developmental or economic project should carry out an assessment of the expected environmental impacts potentially arising from the implementation of the project, and how those impacts can be mitigated through remedial action at the technical, legislative and public levels.

Therefore, the study team has submitted an application to the Ministry of Environment to obtain an environmental clearance for the project. Based on the EIA regulation, the Ministry decided that there is no need to conduct the environmental impact assessment just a preliminary study is needed and since a comprehensive EIA study was conducted during the MP stage for the same project area therefore this study will be adopted for this project.

1.7 Report Contents

- Review of the MP and Proposed Changes
- Distribution System Plan
- Detailed Design
- Components of Works and Cost Estimate

2 REVIEW OF THE MASTER PLAN AND CHANGES PROPOSED

2.1 Existing Water Supply System

Lower elevation areas of Irbid city and suburbs are supplied from the existing Zebdat reservoir by gravity via the existing DN 800 mm pipe. On the other hand high elevation areas are supplied through existing Zebdat PS via the existing DN 600 mm pipe.

Because of the shortage and scarcity of water and the large differences existing in elevation in the entire water supply distribution area, Yarmouk Water Company (YWC) has divided Irbid and suburbs into many sub-district supply areas which are controlled by several main Isolation Valves (IVs) and a rationing of water supply system are implemented in order to secure equitable distribution of water for all costumers within these sub-districts.

However, in high elevation areas and specifically within Bait Ras in the north of Irbid, there are still shortages of water supply due to the low distribution capacity and smaller diameter pipes existing in the area.

2.2 Data Collection, Survey and Investigation

2.2.1 Site Visits

The Study team with a great and essential support from YWC conducted a site visit of the study area in order to identify the project area boundaries, the location of existing water source of Zebdat reservoir/ PS and the existing water system's condition and situation.

Moreover several other site visits were conducted by the study team to check on the accessibility of the route alignments for the proposed strengthening of pipelines in addition to be more familiar with the study and project area.

2.2.2 Data Collection

The data collection works started from the commencement date. In general, a vast majority of the background information and data required for the work activities currently exists either in soft or hard copies.

In order to address the Project's requirements, the following general background information and data were collected during the data collection mission:

1. Previous Studies of the related Projects and Reports

    - MP Final Report (The Project for The Study on Water Sector for The Host Communities of Syrian Refugees in Northern Governorates), January 2015, JICA
    - Final Hydraulic analysis model (EPANET format) for the MP, JICA
    - Hofa –Bait Ras New Transmission Line Project, November 2013, JICA

2. Maps and Drawings provided by YWC

    - Irbid's Existing Water System – GIS data

- Irbid's Base Map – GIS data
- Irbid's Existing Sewer System – GIS data

3. Required Data from various Stakeholders

- Identified main roads belonging to Ministry of Public Work and Housing (MoPWH)-prepared by MoPWH
- Land use map of Irbid city, prepared by Ministry of Municipals Affairs
- District boundaries of Irbid city and suburbs, prepared by Ministry of Municipals Affairs
- Recent population census for the whole Irbid Governorate (however, at the time when demand projection was made, no data was available for the population census within each district), prepared by Statistics Department
- Underground telecommunications network, prepared by Orange, Umniah and Zain
- Existing underground electricity cables, prepared by Irbid District Electricity Company Ltd. However, no data is available regarding all the underground electricity cable within the project area.

2.2.3 Survey and Soil Investigation Works

MP document has identified on the tentative sizes and locations of the pipelines to be rehabilitated and/or strengthened based on the outcomes of the hydraulic network design done at the time. However, due to likely changes in the basic design data such as population and updation of pipe network map, the results may change now. Therefore, detailed topographical and soil survey work has started after getting the results of the new distribution network design.

After finalizing and approving the new strengthening water pipelines in terms of diameters, length and route alignments, the survey and soil investigation works were commenced and the data were used for the detailed design.

2.2.4 Hofa –Bait Ras Pipeline Project

A new 600 mm pipeline from Hofa reservoir to Bait Ras, north of Irbid city as shown in Figure 2-1 is to start operation in early 2017. This pipeline will distribute additional water of 10 MCM/year conveyed from Za'atary PS in Mafraq and effectively mitigate water deficit areas in Irbid to some extent. In the case B (refer to Figure 1-1), water is distributed from the Zebdat reservoir so that this pipeline is used in the BD/DD study as one of the primary mains (explained in chapter 3) to supply water from the Zebdat reservoir.

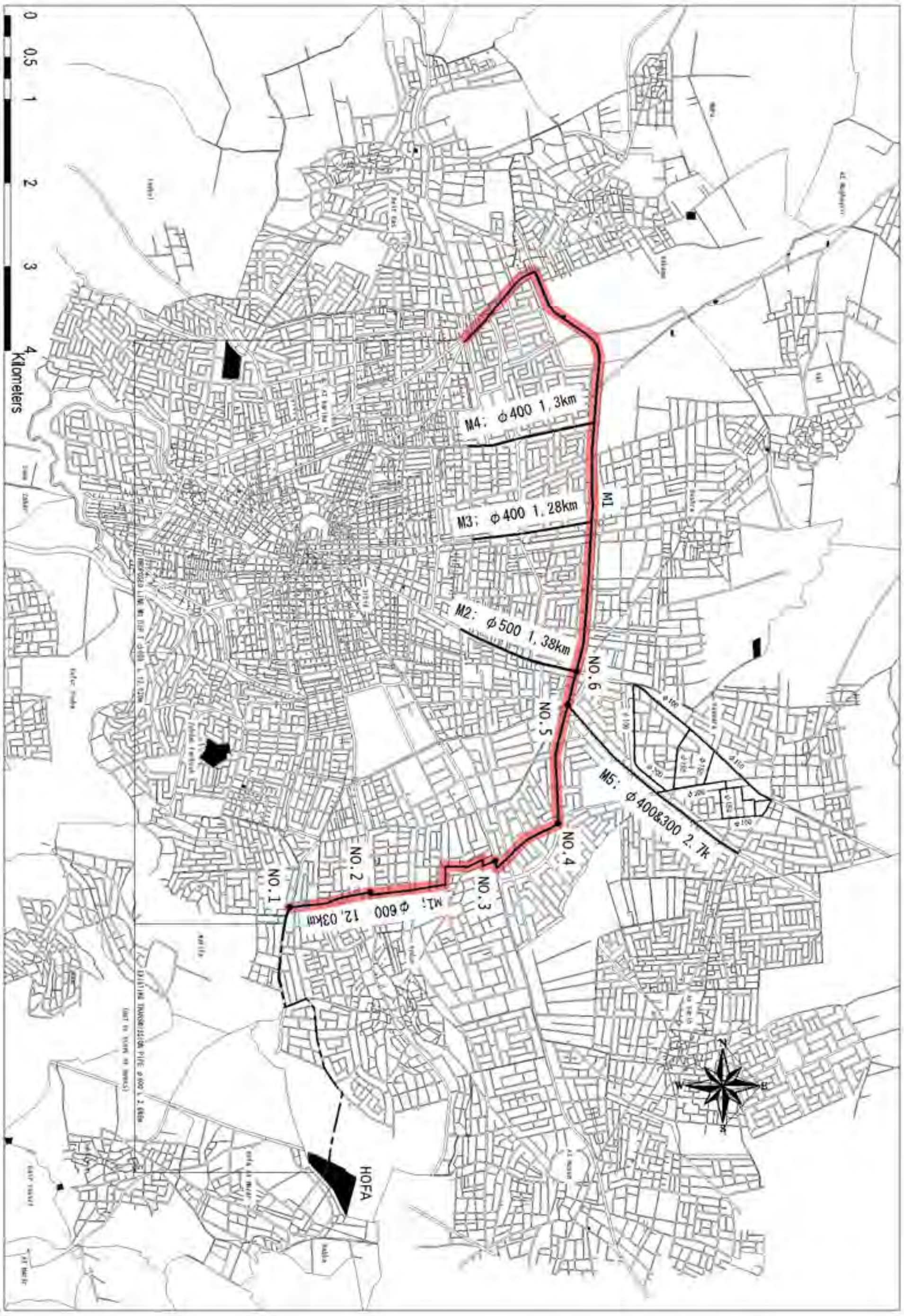


Figure 2-1 Hofa-Bait Ras Transmission Pipeline (JICA Grant Aid Project)

2.3 Overview of MP

2.3.1 MP Report

The MP report covers on the following topics which are the base for this BD/DD study:

- A detailed description on the existing situation of the Study area and about the existing water supply system.
- Presents the current issues and problems in the water supply system in the Study area.

- Describes demand and water source projection of not only the Study area but also the northern governorates and, projects the allocated water sources for the Study Area.
- Describe plans for water supply facilities in Irbid city and its suburbs, based on the allocated water source amounts.
- Explains operation and maintenance (O&M) plan and institutional aspects of YWC based on the conditions of the Study Area, and
- Evaluates financial and economic viability for the proposed project.

2.3.2 Population Projection

(1) Overview of MP

The population projections adopted in the MP report were based on the 2004 population census results which were collected from the Department of Statistics (DoS).

Future population of the Study Area (Irbid city and its suburbs) is estimated using the governorates' growth rates of 2% per annum provided by DOS. Irbid city spread over a large area with marked difference in the development status of various regions within the city. The Study area includes Irbid city, Irbid suburbs within urban growth area (including localities of Aidoon, Aliah, Bait Ras, etc.), and Irbid suburbs outside of urban growth area (including localities of Al'al, As'ara, etc.). The population has also been estimated for the localities of Bani Kinana area in order to consider their demand in future.

Population of various neighborhoods within Irbid city is estimated up to 2035 using the growth rate of Irbid Governorate, which is same for both the Irbid city and its suburban localities.

Population of Syrian refugees cannot be controlled in this plan so this must be regarded as a given condition. Accordingly, future refugee population is considered as fixed number in 2013 year without any further growth.

(2) Review and Changes Proposed

A new updated population projections is presented based on the latest 2015 population census data since the latest population census for settled population (i.e. except for the Syrian refugee) is more than what was pointed out in the MP for the same year by 26.8%. The reason is that the population of the Non-Jordanian other than Syrian refugees has been rapidly increasing. In addition, Syrian refugee's population in Irbid city, suburbs and Bani Kinana district are accounted for as a fixed number, the same in MP.

More details are presented in Section 3.1.2.

Since the population projection for the study area is updated based on the 2015 population census, the water demand is also updated.

2.3.3 Zoning and DMAs

(1) Overview of MP

Water naturally flows down to the lower sites and, if the amount of water is not adequate, water does not reach to higher elevation sites in downstream. Therefore, distribution zones are proposed so as to ensure the equitable water distribution or allocation; to control the water flow to lower sites and divert it to higher sites artificially.

Zoning system is established with 3 tier systems in Irbid and its suburbs as follows:

- Reservoir zone: the largest zone system which is covered by a reservoir, namely Hofa and Zebdat
- Sub-zone: a zone by pumping or gravity flow under a reservoir zone
- District Metered Area (DMA): The smallest component of zone under sub-zones, by which NRW reduction activities will be carried out

The proposed sub-zones and DMAs are generated primarily based on elevation range and existing pipe alignment and secondarily by roads as boundaries. The International Water Association recommends for about 1,500 connections on average for the size of a DMA as a basic standard. However, if we adopt this standard, there will be a large number of DMAs; around 120 in Irbid city only, which won't be manageable for the YWC at present.

Therefore, the number of DMA is reduced at the minimum, mainly considering difference in elevation and localities.

(2) Review and Changes Proposed

The following are the outcomes of the checking of the zoning and DMAs boundaries:

1. The DMAs are not isolated at the identified boundaries,
2. The elevation ranges weren't taken into consideration in the adopted DMAs boundaries,
3. Number of DMAs were not enough to secure adequate and equitable pressure all around each DMA

Based on the outcomes of the zoning and DMAs review, new fully isolated DMAs with one controlled feeding pipeline for each DMA is created in addition to increase in the number of DMAs taking into account of the elevation ranges in order to create more effective water supply system.

2.3.4 Hydraulic Model

(1) Overview of MP

The available hydraulic model (EPANET format) of the water distribution system of the study area including five gravity DMAs (Zebdat GR-01, GR-02, GR-03 within the project area and GR-04, GR-05 out of the project area) and two pump DMAs (Zebdat P-01 within the project area and P-02 out of the project area) illustrates on the following:

1. One hydraulic analysis scenario was adopted in the analysis considering the maximum water demand for year 2035 without considering firefighting requirements.
2. Three proposed outlet water pipelines with a diameter of 1000mm and 2 no's of 800mm from Zebdat reservoir (HWL of 631m and a capacity of 110,000m^3) to feed the five Zebdat gravity DMAs.
3. Two outlet pipelines from Zebdat PS, an existing 600mm and the proposed 600mm, to feed two Zebdat pump DMAs.
4. Within the three gravity DMAs in the project area, the elevation varies in between 432m and 590m, and the elevation within the pump DMA of the project area varies in between 660m

and 556 m. Figure 2-2 below shows the schematic diagram of the elevation differences within the project DMAs.

5. Within the identified DMAs, the pressure head varies in between 43m and 181m within the three gravity DMAs, and the pressure head varies in between 7.4m and 117m within the project pump DMAs.

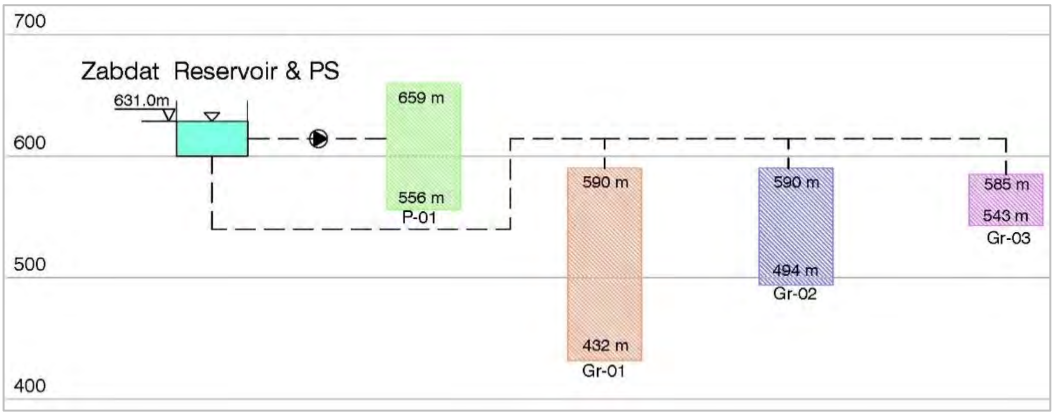


Figure 2-2 Elevation Schematic Diagram

(2) Review and Changes Proposed

Number of DMAs is increased to meet elevation differences in the Study Area for equitable water supply. Accordingly, hydraulic model is newly created taking into consideration of the following outcomes of the hydraulic model.

1. Hydraulic isolation of DMA.
2. Logical sequence of decreasing or increasing the diameter of water pipes.
3. Adequate pressure range

2.3.5 Pipelines Route Alignments

Pipeline route alignments are to be designed after thorough sites reconnaissance to meet the existing condition.

1. The pipelines proposed in the MP in some cases pass through the planned roads but they are actually not yet opened in ground.
2. The pipelines with large diameters pass through narrow and crowded roads.

Therefore, new strengthening pipelines are designed and proposed taking into account of the followings:

- Ensure that all new pipelines pass through accessible and planned road
- Ensure consistency in the diameter changes within the new updated DMAs, and

3 DISTRIBUTION SYSTEM PLAN

3.1 Water Demand Estimation

3.1.1 General

As part of the water supply network design methodology, water demand calculations and estimations are considered essential for sizing of the network. The water demand was estimated based on the population projections.

This section covers on the main assumptions and criteria related to the population and demand calculations.

The population projection and water demand calculations are based on:

- 2015 statistical report from Department of statistics (DOS).
- MP.

3.1.2 Design Population

The population in Irbid governorate is 1.77 million in 2015 according to the census. For the planning purpose, number of settled population (both Jordanian and non-Jordanian) is required excluding number of Syrian refugees that is counted in the census. The same number of Syrian refugees used in the MP is again used in the study because

1) It was agreed in the MP stage that nobody could predict the number of Syrian refugees in future.
2) Although they are slightly increased to about 655,000 in June 2016 from 510,000 in July 2013 in Jordan (UNHCR), the number is fixed as used in the MP. As a result, settled population is estimated in the Table below.

Table 3-1 Census Population in Irbid Governorate

(Unit: persons)

Year/ Governorate	1994 Census	2004 Census	2015 Census		
			(A) Total	(B) Estimated Syrian Refugees	(C)=(A)-(B) Settled Population
Irbid	751,634	927,892	1,770,144	239,750	1,530,394

Source: Department of Statistics (DOS) except estimated Syrian refugees

This settled population is compared with the population used in the MP that is shown in Table 3-2 below. The former is higher than the latter by 26.8%. Therefore, population between 2015 and 2035, target year is adjusted, namely the revised settled population in the localities and neighborhood (see Table 3-3) is those estimated in the MP times 1.268.

Table 3-2 Comparison of Settled Population in Irbid Governorate

(Unit: persons)

Governorate Year	(A) 2015 Census	(B) 2015 Estimated	Ratio of A/B
Irbid	1,530,394	1,206,700	1.268

The 2015 census populations in the district and locality/neighborhood level were not available at the time of population projection. The name and population projection for each of the districts and neighborhoods for year 2015 and 2035 has been based on the MP. Then, they are multiplied by 1.268. The methodology for population allocation used in the MP is explained in Appendix 6.1.

Fixed numbers of Syrian refugees are also added to the estimated population and the planned population is shown in Table 3-3 together with average daily demand (please refer to the following sub-section for details on per capita demand and peak factor for demand estimation).

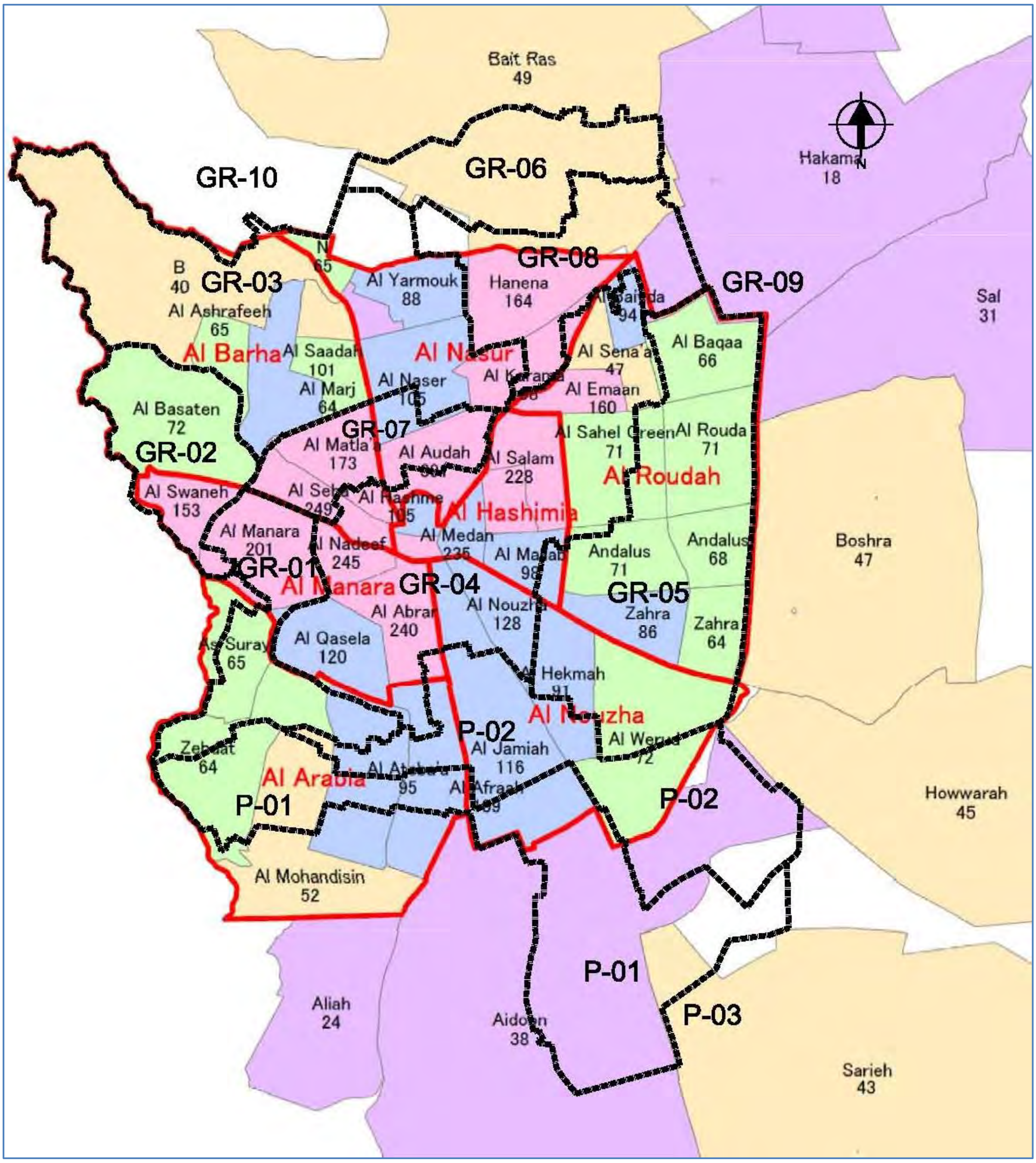


Figure 3-1 Locality and neighborhood within the Project Area

Note: DMAs revised in the Study are shown in this Figure. (Refer to section 3.2.3)

Table 3-3 Population and Water Demand in Irbid City, Suburbs and Bani Kinana District

Area/ Locality	Neighborhood	2015 Population (person)	2013 Syrian Refugees (person)	2035 Settled Population (person)	2035 Settled Population plus 2013 Syrian Refugees (person)	2035 Averaged demand (m^3/day)	2035 Averaged Demand (MCM/y)
Irbid City							
Al Arabia	Al Afraah	16,039	2,513	15,114	17,626	2,415	0.88
	Al Ateba'a	7,712	1,208	15,052	16,260	2,228	0.81
	Al Mohandisin	8,479	1,328	12,324	13,652	1,870	0.68
	As Surayj	292	46	6,331	6,377	874	0.32
	Zebdat	4,825	756	13,394	14,150	1,939	0.71
	Sub-total	**37,347**	**5,851**	**62,214**	**68,065**	**9,325**	**3.40**
Al Barha	Al Ashrafeeh	2,956	463	2,927	3,390	464	0.17
	Al Basaten	6,054	948	14,925	15,873	2,175	0.79
	Al Herafeyeen West	213	33	1,264	1,298	178	0.06
	Al Marj	2,167	339	3,408	3,747	513	0.19
	Al Matla'a	17,483	2,739	16,475	19,213	2,632	0.96
	Al Saadah	10,090	1,581	10,712	12,292	1,684	0.61
	Al Seha	17,694	2,772	16,674	19,446	2,664	0.97
	No Name	-	-	15,793	15,793	2,164	0.79
	Sub-total	**56,656**	**8,876**	**82,177**	**91,053**	**12,474**	**4.55**
Al Hashme	Al Hashme	3,677	576	3,465	4,041	554	0.20
	Al Jamee	1,929	302	2,194	2,496	342	0.12
	Al Mallab	5,242	821	5,722	6,544	896	0.33
	Al Medan	9,182	1,438	8,776	10,215	1,399	0.51
	Al Salam	18,811	2,947	18,100	21,047	2,883	1.05
	Al Tall	1,405	220	2,420	2,640	362	0.13
	Sub-total	**40,246**	**6,305**	**40,678**	**46,983**	**6,437**	**2.35**
Al Manara	Al Abrar	25,873	4,053	24,381	28,434	3,895	1.42
	Al Manara	28,911	4,529	27,243	31,772	4,353	1.59
	Al Nadeef	11,984	1,877	11,292	13,170	1,804	0.66
	Al Qasela	13,744	2,153	13,186	15,339	2,101	0.77
	Al Swaneh	6,986	1,094	9,133	10,227	1,401	0.51
	Sub-total	**87,498**	**13,707**	**85,235**	**98,942**	**13,555**	**4.95**
Al Nasur	Al Audah	43,850	6,869	41,321	48,190	6,602	2.41
	Hanena	21,019	3,293	21,673	24,966	3,420	1.25
	Al Herafeyeen East	654	102	822	924	127	0.05
	Al Karama	17,841	2,795	17,520	20,315	2,783	1.02
	Al Naser	14,631	2,292	13,787	16,079	2,203	0.80
	Al Yarmouk	5,709	894	6,989	7,884	1,080	0.39
	No Name	-	-	1,530	1,530	210	0.08
	Sub-total	**103,704**	**16,246**	**103,641**	**119,887**	**16,425**	**5.99**
Al Nouzha	Al Jamiah	16,184	2,535	17,237	19,772	2,709	0.99
	Al Nouzha	9,281	1,454	8,746	10,200	1,397	0.51
	Al Hekmah	9,130	1,430	9,590	11,021	1,510	0.55
	Al Werud	8,782	1,376	18,126	19,502	2,672	0.98
	Sub-total	**43,378**	**6,795**	**53,699**	**60,494**	**8,288**	**3.03**
Al Roudah	Andalus	-	-	5,092	5,092	698	0.25
	Andalus	7,445	1,166	7,157	8,323	1,140	0.42
	Al Baqaa	3,248	509	8,041	8,549	1,171	0.43
	Al Baiyda	3,828	600	3,732	4,332	593	0.22
	Al Emaan	6,705	1,050	7,882	8,933	1,224	0.45
	Al Rouda	6,741	1,056	9,745	10,801	1,480	0.54
	Al Sahel Green	8,113	1,271	10,160	11,431	1,566	0.57
	Al Sena'a	1,071	168	2,757	2,925	401	0.15
	Zahra	-	-	4,701	4,701	644	0.24
	Zahra	7,233	1,133	6,830	7,963	1,091	0.40
	Sub-total	**44,384**	**6,953**	**66,097**	**73,050**	**10,008**	**3.65**
Total – Irbid City		**413,212**	**64,733**	**493,741**	**558,475**	**76,511**	**27.93**

Area/ Locality	Neighborhood	2015 Population (person)	2013 Syrian Refugees (person)	2035 Settled Population (person)	2035 Settled Population plus 2013 Syrian Refugees (person)	2035 Averaged demand (m^3/day)	2035 Averaged Demand (MCM/y)
Irbid Suburbs within Urban Growth Area							
Greater Irbid Municipality	Aidoon	30,642	4,800	61,915	66,715	6,938	2.53
	Aliah	716	112	6,591	6,703	697	0.25
	Bait Ras	29,714	4,655	63,458	68,113	7,084	2.59
	Bushra	18,756	2,938	40,806	43,744	4,549	1.66
	Hakama	12,238	1,917	18,268	20,185	2,099	0.77
	Hawwara	21,025	3,294	40,527	43,821	4,557	1.66
	Hoson	33,772	5,291	83,239	88,530	9,207	3.36
	Maro	4,816	754	7,668	8,422	876	0.32
	Sal	11,447	1,793	31,324	33,118	3,444	1.26
	Sarieh	31,671	4,962	60,063	65,024	6,763	2.47
Total		**194,796**	**30,517**	**413,858**	**444,375**	**46,215**	**16.87**
Irbid Suburbs outside of Urban Growth Area							
Greater Irbid Municipality	Locality						
	Al'al	7,191	1,127	10,734	11,861	1,234	0.45
	As'ara	1,599	250	2,387	2,637	274	0.10
	Fo'arah	5,467	856	8,161	9,018	938	0.34
	Kofor Jayez	5,139	805	7,670	8,475	881	0.32
	Mghayyer	14,300	2,240	21,346	23,586	2,453	0.90
	Mokhayyam Azmi Mufte (Hoson camp)	27,393	4,291	40,890	45,181	4,699	1.72
	Teqbel	824	129	1,229	1,358	141	0.05
	Um El-Jadayel	1,458	228	2,176	2,405	250	0.09
Total		**63,369**	**9,927**	**94,594**	**104,521**	**10,870**	**3.97**
Bani Kinana District							
Bani Kinana District	Hariema	6,086	953	9,084	10,038	1,044	0.38
	Kharja	7,110	1,114	10,614	11,728	1,220	0.45
	Abu El-Loqas	2,085	327	3,112	3,439	358	0.13
	Aqraba	4,132	647	6,167	6,815	709	0.26
	Bareshta	288	45	430	475	49	0.02
	Ebder	3,820	598	5,702	6,300	655	0.24
	Hartha	6,616	1,037	9,876	10,912	1,135	0.41
	Hatem	8,922	1,398	13,318	14,716	1,530	0.56
	Hebras	5,887	922	8,788	9,710	1,010	0.37
	Hoor	3,273	513	4,885	5,398	561	0.20
	Kherbit Azrit	1,252	196	1,868	2,064	215	0.08
	Khrayybeh	2,351	368	3,509	3,878	403	0.15
	Kofor Soom	11,274	1,766	16,830	18,596	1,934	0.71
	Malka	10,476	1,641	15,637	17,279	1,797	0.66
	Mansoorah	5,927	929	8,847	9,776	1,017	0.37
	Mzaireeb	1,973	309	2,945	3,254	338	0.12
	Rfaid	3,408	534	5,087	5,621	585	0.21
	Saham	9,725	1,524	14,518	16,041	1,668	0.61
	Saidoor	2,436	382	3,636	4,018	418	0.15
	Samar	5,184	812	7,739	8,551	889	0.32
	Soom	8,494	1,331	12,679	14,009	1,457	0.53
	Qasfah	1,187	186	1,772	1,958	204	0.07
	Saileh	1,172	184	1,750	1,934	201	0.07
	Sama El-Roosan	4,693	735	7,006	7,741	805	0.29
	Um Qais	6,475	1,014	9,665	10,680	1,111	0.41
	Yarmook	1,392	218	2,077	2,295	239	0.09
	Yebla	6,143	962	9,169	10,132	1,054	0.38
	Zaweh	1,409	221	2,104	2,325	242	0.09
Bani Kinana District Total		**133,190**	**20,865**	**198,816**	**219,681**	**22,847**	**8.34**
Grand Total		**804,568**	**126,043**	**1,201,009**	**1,327,052**	**156,443**	**57.10**

Note:

1. Irbid city and its suburbs within and outside of Urban Growth Area in Greater Irbid Municipality are the Study Area. Bani Kinana District is outside of Project area but connected with distribution network of the Study Area.
2. Andalus and Zahra are each divided into 2 with the same names based on the map received from the Irbid Municipality office.
3. One area each in Al Barha and Al Naser are with “No Name”. These areas are located in the north-western corner of Irbid city and in the map provided by both the Irbid Municipality and DOS, there does not exist any name for this area. Also, DOS did not have population estimate for this area.
4. Source: Prepared by JICA Study Team based on Mater Plan

The population in 2035 has increased from the one estimated in the MP. The Table above illustrate that the projected Jordanian population in 2035 and Syrian refugee population in Irbid city, suburbs and Bani Kinana district.

3.1.3 Water Demand Estimation

The design flow in the distribution systems of Jordan is different from Japan and other countries, reflecting a rationing (intermittent supply) system. In Japan and other countries, maximum hourly flow is used for design flow that is expressed as follows:

$q = K \times Q$

Where

q: Design flow = Design maximum hourly distribution flow (m^3/hour)

Q: Design average hourly distribution flow (m^3/hour),

Q is calculated based on population and per capita demand.

K: Time coefficient

K = Ratio of daily maximum demand and daily average demand × Hourly peak factor.

If pipe sizes are decided for rationing system, pipe sizes will become much larger than those for a continuous flow because large amount of water i.e., one week’s demand, needs to be distributed within a short period of about 24 to 48 hours. In order to avoid such large diameter with associated large costs, pipe size is decided assuming a continuous flow in Jordan. However, different design flow is used that as shown below.

$q = K \times Q$

Where

q: Design flow that is peak summer demand (m^3/hour)

Q: Design flow for winter demand (m^3/hour),

Q is calculated based on population and per capita winter demand.

K: Time coefficient

K = Seasonal peak factor (SPF) × Diurnal peak factor (DPF)= 1.17×1.5=1.8

Hydraulic calculation is done based on the above design flow; and the diameter is calculated in consideration that the appropriate dynamic water pressure is maintained; that the distribution of water pressure in the main is as uniform as possible; and that the flow velocity in the main is within a suitable range.

Considering the data that have been incorporated in the MP Report and all the Related Calculations, Table 3-4 presents per capita consumption and water demand taking into account of the leakage ratio of 20 % up to 2020 and 15 % from 2020 to 2035 for the Average Demand.

Table 3-4 Per Capita Water Consumption and Demand in Winter for Jordanians

(Unit: lpcd)

Category	Water Consumption	Water Demand (- 2020)	Water Demand (2021 – 2035)
City	116	145	137
Rural	88	110	104

As explained in detail in following sections, three gravity zone DMAs of MP have been now re-arranged into 8 DMAs, GR-01 to GR-08 for better management of pressure equalization based on elevation ranges. Population allocation to each DMA has been calculated freshly.

Based on above population figures, Table 3-5 shows the design population and daily average water demand for each DMA created newly.

Table 3-5 Planned Population and Water Demand in DMAs

Zone Category	Sub Zone Number	Population in 2035 (persons)	Daily Average Water Demand in 2035 (m^3/d)	Remarks:
Zebdat Gravity	GR-01	29,231	4,005	Project Area and Study Area
	GR-02	28,642	3,924	
	GR-03	68,660	9,406	
	GR04	187,220	25,649	
	GR-05	70,597	9,672	
	GR-06	14,985	1,558	
	GR-07	63,317	8,674	
	GR-08	39,556	5,239	
	Sub Total	502,208	68,127	
	GR-09*	144,269	14,127	Study Area
	GR-10*	102,152	10,213	
	Bani Kinana*	214,283	12,587	
	Sub Total	460,704	36,927	
	Total	962,912	105,054	
Zebat Pump	P-01	57,043	7,044	Project Area and Study Area
	P-02	23,341	3,198	
	Sub Total	80,384	10,242	
Grand Total		1,043,296	115,296	

Note: * Total populations and water demand in GR-09, GR-10 and Bani Kinana. Water is supplied by local sources or supplemented from Zebdat system. Refer to 3.2.3 and 6.1.3.

As a general rule, for designing the diameter of the distribution main, firefighting water demand shall be added in the case of the distribution main for a service area with a design population less than 100,000 persons. However, since the population in this project area is more than 100,000, firefighting water demand has not been considered additionally.

3.2 Proposed Distribution System

3.2.1 General

Since water demand within Irbid city and suburbs has increased particularly by the inflow of Syrian refugees and in order to alleviate the “no-water” condition along with equitable supply to all customers, the following are set as the main objectives of this study for improving the water supply system within the project area.

- Improvement of inadequate distribution system by strengthening and restructuring of the existing water distribution network.
- Reduction of leakage through replacement of inferior pipes and adequate maintenance of pipes (out of scope of this project)
- Improvement of distribution management and technical capacity for equitable supply.

As per the MP, the facilities for strengthening and restructuring of water network are proposed to be implemented under this project (Phase 1) while facilities for rehabilitation are proposed to be implemented during the next phases 2 to 4.

The strengthening of pipeline would mean that a new pipeline is laid without removing or disconnecting the existing pipelines.

3.2.2 Zone and District Meter Area

District Metered Areas (DMAs) represent zones within a distribution zone that supply water to customers. They are supplied from the distribution zone reservoir or PS at Zebdat through primary mains. The Study Area is divided into 10 gravity DMAs and 3 pump DMAs. Within the DMA there is a combination of secondary and tertiary distribution pipes and service connections.

DMAs are designed with respect to the following criteria:

- Provided with district flow meters
- Provided with flow control valves
- Pressure to be maintained at minimum 2.5 bars and maximum 7.5 bars
- Pressure Reducing Valves / electronic controllers are to be used where pressure reduction is necessary
- No pipes should cross a district boundary

(1) Gravity Zone

The Study area is divided into ten (10) gravity DMAs depending on the elevation variation in Irbid. The demarcation of DMAs is shown in Figure 3-3 below. This criterion will ensure that the water will be supplied to all DMAs with the acceptable pressure. While the water demand of all 10 DMAs and Bani Kinana district is considered for network analysis of primary mains (see item (3) for definition), pipeline design for strengthening is done for only 8 DMAs under this study.

(2) Pump Zone

Since there are some districts in Irbid that are higher than Zebdat reservoir, the pumping is required to supply water to these districts. The pump zone is divided into three (3) DMAs. The pump DMA P-01 of the MP is split into two DMAs now as new P-01 and P-02, and the earlier P-02 shall become now as P-03. The pipeline and pumps are designed separately for the new P-01, P-02 and P-03. The Pipeline design for strengthening is undertaken for P-01 and P-02 (P-01 of MP) only under the present study. However, pumps for P-01 and P-02 are out of the Project although pump capacity (flow and head) is suggested in this study.

(3) Pipe Line

The different pipelines to be used in the distribution system are defined as below.

a) Transmission Main

These pipelines convey water from water resources or water treatment facilities up to the storage reservoirs used for distribution of water. These pipelines are out of scope of this study and project.

b) Primary Main

Primary mains are those pipelines that convey water from the storage facility to the entry of the DMAs. No service connections will be allowed from these pipelines except for isolated major consumers, which will be regarded as DMA.

c) Secondary Main

Secondary mains are used for the distribution of water within each DMA. The secondary network will be subject to various flow conditions during operation. Peak hourly flow condition is applied to size not only the secondary mains but also primary mains. After checking the pressures at minimum flow condition which is assumed 30% of average flow at night, changes of DMAs boundaries or installation of pressure reducing valves (PRVs) are considered as needed. The diameter is sized in accordance with the three flow conditions and the agreed optimum pressure at the customer connection.

Minimum diameter of 150mm is recommended.

d) Tertiary Network

Tertiary networks are pipelines that branch service connection pipes within a DMA. Incidentally it is service connection pipes that are used to supply water to the customers. Tertiary pipe diameter will be less than 150 mm. These pipelines are also out of scope of this study and project.

Figure 3-2 presents on a schematic diagram of the classification of pipes.

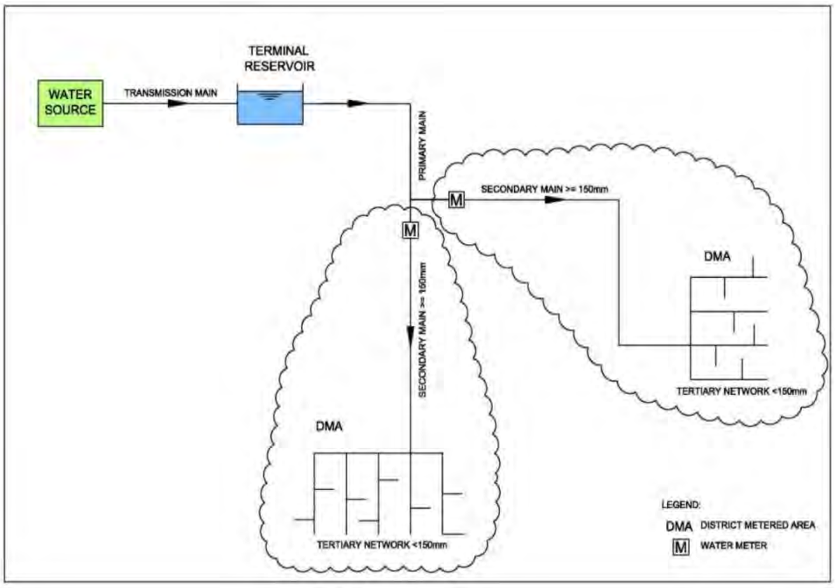


Figure 3-2 Pipe Classifications

3.2.3 Gravity Zone

(1) DMA

Figure 3-3 and Figure 3-4 show a plan and schematic diagram with elevation in DMA for the new gravity DMAs within the project area.

Eight (8) gravity DMAs (GR-01to 08) within the project area in addition to two gravity DMAs (GR-09 and GR-10) and Bani Kinana district outside of the project area represent DMAs within a distribution zone that supply water by gravity to customers from existing Zebdat reservoir. Branching points to 3 DMAs (GR-09 and 10 and Bani Kinana district) are shown in Figure 3-4 and Figure 3-5.

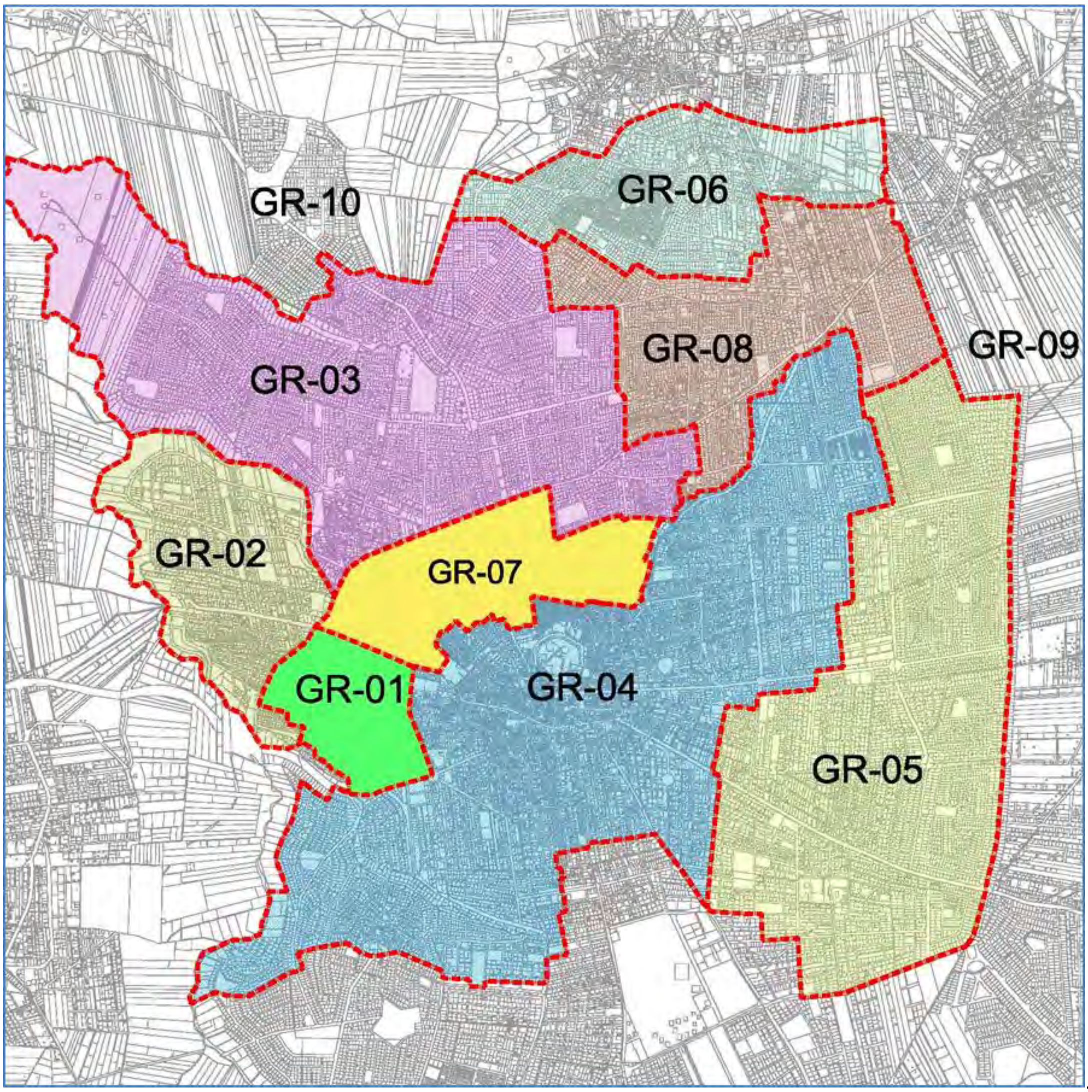


Figure 3-3 Gravity Zone DMAs

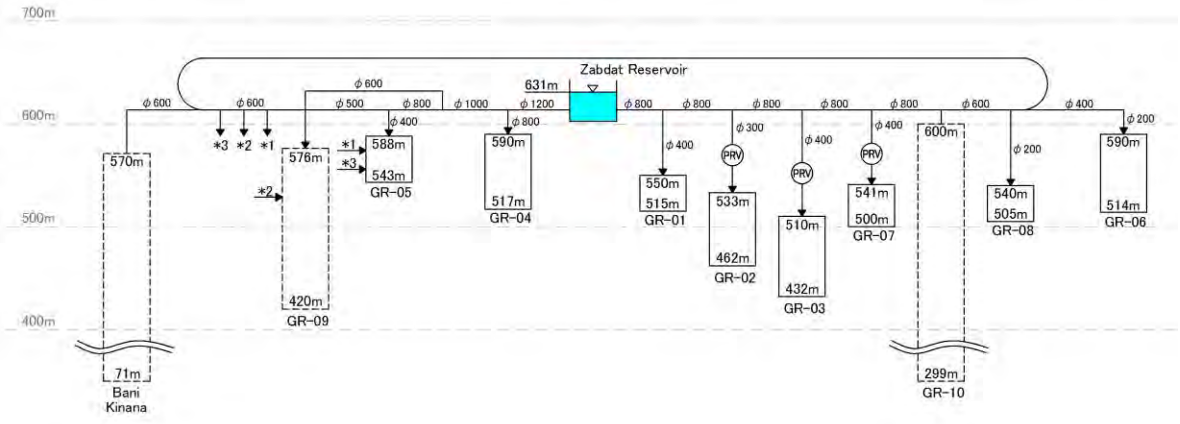


Figure 3-4 Gravity Zone Schematic Diagram (DMA and Primary Mains)

(2) Primary Mains

Primary mains are designed based on the followings;

1. Primary mains are originated from the Zebdat reservoir that has large quantity of storage volume covering demand in all DMAs.
2. Existing Zebdat reservoir with a capacity of 110,000 m3, HWL of 631m, is the main source for water.
3. The Zebdat reservoir is the highest point in the gravity zone so that DMA reservoir is not planned.
4. Three primary mains are planned; eastern, central and western ones.
5. The eastern primary mains supply water to GR-05, GR-09 and part of GR-06, utilizing part of the existing Hofa – Bait Ras pipeline.
6. The central primary mains supply water exclusively to GR-04 that is the largest DMA and covers the central Irbid.
7. The western primary mains supply water to GR-01, 02, 03, 07, 08, 10 and part of GR-06.
8. The eastern and western primary mains are interconnected at their tail ends forming a ring primary mains, thus water can be supplied to all DMAs, if required.
9. Three primary mains are also interconnected near the Zebdat reservoir.

The proposed strengthening pipelines would be laid as additional pipelines to the existing pipelines. Figure 3-5 shows Primary and Secondary Mains for each DMA and Figure 3-13 shows strengthen pipes.

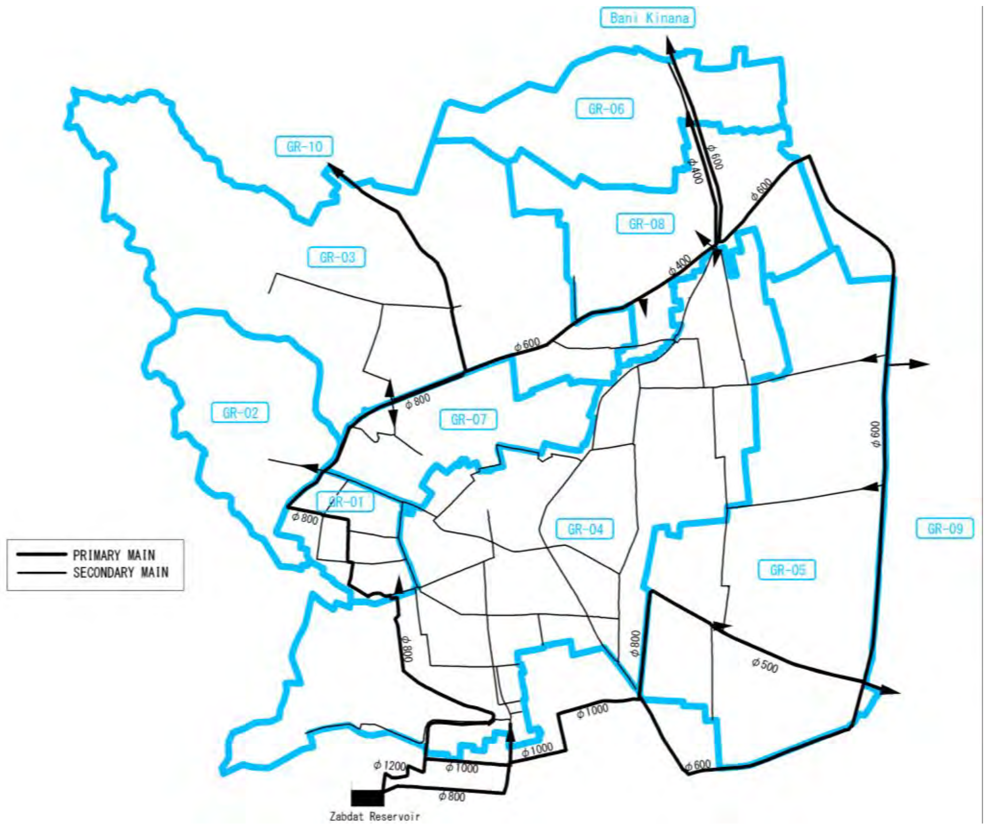


Figure 3-5 Primary and Secondary Mains in Gravity Zone

Note) Symbol identifies the locations of main feeding points to each DMA.

(3) Pipe

In addition to the existing water distribution network with diameters varying from 50mm up to 600mm and based on the hydraulic analysis results, the new gravity water system includes the following:

1. One proposed outlet pipeline with a diameter of 1200mm in addition to the existing 800 mm pipelines to feed all gravity DMAs.
2. Feeding pipeline for each DMA is installed with a flow control valve and a flow meter at the inlet.
3. New strengthening of water pipelines consists of different diameters of pipes between Ø 150mm and Ø 1200mm all around the gravity DMAs.
4. New additional Ø100 mm pipelines are required due to the disconnections and connections at the DMAs boundaries.
5. PRVs are provided for DMA GR-02, GR-03 and GR-07 with the following pressure reduction.

Table 3-6 Downstream Pressure after Pressure Reduction

	GR-02	GR-03	GR-07
Downstream Pressure(bar)	4.5	5.5	8.0

6. Water networks are arranged in a looped pattern. This will allow flow to reach to any point of demand from more than one direction. This will have the effect of eliminating stagnant water problems associated with dead-end pipes.

The proposed strengthening pipelines would be laid as additional pipelines to the existing pipelines.

3.2.4 Pump Zone

(1) DMA

Figure 3-6 and Figure 3-7 show a plan and schematic diagram for the pump DMAs within the study/project area.

Two pump DMAs (P-01 and P-02) within the project area and another pump DMA (P-03) outside of the project area represent DMAs within a distribution zone that supply water by pump to customers from existing Zebdat PS.

(2) Primary Mains

Two primary mains are planned; one for each of P-01 (high pump head, 50m) and P-02 (low pump head, 30 m) DMAs. Primary main of P-01 utilize the existing 600 mm pipe while new 400 mm pipe are planned for primary main of P-02. Pumps and pipes for P-03 (former P-02 in the MP) are not designed in this study. However, part of Hofa-Bait Ras pipeline in the Aidon locality, different section used in the eastern primary main, can constitute a primary main for P-03.

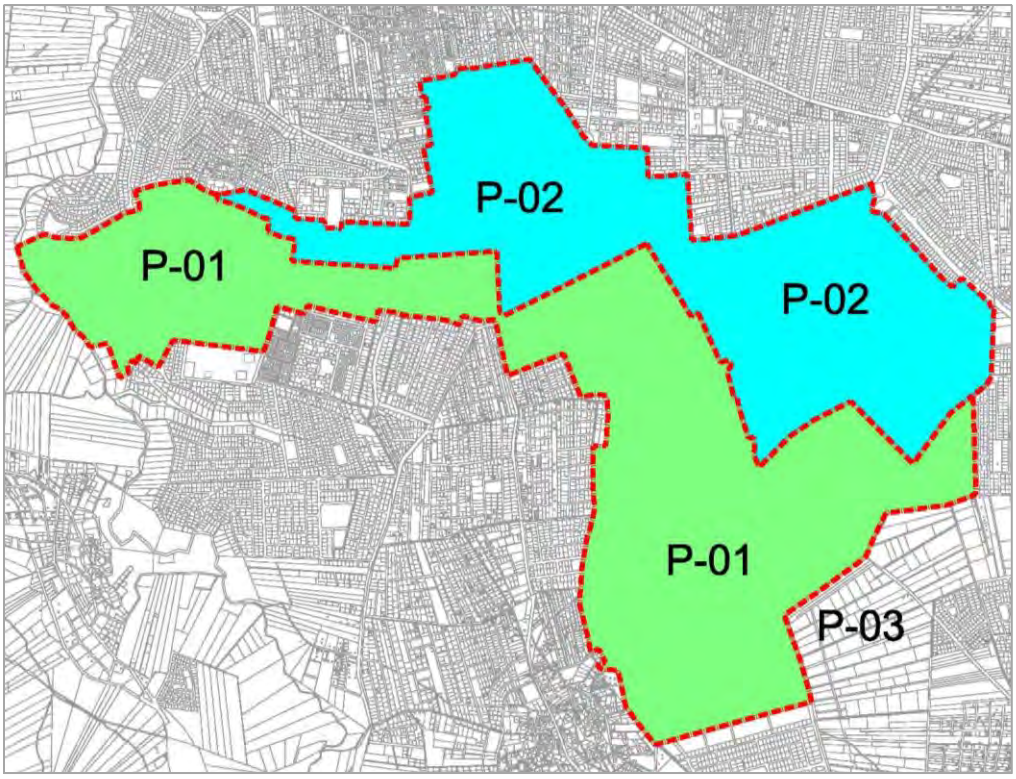


Figure 3-6 Pump Zone DMAs

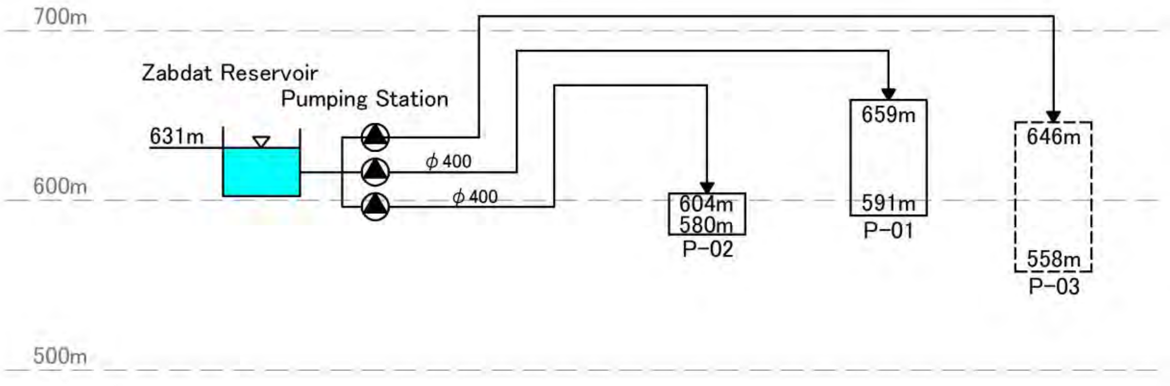


Figure 3-7 Pump Zone Schematic Diagram (DMA and Primary Mains)

Note: Pipes for P-03 and pumps for P-01 to P-03 is out of the Project Scope.

(3) Pipe

In addition to the existing water distribution network with diameters varying from 50mm up to 600mm and based on the hydraulic analysis results, the new pump water system includes the following:

1. Existing Zebdat PS is the main source for water as follows.
    - At maximum flow scenario, Pump 1 with a head of 50m is to feed DMA P-01 and Pump 2 with a head of 30m is to DMA P-02

- At the minimum flow scenario, Pump 1 with a head of 42m is to feed DMA P-01 and Pump P2 with a head of 20m is to DMA P-02

2. Two outlet pipelines (existing Ø 600mm to DMA P-01 and new Ø 400mm to DMA P-02).
3. One controlled feeding pipeline for each DMA
4. New strengthening water pipelines consist of different pipe diameters between DN 100mm and DN 600mm all around the pump DMAs.

The proposed strengthening pipelines would be laid as additional pipelines to the existing pipelines.

Figure 3-8 shows Primary and Secondary Mains for each DMA and Figure 3-14 shows strengthen pipes.

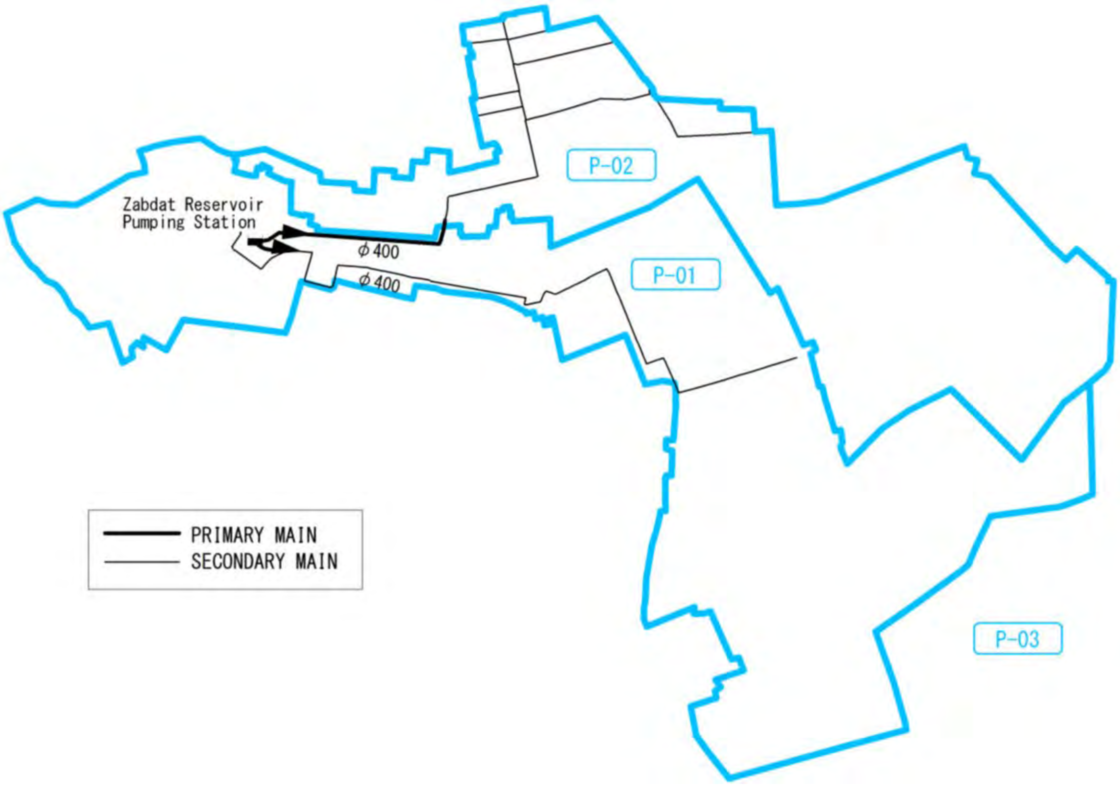


Figure 3-8 Primary and Secondary Mains in Pump Zone

Note) Symbol identifies the locations of main feeding points to each DMA.

3.2.5 Hydraulic Network Analysis and Design

Water Cad Software was used for the analysis of the water distribution network.

(1) Design Criteria for Hydraulic Network Analysis

1) Flow Formula

The Hazen-Williams equation was used for the hydraulic analysis of the distribution networks. The equation is as follows:

$$V = 0.849\, C\, R^{0.63}\, S^{0.54}$$

Where V = Flow velocity (m/s)
C = Hazen-Williams roughness coefficient (C-value)
R = Hydraulic Radius (m)
S = Hydraulic slope (m/m)
C-value as 110 for both the new as well as existing pipes is used in the model.

2) Velocity

Design is based on the economical velocity for calculating the pipe diameter. The following velocity ranges are adopted for sizing of new pipes.

- The gravity main: 0.30 -1.50 m/s
- The pump main: 0.75-1.80 m/s

3) Pressure

- Maximum static pressure: 7.5 bars in principle
  (but there can be exceptions due to site conditions)
- Minimum effective pressure: 2.5 bars in principle

(2) Assumptions for Hydraulic Network Analysis

The hydraulic analysis of the proposed water distribution network was carried out and modeled assuming the following:

- A gravity supply system from existing Zebdat reservoir for the gravity DMAs and pump supply system from Zebdat PS for the Pump DMAs.
- The new distribution network is designed for the design horizon year 2035 water demand projections in addition to the Syrian refugees.
- Continuous water supply system and checked for the rationing of water supply.
- Only one source for water supply is considered to act as a central supply location.
- The distribution networks with pipelines diameter from 63 mm and above were added to the Water Cad models of the distribution zones. The demand loading was distributed to the smaller lines in proportion to the areas served.
- Distribution pipelines of less than 63 mm in diameter are not included in the hydraulic analysis.
- The network is designed to meet the design criteria requirements.

(3) Maximum Flow Scenario

The design capacity of the proposed water distribution network was designed based on Maximum hourly demand scenario and checked for the minimum night demand and rationing of water supply scenarios.

The hydraulic model for the proposed distribution networks were run for the maximum hourly demand scenario in order to check the capability of the water network to deliver the needed demand at the maximum consumption.

a. Gravity Zone

The pressure results for the gravity zone are graphically presented in Figure 3-9 which can be summarized as follows:

- 85.7% of the junction's pressures, weighted by water demand, are within the adequate pressure range in between 2.5 and 7.5 bars.
- 14% of the junctions at the borders of the DMAs boundaries which have no other source or at limited areas inside DMAs with low levels have a pressure more than 7.5 bars up to 11 bars.
- Around 0.3% of the junctions have a pressure less than 2.5 bars but above 1 bar at the high level areas of Beit Ras which have no other source. However, this percentage can be considered as an acceptable percentage in the maximum scenario.

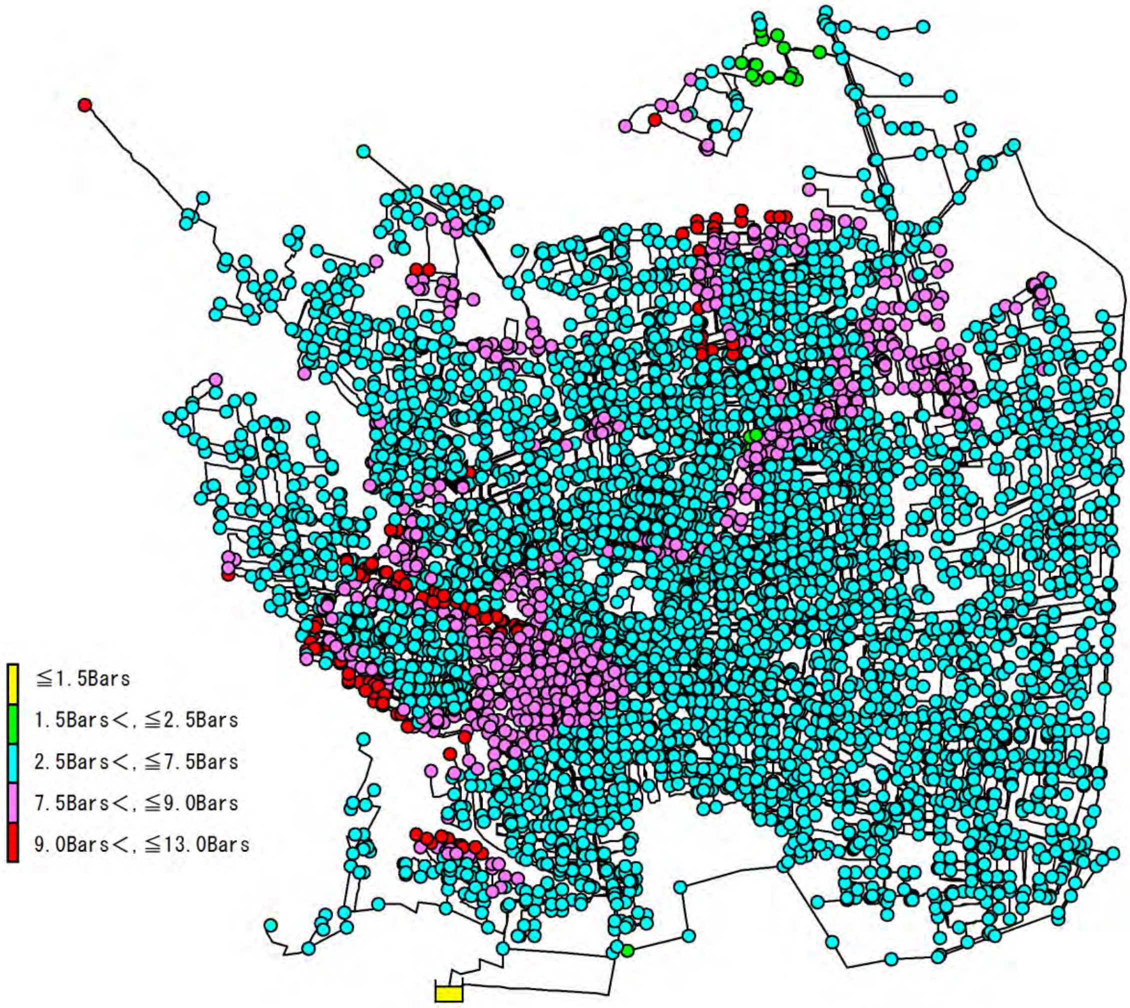


Figure 3-9 Pressure Results of Gravity Zone- Max. Flow Scenario

b. Pump Zone

The pressure results for the pump system are graphically presented in Figure 3-10 which can be summarized as follows:

- 95.7% of the junction's pressures are within the adequate pressure range in between 2.5 and 7.5 bars.

- 3.6% of the junctions at the borders of the DMAs boundaries which have no other source or at limited areas inside DMAs with low levels have a pressure more than 7.5 bars up to 9.2 bars.
- Around 0.7% of the junctions have a pressure less than 2.5 bars but above2.2bars.

Figure 3-10 Pressure Results of Pump Zone - Max. Flow Scenario

(4) **Minimum Flow Scenario**

a. Gravity Zone

The hydraulic model for the distribution network was run for the minimum hourly flow scenario during the night hours when there is low demand for water in order to check the maximum operating pressure within the network.

The calculation of this scenario is based on the average daily demand multiplied by the minimum hourly consumption factor as 0.3.

In order to maintain the pressure within the adequate ranges, the setting of the PRVs in the gravity zone and the pump head in the pump system will be reduced.

The pressure results for the gravity zone are graphically presented in Figure 3-11 which can be summarized as follows:

1. 62% of the junction's pressures are within the adequate pressure range in between 2.5 and 7.5 bars.
2. 38% of the junction's pressures are more than 7.5 bars.

b) Pump Zone

The pressure results for the pump zone are graphically presented in Figure 3-12 which can be summarized as follows:

1. 82% of the junction's pressures are within the adequate pressure range in between 2.5 and 7.5 bars.
2. 17% of the junction's pressures are more than 7.5 bars.

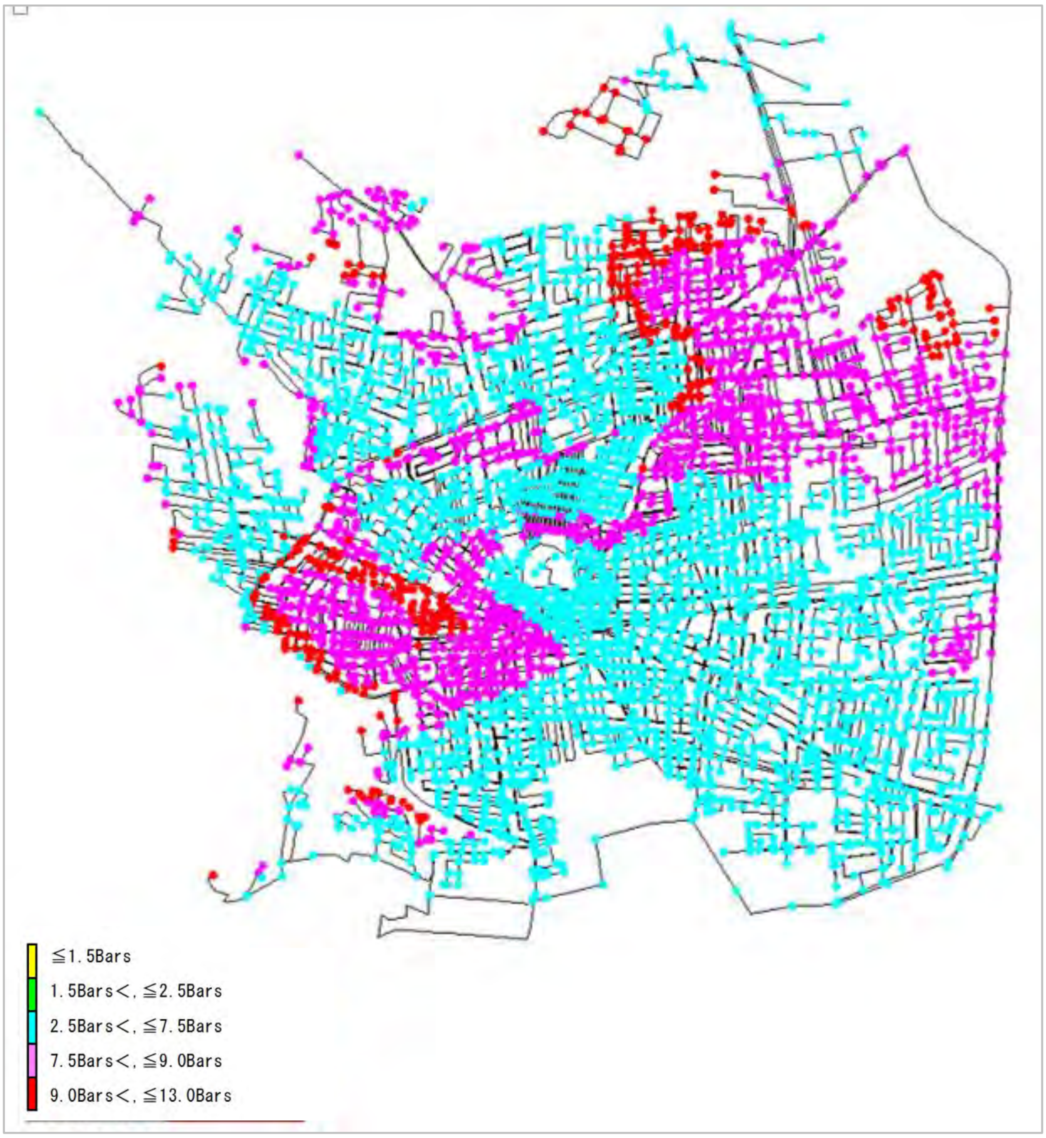


Figure 3-11 Pressure Results of Gravity Zone- Min. Flow Scenario

Figure 3-12 Pressure Results of Pump Zone- Min. Flow Scenario

(5) Conclusion on the Hydraulic Analysis

Since the project area is situated on a large plateau with ground elevation ranging from 631 m to 432 m in the gravity zone and there is limitation in source water supply, areas located at low elevation will continue receiving water all the time, while the areas at the tail-end and at a high elevation may not receive the sufficient water. The study team has made exercises on several ways of DMA creations for equitable water supply as much as possible. But any configuration of DMA boundaries with these large areas and high undulations have difficulty in achieving the adequate and equitable pressure all around the project area. However, this problem can be minimized in future if the number of DMAs are increased by splitting up some of the DMAs.

The hydraulic analysis results for the three scenarios of maximum, minimum and rationing of water supply (later explained) illustrate on the following:

- Varying in the elevation ranges even within the DMA and depending on around 90% of the water distribution network as existing, the pressures in acceptable ranges can't be guaranteed to 100%.
- Moreover, in order to have a balanced water supply system as much as possible, it is recommended to use a SCADA system (Supervisory Control and Data Acquisition) to create more controlled system.

3.2.6 Proposed Water Distribution Network

Based on the results of hydraulic network analysis and design, the water distribution network is proposed including the existing pipes and the new pipes.

Figure 3-13 shows on the proposed water distribution network of the gravity zone while Figure 3-14 shows on the proposed water distribution network of the pump zone.

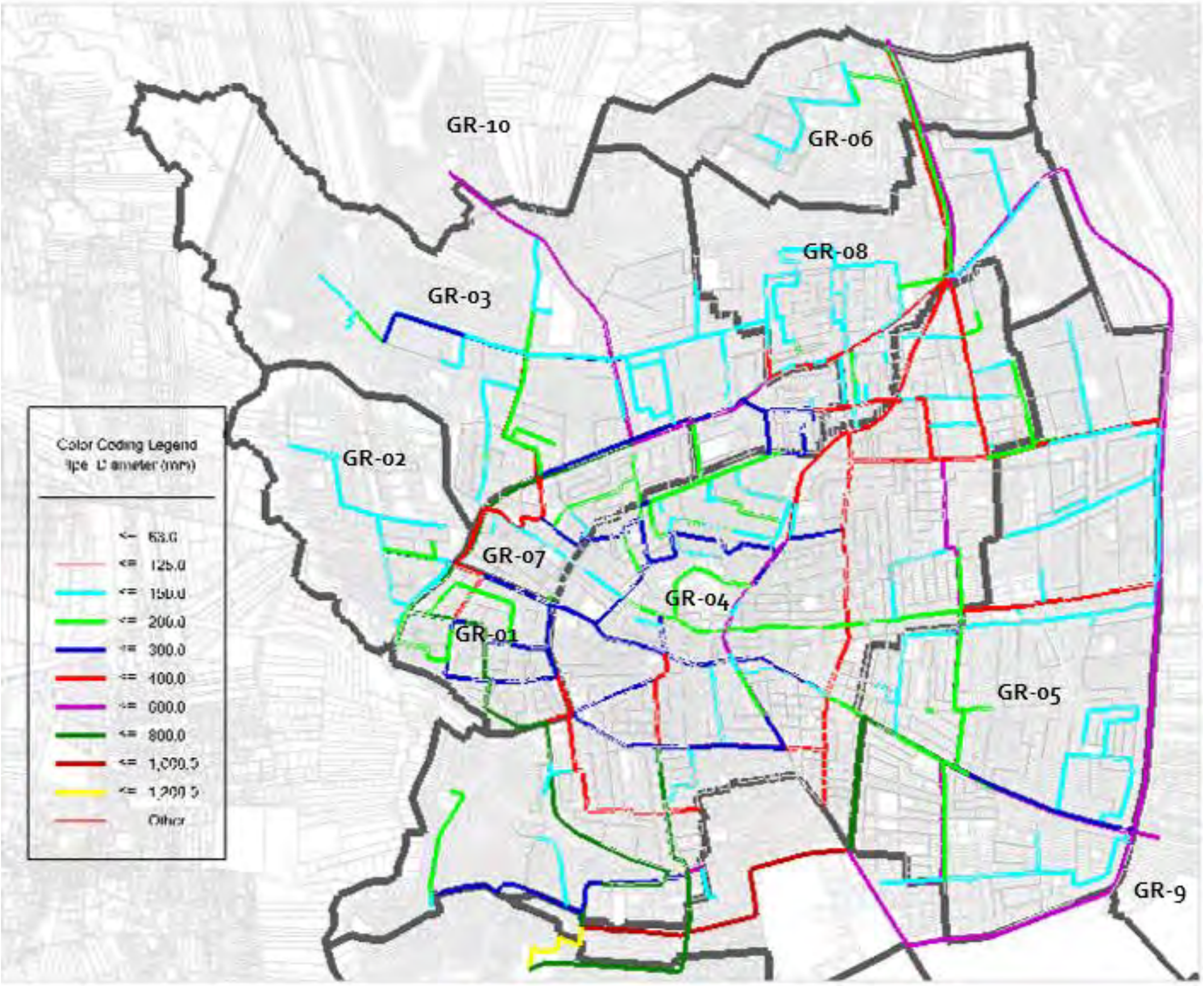


Figure 3-13 Proposed Water Distribution Network of the Gravity Zone

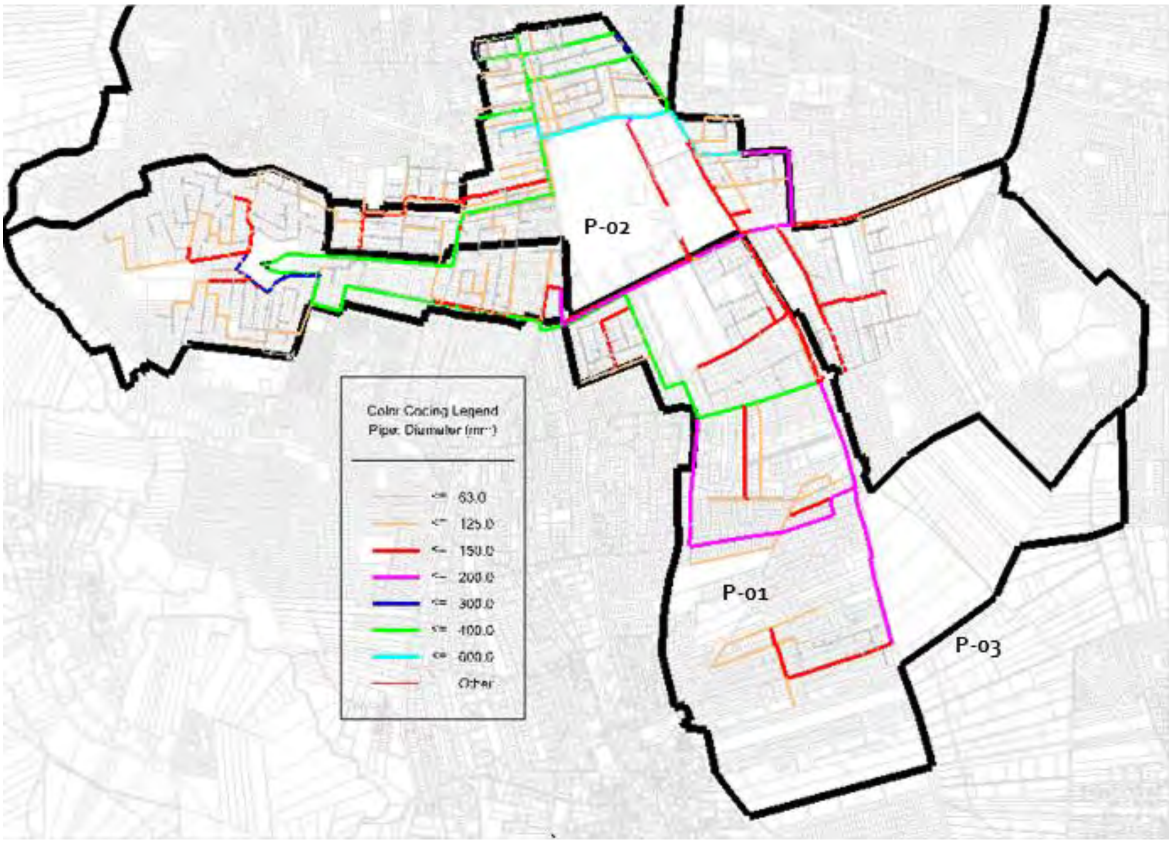


Figure 3-14 Proposed Water Distribution Network for the Pump Zone

3.3 Rationing Plan

3.3.1 Necessity

Available water supply will meet water demand in 2035 for the northern governorates and YWC can practice a continuous supply as per MP. The assumptions used in the MP and the current study are:

- Water would be available from Eastern and Western Transmission mains in the scheduled years and as per planned/allocated quantities
- Settled Population is projected based on 2015 census and number of Syrian refugees is counted at 2013 level only.
- Leakage is improved to 20% (up to year 2020) and 15% after that.

The above assumption may not be materialized soon and the existing rationing system is likely to continue for some years. The pipe size is determined based on a continuous supply and is confirmed that water can be distributed in Irbid. Nonetheless, some scenario of water distribution under rationing system is developed and water pressure is checked in the study area.

Assumptions developing some scenario are as follows:

- Zebdat reservoir has a large capacity: 110,000m^3 equivalent to 1 day volume of 110,000 m^3/day = 4,600m^3/hour = 40 MCM/year
- Two days supply per week.
- Irbid is divided into 3 blocks for rationing purpose.

3.3.2 Rationing with 3 Blocks and supply twice a week

Water amount of 3.5 (7 days water demand supplied in 2 days) times of daily average demand need to be supplied into each block under the rationing system. This is two times of the water amount used for pipe size design in this study. Pipe size is designed based on hourly maximum demand that is 1.8 (seasonal factor 1.2 x hourly peak factor 1.5) of daily average demand

Irbid is to be divided into 3 blocks for rationed water supply. A Sample of 3 blocks division is shown in Figure 3-15 , considering the following objectives to be fulfilled:

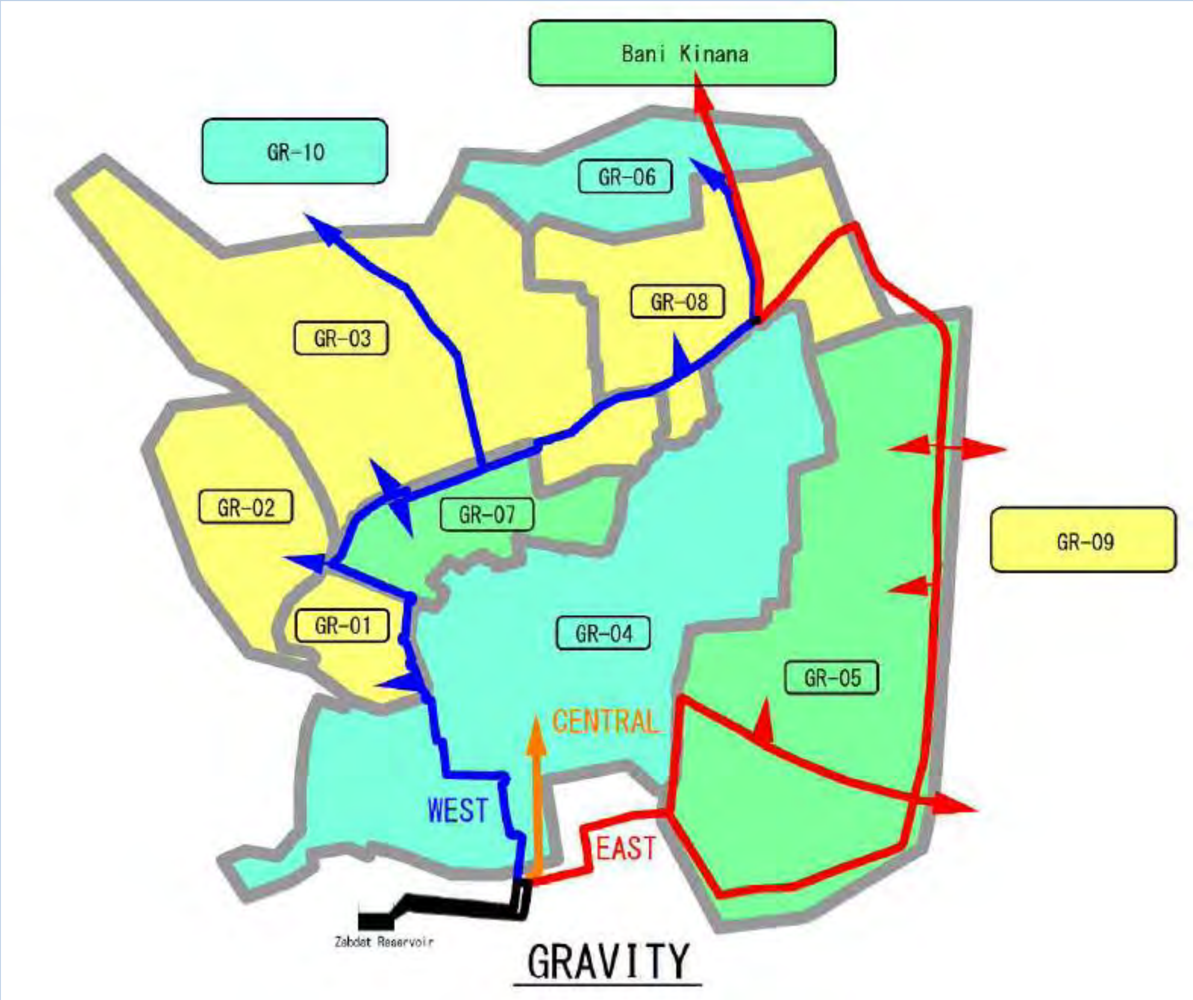
- Demand in each block is equal as far as possible
- Equalize water quantity flowing in the eastern and western primary mains as much as possible.

The following table shows the daily average water demand in each DMA and rationing supply amount for 2 days' supply per week.

Table 3-7 Demands in DMA

Zone category	Sub zone number	Population in 2035 (persons)	Daily average water demand in 2035 (a)		Maximum hourly demand ((a) x .1.8)	2 days supply per a week demand ((a) x 3.5)
			(m3/day)	(L/S)	(L/S)	(L/S)
zebdat gravity zone	GR-01	29,231	4,005	46.4	83.5	162.3
	GR-02	28,642	3,924	45.4	81.8	159.0
	GR-03	68,660	9,406	108.9	196.0	381.1
	GR-04	187,220	25,649	296.9	534.4	1039.1
	GR-05	70,597	9,672	111.9	201.5	391.9
	GR-06	14,985	1,558	18.0	32.5	63.2
	GR-07	63,317	8,674	100.4	180.8	351.4
	GR-08	39,556	5,239	60.6	109.2	212.3
	GR-09	144,269	14,127	163.5	294.4	572.3
	GR-10	102,152	10,213	118.2	212.8	413.8
	Bani Kinana	214,283	12,587	145.7	262.3	509.9
	Sub Total	962,912	105,054	1,215.9	2189.2	4256.3
zebdat pump zone	P-01	57,043	7,044	81.5	146.8	285.4
	P-02	23,341	3,198	37.0	66.7	129.6
	Sub Total	80,384	10,242	118.5	213.5	415.0
Total		1,043,296	115,296	1,334.4	2402.7	4671.3

Based on the demand allocation within the project area and in order to supply water with adequate and equitable pressure as much as possible, the project area could be divided into three blocks as shown in Figure 3-15. Table 3-8 shows water demand for each block.



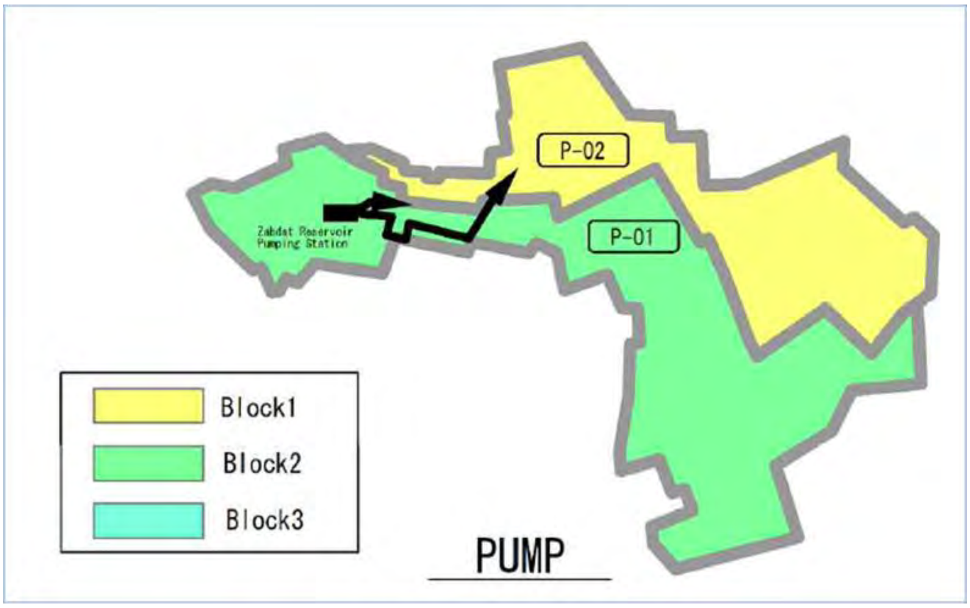


Figure 3-15 Example of Blocks for Water Rationing

Table 3-8 Total Expected Flow within Each Block

(m^3/d)

	GRAVITY						PUMP		Total
	WEST		EAST		CENTRAL				
Supply Block1	GR-01	4,005	GR-08	5,239			P-02	3,198	39,899
	GR-02	3,924	GR-09	14,127					
	GR-03	9,406							
	S.T	17,335	S.T	19,366	S.T	-	S.T	3,198	
Supply Block2	GR-07	8,674	GR-05	9,672			P-01	7,044	37,977
			Bani Kinana	12,587					
	S.T	8,674	S.T	22,259	S.T	-	S.T	7,044	
Supply Block3	GR-10	10,213	GR-06	1,558	GR-04	25,649			37,420
	S.T	10,213	S.T	1,558	S.T	25,649	S.T	-	
Total		36,222		43,183		25,649		10,242	115,296

3.3.3 Network Analysis

Network analysis was conducted for the blocks 1, 2 and 3 independently.Figure 3-16, Figure 3-17 and Figure 3-18 show pressures and velocity for blocks 1, 2 and 3.

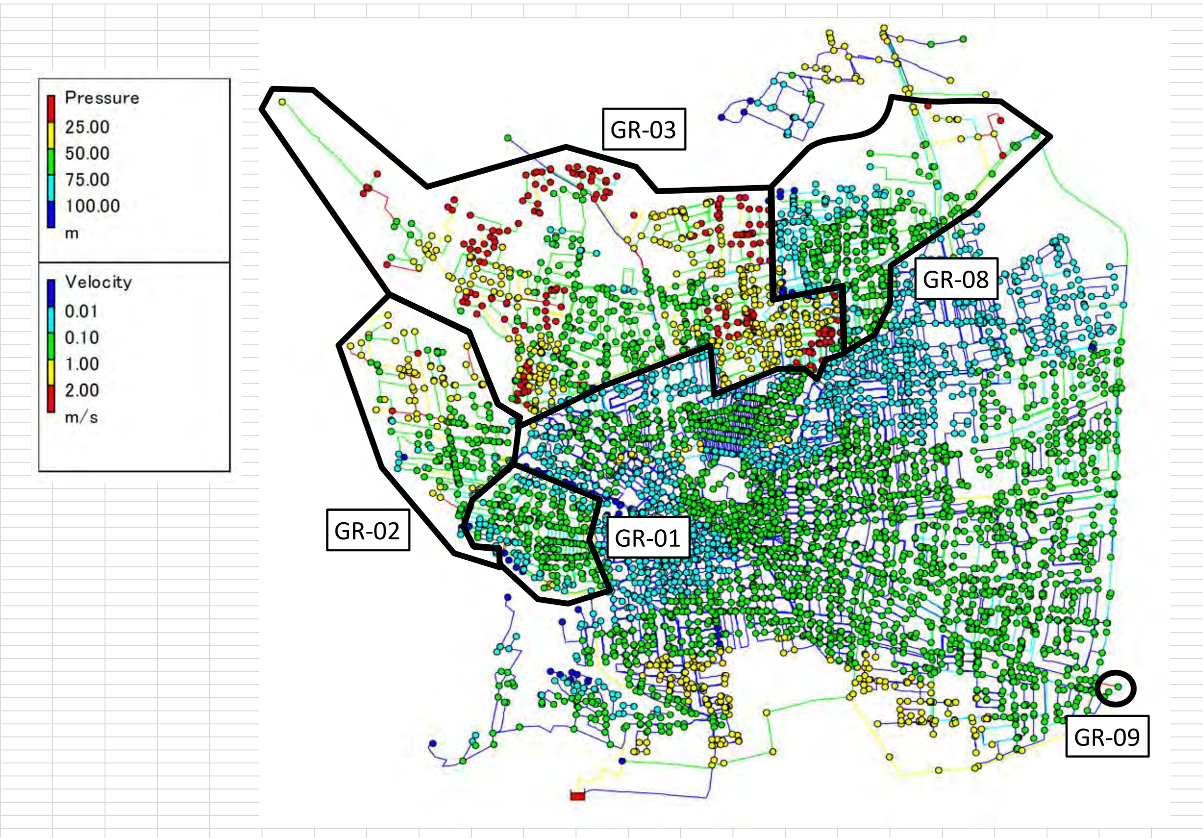


Figure 3-16 Pressure and Velocity - Supply block 1

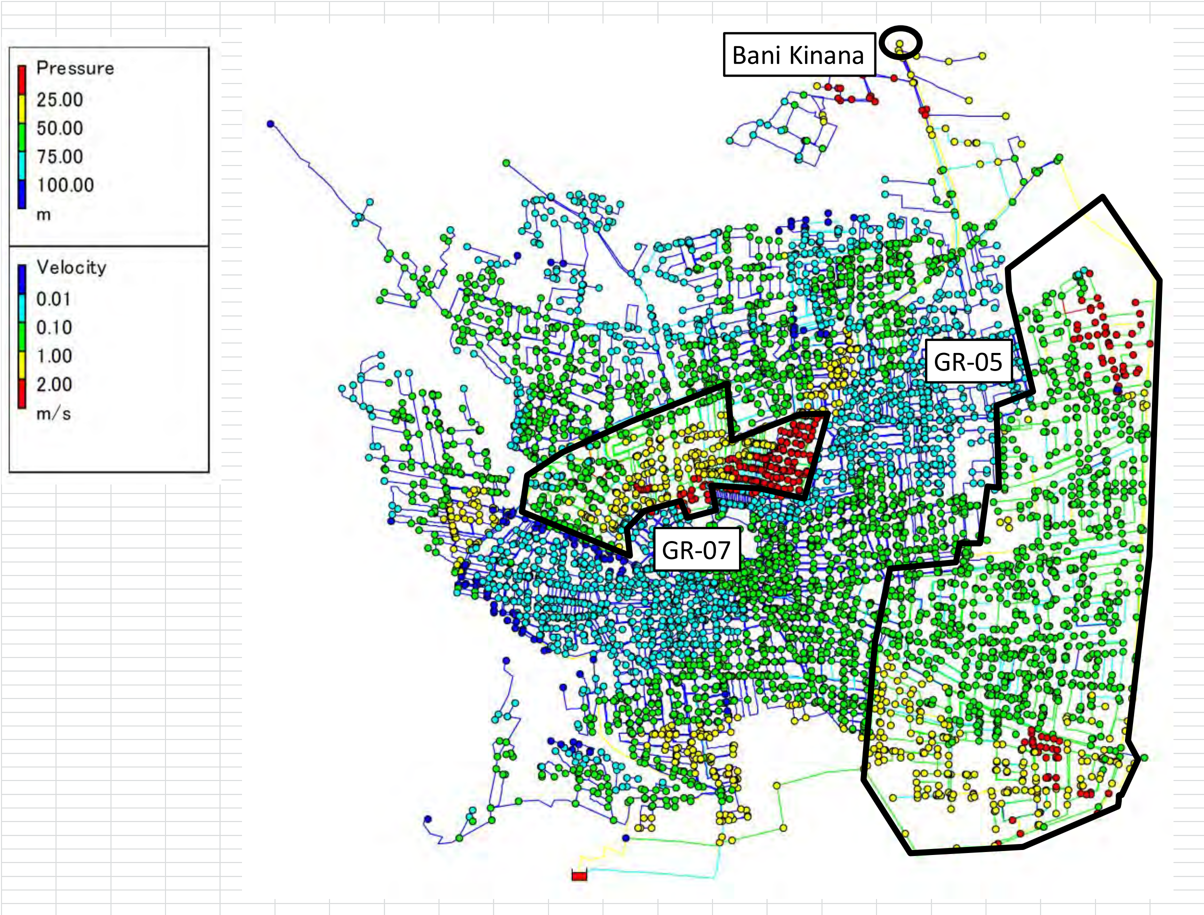


Figure 3-17 Pressure and Velocity - Supply block 2

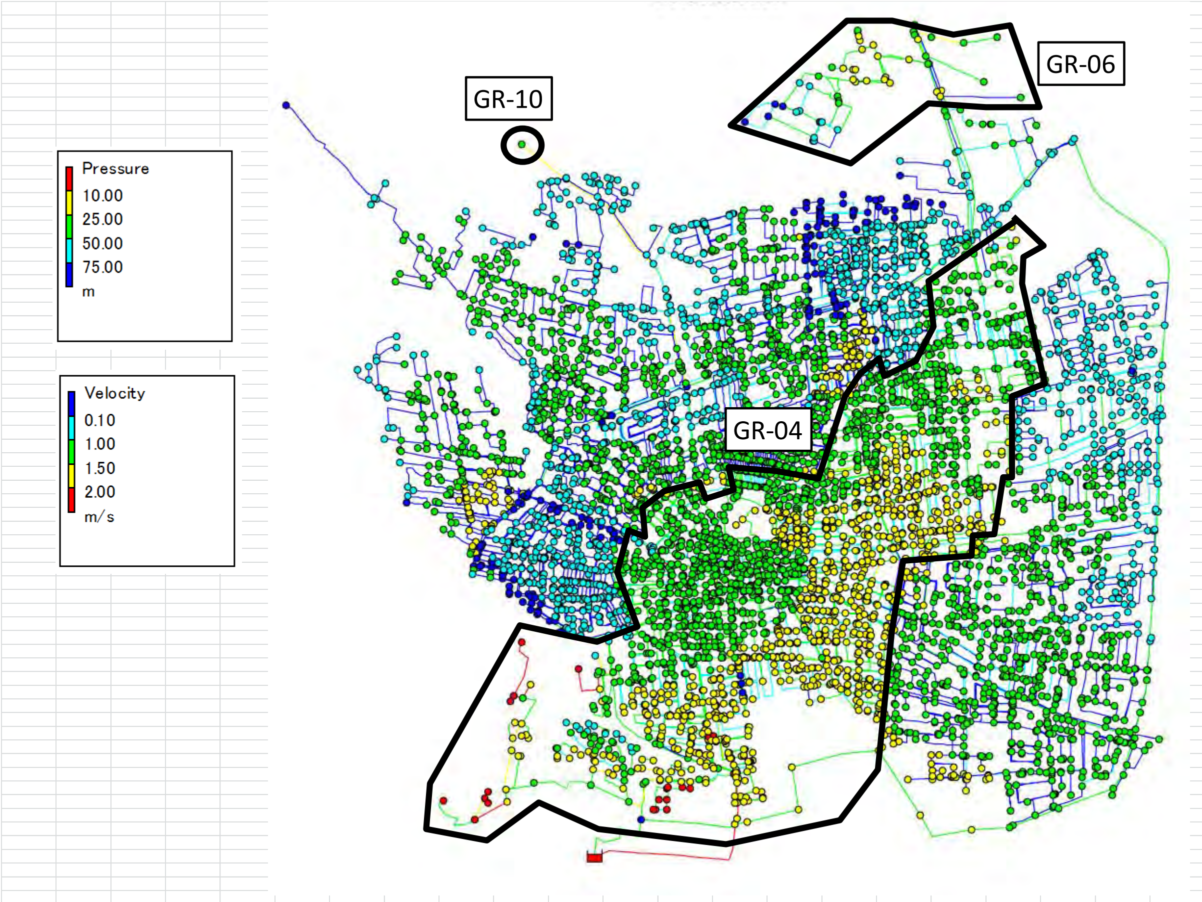


Figure 3-18 Pressure and Velocity - Supply Block 3

3.3.4 Supply to Bait Ras and Bani Kinana

Bait Ras (DMA GR-06) with an altitude of 600m is located in the northern Irbid, farthest from the Zebdat reservoir at an altitude of 600m. As proposed in the MP, pumping water to Bait Ras shall be stopped and water shall be supplied by gravity in order to save the high energy costs. Two primary mains under this design; eastern primary mains and western primary mains which emanate from the Zebdat reservoir and join near the Bait Ras, will act as transmission pipes to Bait Ras.

As per hydraulic network analysis, the water shall reach to Beit Ras area with a pressure not less than 10 m. However, during the study, YWC has raised a concern on possible difficulty in supplying water to Bait Ras. So, in case of above anticipated problem, the following additional measures can be undertaken:

1) YWC is planning to rehabilitate the existing reservoir at Bait Ras. If necessary, YWC can install booster pumps to secure water supply to a limited water deficit areas in Bait Ras
2) Under the rationing system, although Bait Ras is grouped into block 3, water is exclusively supplied to Bait Ras for a few hours depending on its demand. This is achieved by closing inlet valves in all DMAs except in DMA GR-06.
3) Planned pump to the pumped DMA can be utilized to supply water exclusively to Bait Ras for a few hours. This is also achieved by the same valve operations mentioned in item 2).
4) Water can be supplied exclusively to Bait Ras for a few hours from Hofa reservoir by gravity.

3.4 SCADA System

3.4.1 General

SCADA system is out of scope of this Study, however electrically-driven flow control valves, flow meters and pressure gauges are proposed in this Project. Therefore, SCADA system shall be developed using these equipment. SCADA system will become indispensable components of the distribution system due to the reasons below.

- Large number of DMAs is proposed for equitable water distribution.
- Water Supply by Rationing system will continue for some time at least.
- Under the rationing water supply, water can be supplied alternatively to each of 3 blocks, combination of DMAs.
- Operation on closing of valves to non-supplied DMAs and opening of control valves to supplied DMAs will be needed on day to day basis.
- Monitoring of inflow to DMAs and pressure inside of DMAs.
- Automatic operation for relieving personnel from routine operation for more monitoring and maintenance activity.
- Among the supplied DMAs in the block, flow control is required to adjust uneven water supply to each DMA that depends on water demand in each DMA that will change year by year because of uneven development of the areas.
- Easier detection of leakages and making provision for better assessment of non-revenue water (NRW) in future.
- Monitoring water quality through on line detectors such chlorine, turbidity analyzer in future.
- Facility for energy management and saving by optimizing pump operations.

SCADA system is comprised of SCADA center and remote stations. Remote station is placed in each entrance of DMA and reservoir/PS and handles input signal from process equipment and output the control signal to the local facilities. SCADA center should be placed in the office where operation and maintenance crews for the distribution facilities are stationed.

3.4.2 Control

For the electrically controlled drives the control shall be selected by local Manual-0-Remote or Manual – Remote switches. For each drive the signals of the selector switch positions shall be transmitted for information via PLC to SCADA.

The manual local control is located at Local Control Panels (LCPs) and/or at the front panel of local switch- and control gears (e.g. the MCCs). The manual local control is provided for the possibility of maintenance and repair. The usual operation should be automatic (selector switch in position “remote”).

The automatic control (automation) is the closed loop control operated by the implemented programs in the PLCs and finally controlled

- by the measuring devices (instrumentation) or
- by programmed time schedules or other logical links

The supervisory control at the SCADA center is manual control by experienced operators, which overwrites the automatic control (but not the manual local control and not the emergency control). If

criterion for this automatic control is defined, central supervisory automatic control features can be programmed in the SCADA system. Here “Supervisory” means the automatic influence between different stations at different locations. The simplest kind of automatic is a certain time schedule control.
After operational experience of about two year with the means of SCADA and after an intelligent assessment of the acquired and stored data, those criteria for automation could be investigated and new supervisory automation program could be implemented for improvement of plant operation.

3.4.3 Design Requirement of SCADA

Basically the detailed design of the SCADA system is a responsibility of the selected contractor for supply, installation & commissioning of the SCADA system. Thereby the contractor shall prepare and submit for approval complete design documents for SCADA in line with the technical scenarios and shall be followed the standard design documentation as noted below:

- Functional Design Specification
- Layout drawings of the equipment with integration into the civil/architectural drawings
- Data sheets of the equipment
- Shop drawings of the ICA cubicles
- Documentation of the Automation and the RTU and local HMI application programs

3.4.4 Distribution SCADA Configuration

The Distribution SCADA is a decisive tool of the Irbid water supply system. All relevant data of the DMAs are collected, appraised and stored for future decisions. The SCADA software shall manage the incoming data.

By organizing the acquired data for an easy overview of water supply SCADA will help the operators and engineers finding prompt but strategic decisions, like bulk leakages, black-out of PS, etc.

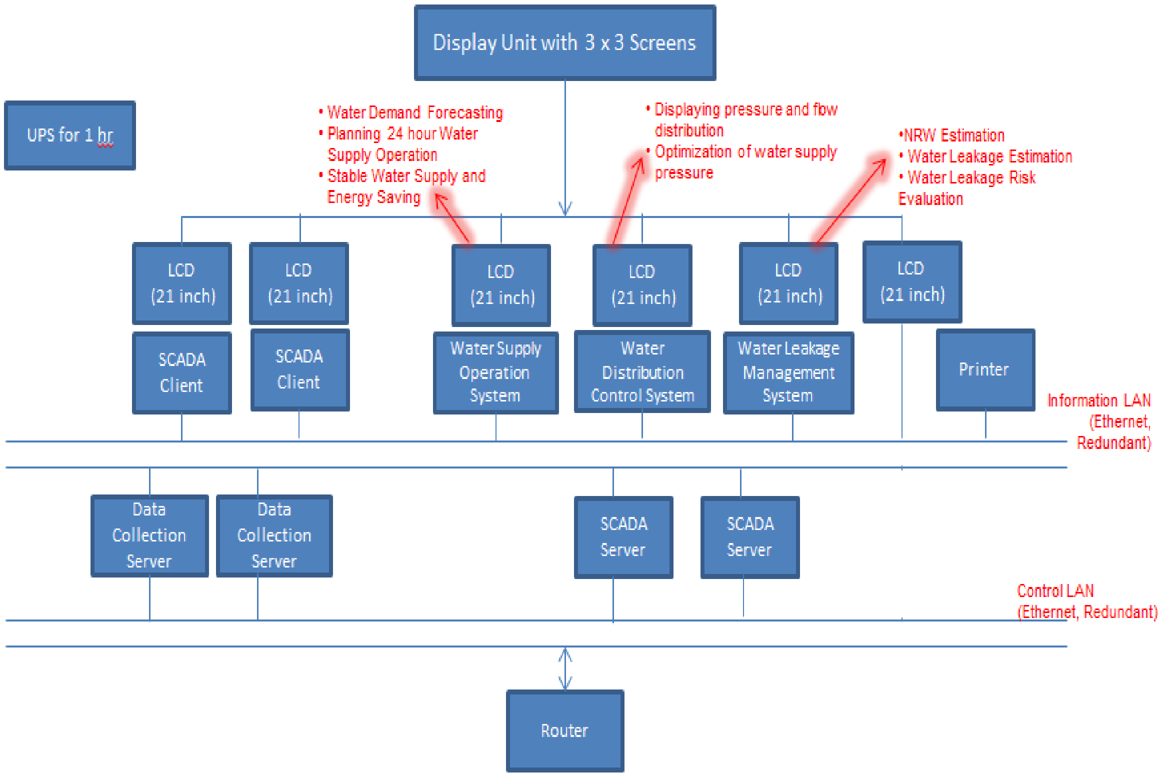


Figure 3-19 Distribution SCADA (Router shall get signals from DMAs)

3.4.5 DMAs Automation

The valves will be automatically controlled by the "far" pressure (minimum limit) and the pressure "before" the valve (maximum limit).

All relevant data of the UPS and main power supply if applicable; Flow meter; Pressure transmitters; valves; shall be sent to SCADA and stored in the local data logger. The data loggers shall have the capacity to store all station's data of minimum one week.

It shall be possible that at the distribution SCADA center all relevant parameters (timers, maximum and minimum pressure limits) for the automation can be changed. At the SCADA center the automation mode can be switched on and off as well as the valves can be closed and opened, provided that the DMA valve station is not in local manual operation mode.

Figure 3-20 shows SCADA Configuration at each DMA.

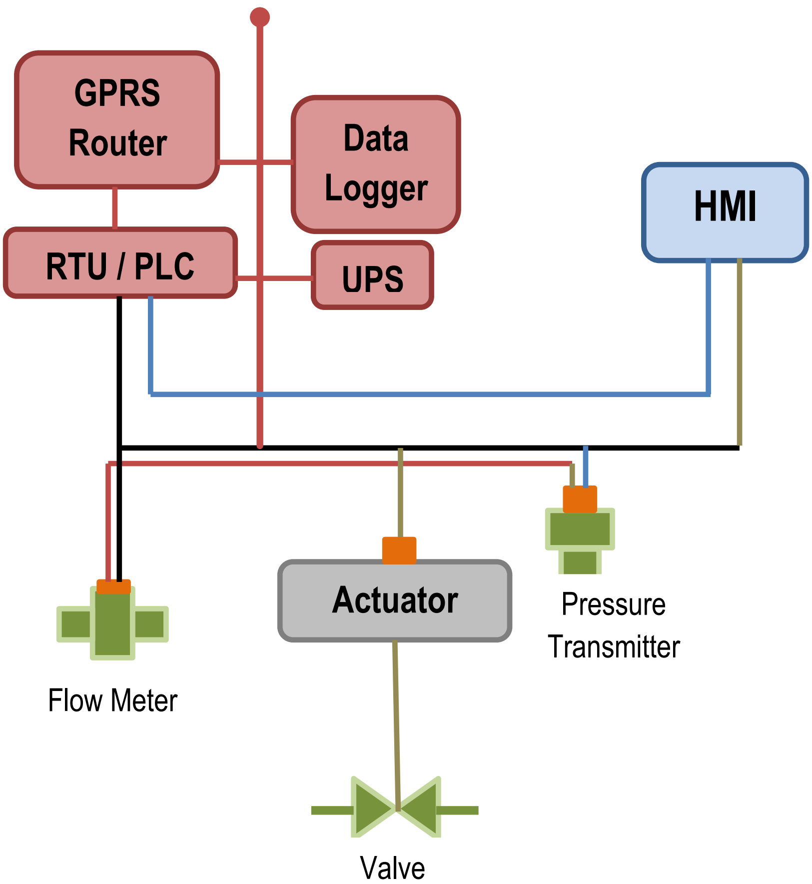


Figure 3-20 SCADA Configuration at DMAs

3.4.6 Water Leakage Management Software

The SCADA will provide leakage management software for reduction of Non-Revenue Water (NRW) based on the Geographical Information System (GIS) platform. The software shall support NRW reduction activities in waterworks by estimating NRW/leakage at each DMA and leakage risk evaluation of pipeline.

Water Leakage Management Software will have the following functions:

- NRW Estimation
  NRW amount shall be estimated for each DMA with necessary data, such as inlet flowmeter measurement and metered consumption. The system should be easy-to-use for the NRW situation. The system shall gather the inlet flowmeter measurement and calculate for estimation of NRW amount online. The system shall manage the billing data for estimation of NRW amount. As an output, the system shall estimate NRW amount for each DMA with color coding on the GIS.
- Water Leakage Estimation
  Amount of water leakage shall be estimated at each DMA. The function allows for the prediction of new water leakage information and shall be shown on GIS.
- Leakage Risk Evaluation of Pipeline
  Leakage risk of pipeline shall be evaluated. The evaluated leakage risk can be used as reference for maintenance of pipeline such as prioritization of leakage survey and planning of pipe replacement. It shall have to manage water leakage history database. It shall be done by using the

pipe network asset information e.g. pipe type, installation year, land environment etc. The risk factor shall be displayed on the GIS adjusting the color accordingly.

4 DETAILED DESIGN

Detailed design is carried out for the new strengthening pipelines wherever required. The plan and profiles of the same are presented in Volume 4-Drawings. This Chapter presents the design basis in the following orders:

1) Survey Works
2) Pipe Material
3) Pipe-laying Method; Open-cut method and Trenchless method
4) Pipe Alignment
5) Thrust Protection
6) Ancillary Pipe Appurtenances

4.1 Survey Works

Prior to the preparation of the detailed designs for the proposed strengthening pipelines, field verification by the design team was conducted addressing specifically the following:

- Accessibility of the routes for pipelines installation;
- Proper alignment of the pipelines along the route; and
- Any difficulties which may be encountered during pipelines installation

4.1.1 Topographic Survey

A topographical Survey was carried out to establish the ground surface features and to determine the natural gradient in order to locate the proposed strengthening pipelines at the most appropriate locations.

The following general categories of details were surveyed:

- Roadway where the survey includes Road centerline, Crown, Edge of Seal. Profile is obtained by surveying above features every 20 m, and at change of grade.
- Any existing Structures including Bridge and Culvert.
- Any existing Utilities including Water valves, Fire hydrant, Power pole, Telecom and electricity manholes (if exist)
- Permanent buildings, porches and canopies
- Boundary features: walls, fences, hedges with type and height annotation
- Street furniture
- Utilities plant and service (manhole) covers where visible
- Changes of surface with full annotation
- Earth works, Top and Bottom of slopes, Quarries and rock faces
- Ground levels

Any other feature likely to impact upon the proposed work.

The main coordinates were obtained from Land and Survey Department while the elevation point was given by Royal Geographic Center.

The report of topographic survey including the bench marks is attached in Appendix 6.7

4.1.2 Soil Survey

Terms of Reference for Soil Investigation Works were prepared to provide the Engineer with surface and subsurface conditions at the project site including the physical, chemical and mechanical properties of ground materials in order to provide the Engineer at the detailed design stage with the needed information for the detailed design and construction of most suitable and safe structures and to assess the stability of the sites and to provide the design engineers with general measures to enhance the stability and safety of the existing sites and assess existing networks.

The report of soil survey is attached in Appendix 6.8.

4.2 Pipe Material

Pipe materials are basically in conformity with the following:

- Pipe material, with which no risk of water contamination is brought about,
- It is safe against inside pressure and external forces,
- It conforms to the burial condition, and
- It possesses good property of laying which conforms to the environment of burial ground.

4.2.1 Characteristics of Pipe Material

Pipe materials are different from each other in terms of material, method of manufacture, standard dimensions, strength, coating on inside and outside walls etc. Therefore, the most suitable materials are selected in consideration of hygienic property, compatibility, resistance to earthquake, ease of maintenance etc. The characteristics of pipe materials used for distribution mains are shown in Table 4-1. More details about pipe material selection are presented in Appendix 6.3.

Table 4-1 Characteristics of main pipe materials used for distribution mains

Pipe material	Advantage Disadvantage	Disadvantage
Ductile iron pipe	(1) Pipe body is strong, high in ductility and can withstand strong impact. (2) High durability (3) Such flexible joints as K, T, U type etc. can deal with deformation of soil owing to their ability to expand and bend. (4) Such rigid joints as NS, S, SII etc. can deal with bigger expansion and contraction than the flexible joints; and furthermore can cope up with the bigger deformation of soil as they possess dislodge-resistant joint. (5) Easy handling	(1) Relatively heavy (2) Protection of special fittings is needed depending on the type of material. (3) Easily corroded if the protection coating of the inside or outside wall is damaged. (4) The K, T, U type etc. joint may slip off if the degree of expansion exceeds the prescribed limit due to fluidization or cracking of the soil at the time of an earthquake.
Mild Steel pipe	(1) Pipe body is strong, high in ductility and can withstand strong impact. (2) High durability (3) Can be composed as one body by welding, and able to deal with movement of soil by strength of its body and ability to transform. Where soil movement is large, expansion joint or thicker pipe wall can be applied. (4) Easy handling for construction	(1) Although professional skill is required for the welding joint, automatic welding is available. (2) Protection against electrolytic corrosion shall have to be taken into account. (3) Easily corroded if the protection coating of the inside or outside wall is damaged.

Pipe material	Advantage Disadvantage	Disadvantage
	(5) Pipe coated with corrosion-proof material (polyurethane or polyethylene) is available.	
Stainless steel pipe	(1) Pipe body is strong, high in ductility and can withstand strong impact. (2) High durability (3) Excellent corrosion resistance (4) No lining or painting is needed	(1) The joint welding work is time-consuming (2) Means of isolation from other metal material is needed.
U- PVC pipe	(1) Excellent corrosion resistance (2) Handling is easy owing to its light weight (3) Roughness of the inside wall does not change. (4) The RR long joint is superior than the RR joint in terms of expandability.	(1) Body strength is smaller than metal materials. Resistance to the impact reduces in low temperatures. (2) Vulnerable to heat and UV ray (3) Softened by such organic solvent as thinner (4) Protection of special fittings is needed depending on the type of material. (5) Sufficient examination prior to its use is required for the RR long joint for its resistance to an earthquake since it has only a little experience to deal with a disaster because of its short application history.
Polyethylene pipe	(1) Excellent corrosion resistance (2) Handling is easy owing to its light weight (3) Pipe can be made as one body by butt fusion welding and electrofusion welding and so can deal with the movement of soil. (5) Roughness of the inside wall does not change.	(1) Body strength is smaller than metal materials. (2) Vulnerable to heat and UV ray (3) Caution shall be paid for its permeability to organic solvents. (4) Pipe laying under rainy condition or where water springs out is difficult in the case of the butt fusion welding method. (5) Such special tools as the controller is needed in the case of the butt fusion welding method. (6) Sufficient examination on earthquake resistance prior to its use is required since it has no disaster experience in weak soil.

4.2.2 Design Pressure

Materials and their classes of proposed pipelines are selected considering the pressures as per follows.

- Gravity system : Static pressure + surge pressure (water hammer)
- Pump system : Static pressure or pump head, whichever is higher + surge pressure (water hammer)

Static pressures of pipelines are calculated based upon the water level of Zebdat reservoir or pump head and elevations of pipelines.

Surge pressures (water hammer) can occur due to pump failure, pump operation (start up and shut down), sudden closure of valve, column separation and malfunctioning of check valves. The surge events which have been considered are the result of the three most common instances, pump failure, rapid pump start up and sudden valve closure. The surge analysis was examined and appropriate measures were considered as needed. The surge analysis is shown in the Appendix 6.5.

Thus, Design pressures are as follows.

Table 4-2 Design Pressures

Zone		Static pressure/pump head, whichever is higher + surge pressure (water hammer)	Remarks
Gravity Zone		130m (12.8bar)	for proposed primary mains
		160m (15.7bar)	for proposed secondary mains
Pump Zone	P-01	100m (9.8bar)	for proposed secondary mains
	P-02	80m (7.9bar)	

Note:
1 Water level of Zebdat reservoir is 631 m
2 Pump Head for DMA P-01is 50m.
3 Pump Head for DMA P-01 is 30m.

4.2.3 Recommended Pipeline Materials

Based on the above evaluation of the different characteristics of pipe materials, the availability of material in the market and previous experience in Jordan, the following selection is recommended for use:

1. Ductile Iron (DI) pipe of grade C30 and C40, internally cement mortar lined and externally coated with an alloy of zinc and aluminum (85% Zinc and 15% Aluminum), are recommended for the primary pipelines with diameters of 150mm and above.
2. For the distribution networks with pipe diameters less than 150 mm, it is recommended that HDPE pipes of 16 bar pressure class be used.

4.3 Pipe Laying Method; Open-cut Method and Trenchless Method

Laying of distribution pipes has been generally carried out by open cut method in Jordan except crossing of national roads that are shown in Figure 4-1. In that case, trenchless method is required according to the guidelines of MoPWH. However, in this case, as open-cut method has been allowed in all of the crossings within city center except three points along the old Amman road.

Pipe jacking is a trenchless technology method for installing a prefabricated pipe through the ground from a driving shaft to a reception shaft. The length of the commonly used jacking method is in general 50 m to 100 m. The shield driving method is, in turn, employed in the cases of large-scale work for water mains with a large diameter and length.

By the jacking method, a leading head is attached on the head of pipe; excavation is operated from a jacking shaft etc.; the excavated soil is carried out; and one span of the pipe is laid.

The pipe jacking method shall be in conformity with the following:

(1) An appropriate method shall be selected synthetically examining the safety and soundness of the construction work based on a survey in advance on geotechnical quality, obstacles, environment etc. and prior consultation with the concerned authorities.
(2) The pipe material, which is suitable for the required diameter, the length, the depth and method of laying, shall be selected for pipe jacking in consideration of its strength, durability and the ease of construction.

(3) The guide pipe shall have the structure suitable for the diameter of the jacking pipe, geotechnical quality, and the construction method.

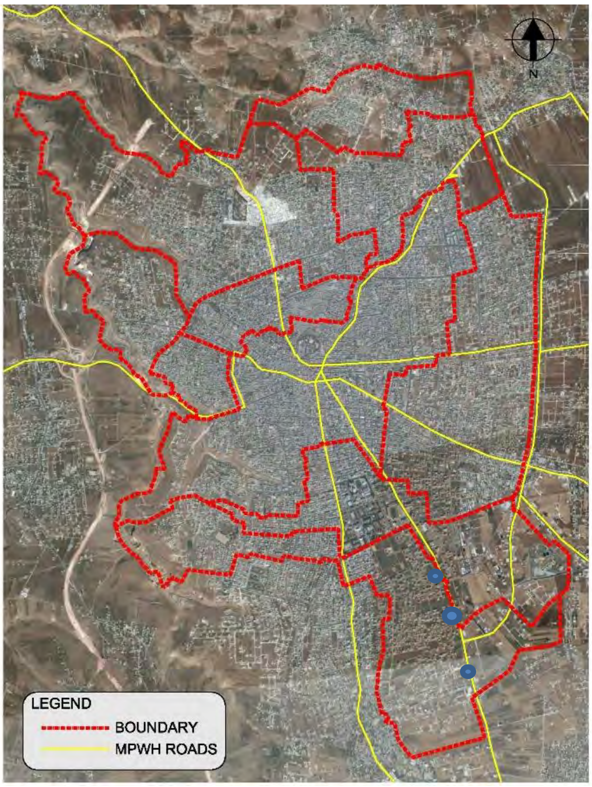


Figure 4-1 National Road and Crossing Points with Trenchless Method

4.3.1 Pipe trenches (Municipality and MoPWH)

(1) Cross Section

Width of trenches for DI pipes of 150 mm diameter and HDPE pipes of 63mm diameter shall be equal to the pipe diameter plus 600 mm according to WAJ specifications.

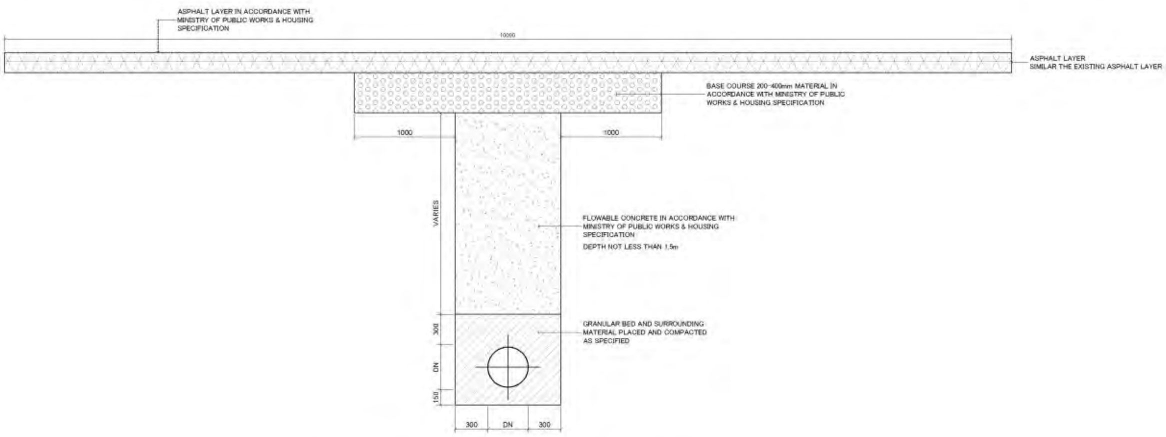
Pipes shall be laid along either the municipality's road or MoPWH's road. They have standard cross-sections of pipe trenches as shown below.

Soil for backfilling shall be selected so that compaction of backfilled soil can be carried out properly. In case water mains are laid in loose soil, the condition of the ground and the magnitude of subsidence of the mains shall be examined; and then the suitable method of laying, pipe material and joints shall be chosen.

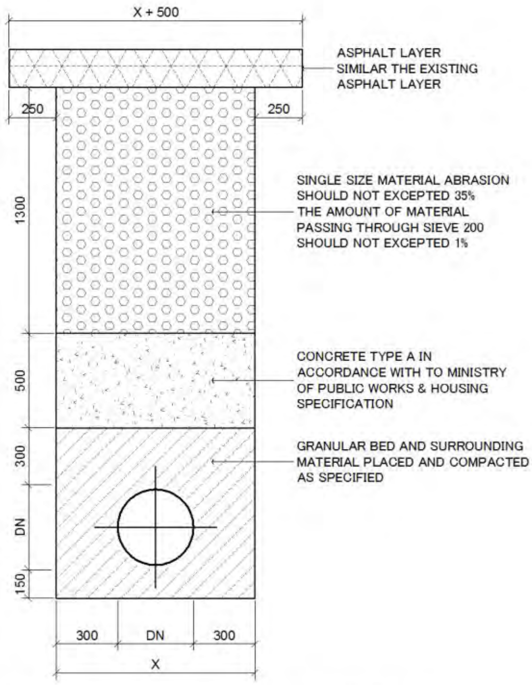
Pipe bedding materials under the pipe barrel shall be granular selected material free of stones with a minimum thickness of 25 percent of the pipe outside diameter or 100 mm whichever is more. Pipe embedment material shall consist of compacted selected sandy soil. The minimum thickness of compacted sandy soil embedment material over top of the pipe shall be 300 mm.

(2) Warning tape

underground warning tape shall be laid in the ground above water mains so that the location of the main can be recognized to avoid damage which may be caused by other construction work (see Figure 4-2 Typical Trench Cross Sections Details within MoPWH Roads)

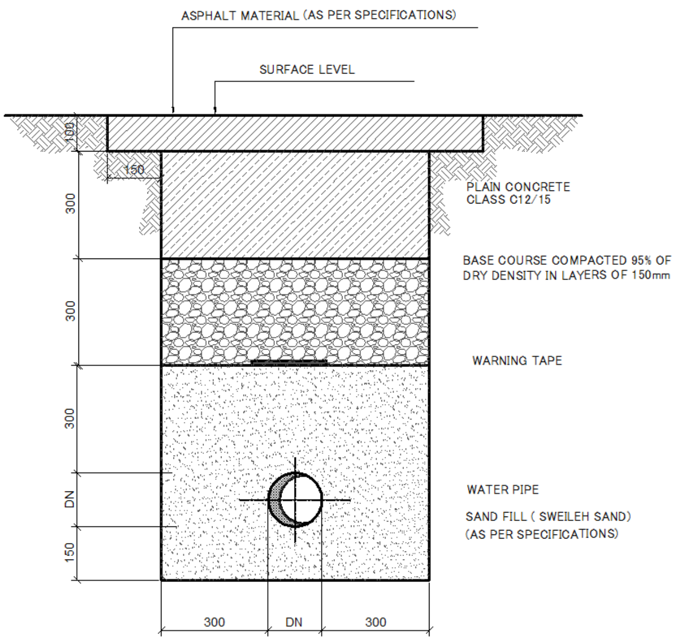


CROSS SECTION OF PIPELINE CROSSING THE ROAD

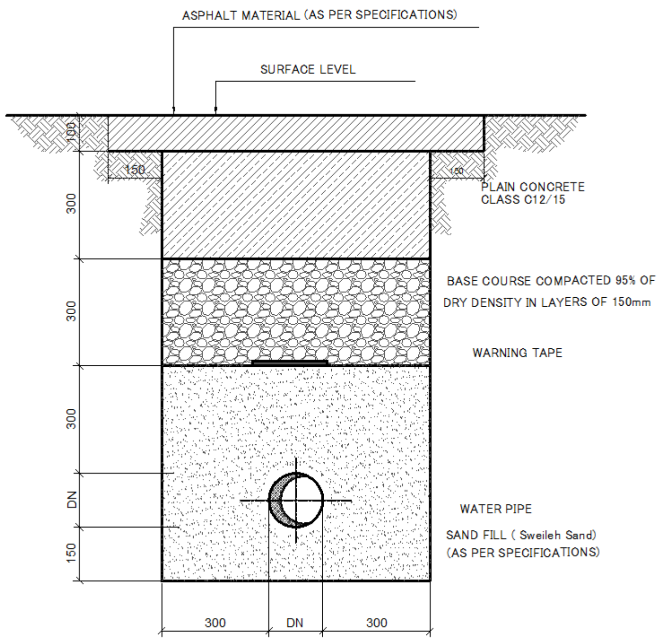


CROSS SECTION OF PIPELINE ALONG THE ROAD

Figure 4-2 Typical Trench Cross Sections Details within MoPWH Roads



ALONG ROADS WITH ASPHALT SURFACE



FOR PIPES CROSSING ROADS WITH
ASPHALT SURFACE AT SKEW OR RIGHT ANGLES

Figure 4-3 Typical Trench Cross Sections Details within Irbid Municipality Road

4.4 Pipeline Alignment

4.4.1 Alignment

Deviation of a pipeline around an obstruction can be achieved by deflection at pipe joints or in combination with bends or connectors. The deflection angle permitted at a flexible joint shall be in accordance with the applicable standards and/or pipe manufacturer's recommendation. For laying of plastic pipes on curves, minimum radii are to be as per pipe manufacturer's recommendations. If deflection of joints does not provide the necessary deviation, bends and other fittings shall be used.

4.4.2 Alignment with Regard to Sewers and Crossing of Sewers

Water lines shall be placed with a minimum of 0.5 m horizontally from any existing or proposed gravity sewer line, storm water line, septic tank or subsoil treatment system. The horizontal distance shall be measured from the outside edge of the water line to the outside edge of the line or structure.

Water lines crossing sewer lines shall be placed on a minimum of 0.5 m above the sewer line. The vertical distance shall be measured from the outside edge of the water line to the outside edge of the sewer line. A full length section of the water line shall be placed at the crossing so as to maximize the distance of the joints from the sewer line. When the distance is less than 0.5 m, the water line shall be encased in concrete for a total length of 3 m centered on the crossing point.

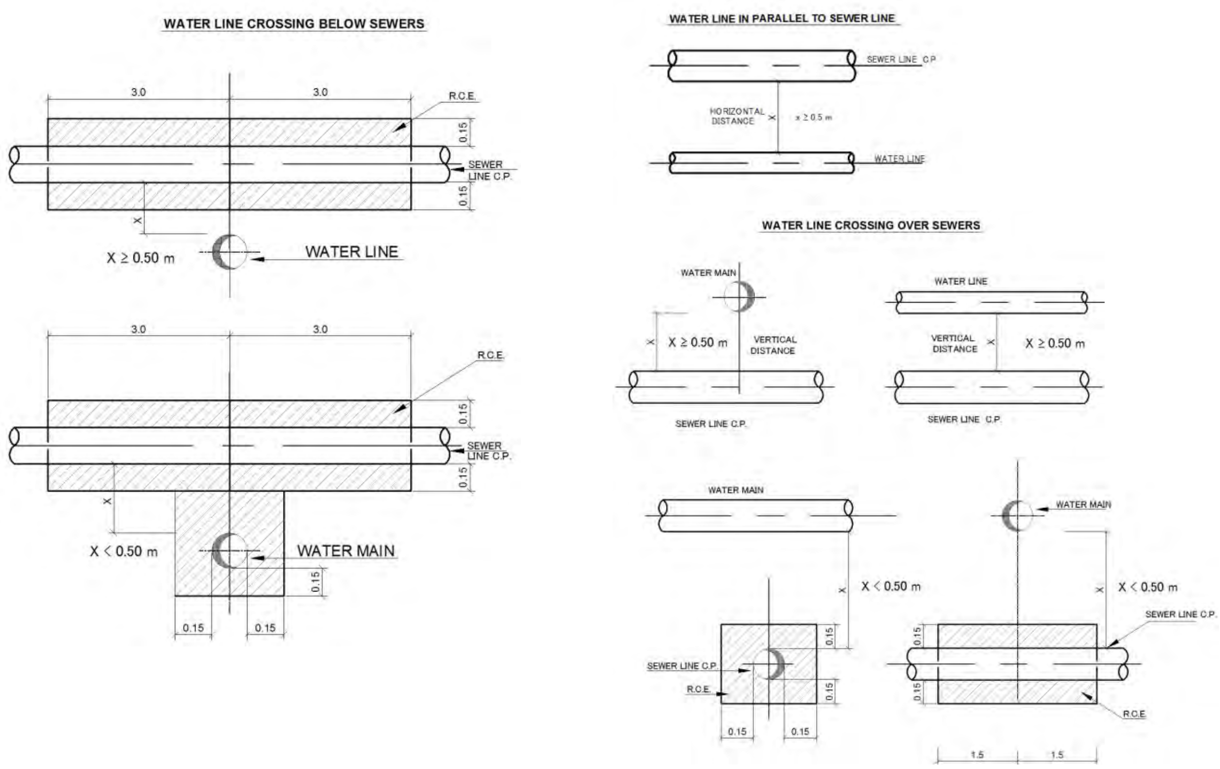


Figure 4-4 Alignment with Regard to Sewers and Crossing of Sewers

4.5 Thrust Protection

The maximum water pressure shall be the total of the maximum static water pressure and the surging water pressure in consideration of safety. The protection of special fittings for the ductile iron pipe and the hard PVC pipe shall be, as a general rule, made by concrete blocks or anti-escapement joints. However, fixtures for the prevention of escape can be used for small size water mains in case sufficient binding force of surrounding soil can be expected.

The requirement for the protection of special fittings can be reduced to or omitted for the welded steel pipe, the stainless steel pipe and the polyethylene pipe with fusion joints. However, protection with concrete blocks shall be made in case expansion joints are installed within the effective distance for the joints to suppress the imbalanced stress.

Thrust Blocks or Restrained Joints are required for all rubber jointed push-fit type pipe operating under pressure at all tees, bends, valves and hydrants to prevent the pipe movement.

Size of the thrust blocks or length of the restrained joints will be calculated based on the pressure in the pipe and soil conditions. The choice between the two types depends on site conditions and will be determined during the detailed design phase.

The size of the adopted thrust blocks for all pipes diameters in this project were taken from YWC based on a test pressure of 16 bars.

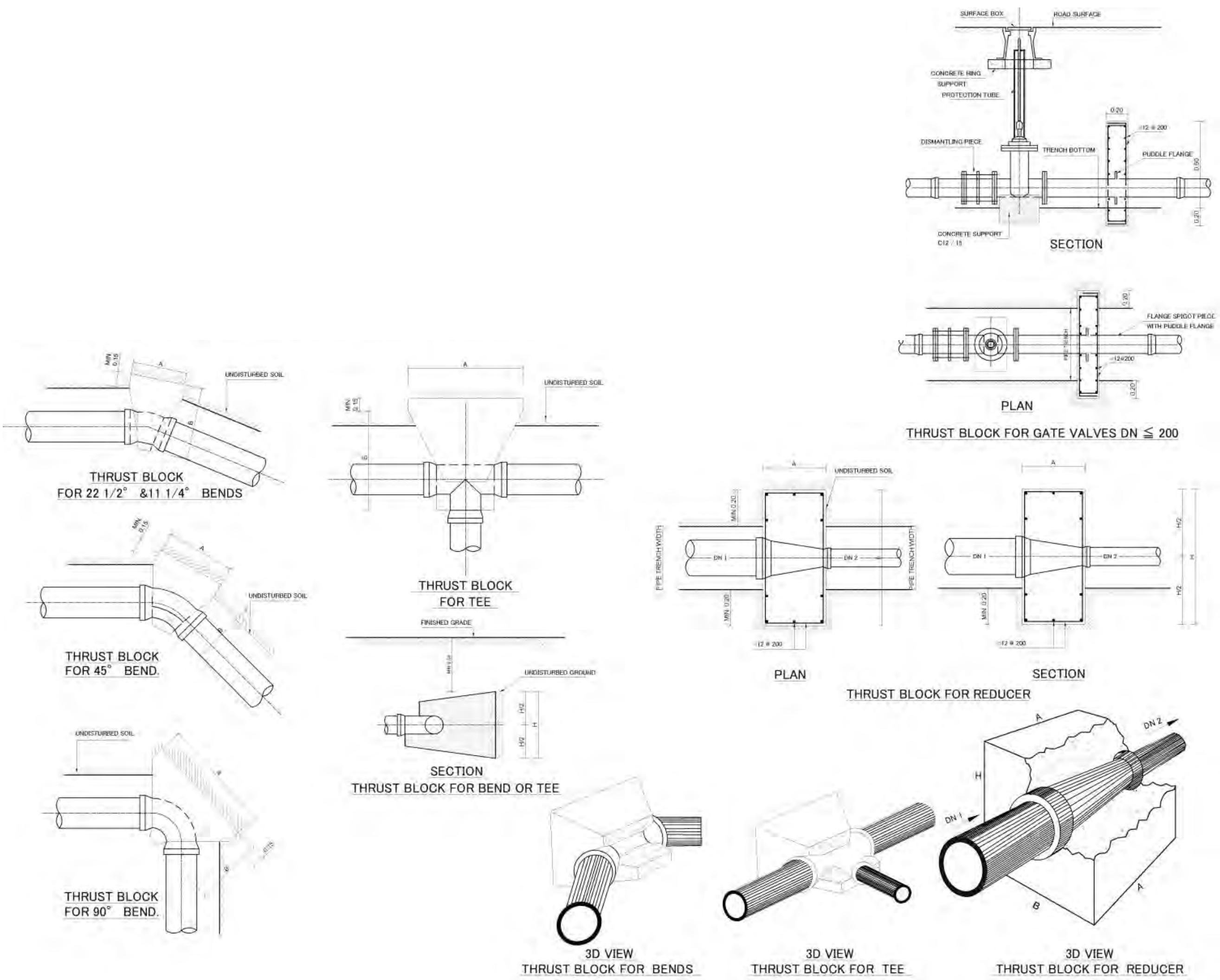


Figure 4-5 Sample Drawing of Thrust Block

4.6 Ancillary Pipe Appurtenances

Ancillary facilities of distribution system include the followings;

- Isolation valves,
- Flow control valves,
- Pressure reducing valves,
- Flow meters,
- Pressure gauges,
- Air valves,
- Drainage facilities,
- Hydrants,

4.6.1 Isolation Valves

The isolation valves are installed on the primary mains at junctions with feeding pipe to DMA. Junctions are shown on Vol.4-Drawings/Typical Details- ST 01 and ST 02.

The diameter of the isolation valves should be equal to the diameter of the main pipeline. It is recommended to use

- Resilient seat gate valves for isolation valves in sizes up to and including 300 mm diameter.
- Resilient seat butterfly valves for isolation valves in sizes 350 mm and greater diameter.

Table 4-3 Specification of Isolation Valves

Diameter	Type	Pressure ratings	Material
300 mm and below	Gate valve	PN16	Ferrum Casting Ductile
350 mm and above	Butterfly valve	PN16	Ferrum Casting Ductile

Valve with diameter of 400 mm and above shall be fitted in with a bypass valve or have the function to fill water in itself and the valve box shall be of a strong structure, and shall not cause any obstruction for the operation and inspection of the valve. Surface boxes are proposed to be used for valves of 250 mm diameter and below while reinforced concrete chambers are proposed for larger diameter or groups of valves.

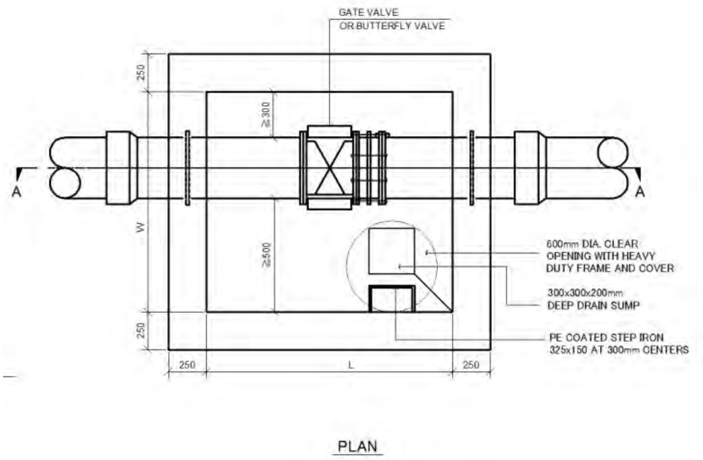


Figure 4-6 Sample Drawing of isolation valve

4.6.2 Flow Control Valves

Electrically-driven flow control valves are installed at the entrance of each DMA and, they can be connected with SCADA system in future. The opening or closing of control valves is usually done automatically by electrical actuators.

Table 4-4 Specification of Flow Control Valve

Location (entry of DMAs)	Diameter(mm)	Type of Valve	Pressure ratings	Material
GR-01	400	Butterfly valve	PN16	Ferrum Casting Ductile
GR-02	300			
GR-03	400			
GR-04	800			
GR-05	600,400,400			
GR-06	400			
GR-07	400			
GR-08	300,300			

Note: GR-09 and GR-10, Bani Kinana District, P-01 and P-02 are out of scope of works.

Surface boxes are proposed to be used for valves of 150 mm diameter and below while reinforced concrete chambers are proposed for 200 mm diameter and above diameter or groups of valves.

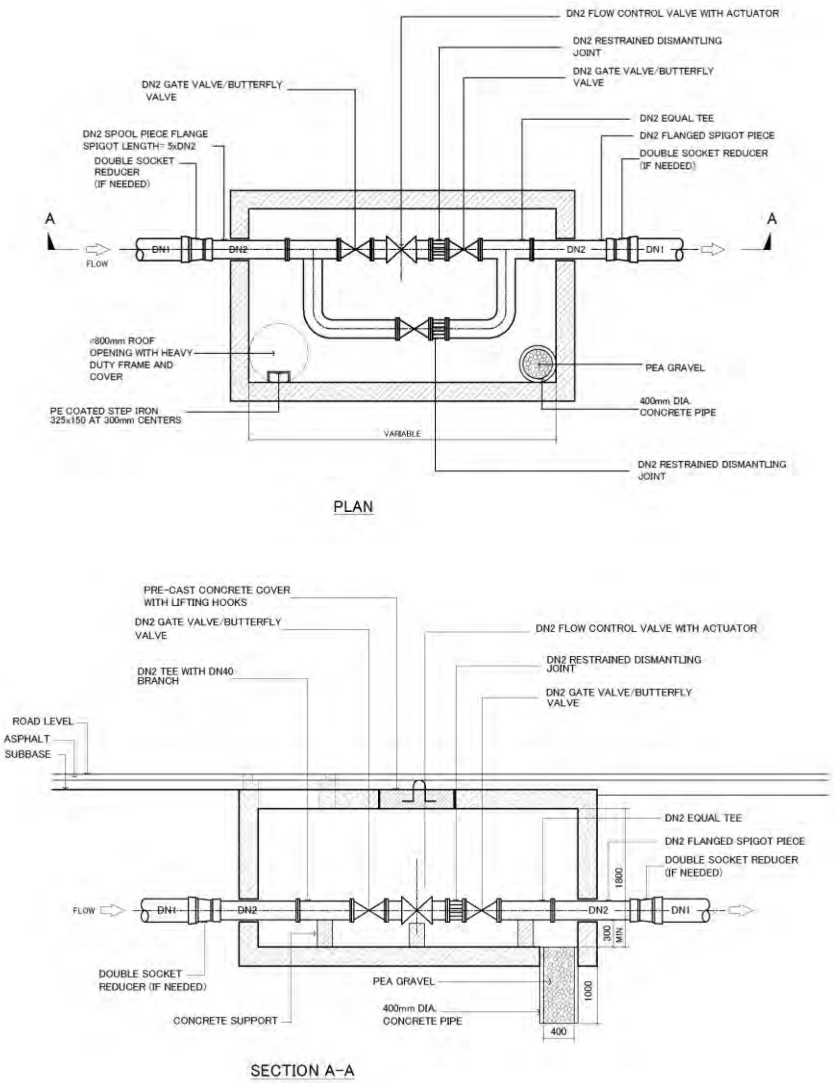


Figure 4-7 Sample Drawing of Flow Control Valve

4.6.3 Pressure Reducing Valve

Pressure reducing valves shall possess functions suitable to the condition for water pressure reduction and it is recommended to install pressure reducing valves with flow modulating pressure controllers at the entry of DMA GR-02, 3 and 7.

Table 4-5 Specification of Pressure Reducing Valve

Location (entry of DMAs)	Diameter(mm)	Type	Pressure rating
GR-02	250	Auto valve	PN16
GR-03	350		
GR-07	350		

Moreover, a bypass pipe of the same diameter as the pressure reducing valve is installed in parallel.

A reinforced concrete chambers are proposed for the pressure reducing valves.

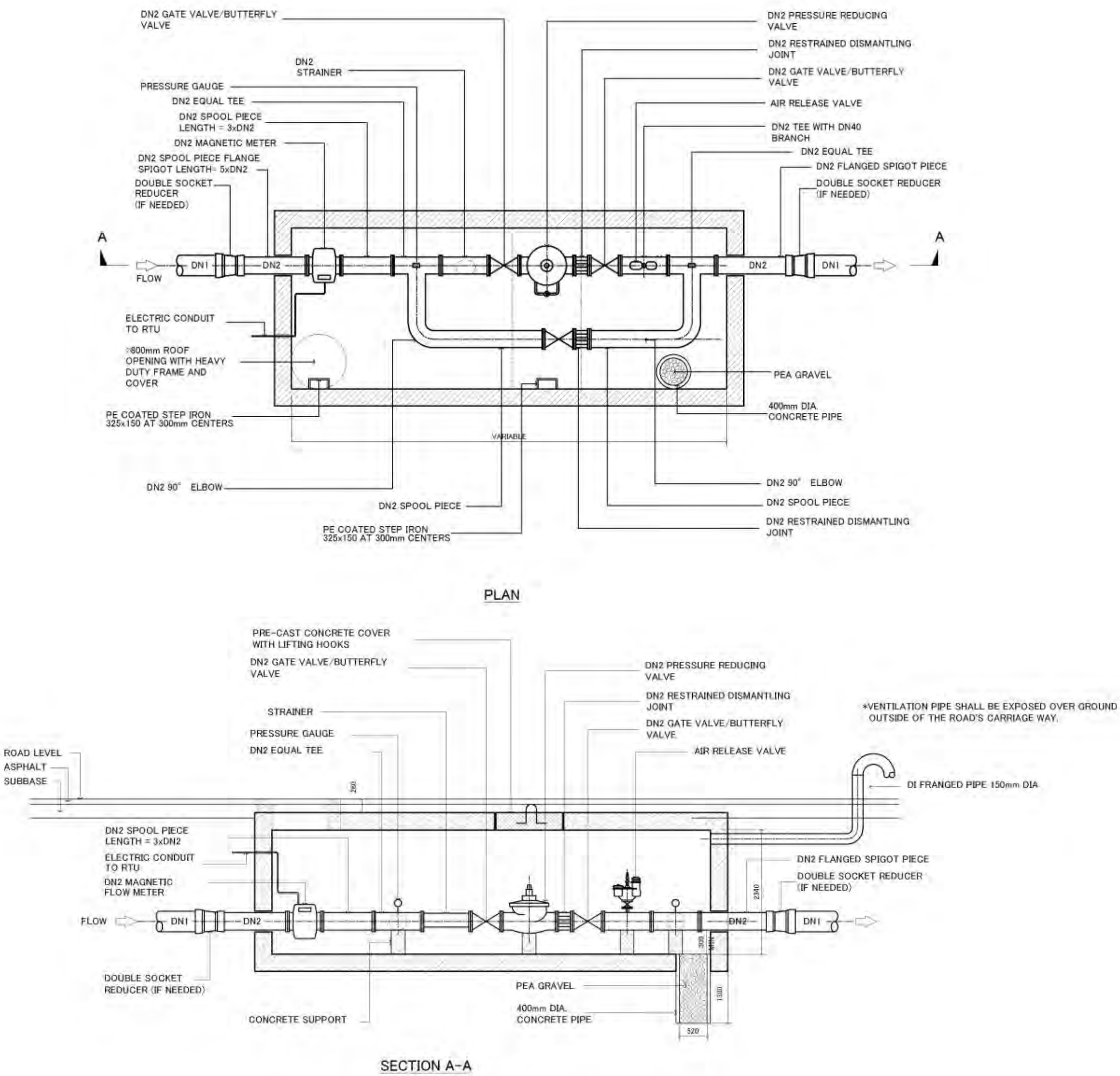


Figure 4-8 Sample Drawing of Pressure Reducing Valve

4.6.4 Flow Meter and Water Pressure Gauge

Electromagnetic flow meters (See Figure 4 9) shall be installed at the outlet of Zebdat reservoir for gravity zone (this work for pump zone is out of scope) and at the entry points of each DMA in the distribution system. It is desirable to set up a facility to control the data and information on the flow and the water pressure.

Power source of flow meter and water pressure gauge shall be prepared from nearby commercial electrical cables.

Table 4-6 Specification of Flow Meter and Water Pressure Gauge

	Locations		Type	Diameter of flow meter (mm)	Flow Range(m^3/h) Max	Pressure rating
Flow Meter	The outlet of Zebdat Reservoir for Gravity System		Electromagnetic Flow Meter	1200	15,300	PN16
	the entry points of each DMA in the distribution system	GR-01		400	600	
		GR-02		300	600	
		GR-03		400	1,400	
		GR-04		800	3,700	
		GR-05		600, 400,400	1,400	
		GR-06		400	200	
		GR-07		400	1,300	
		GR-08		300,300	800	
Water Pressure Gauge	the entry points of each DMA in the distribution system		Electronic Pressure Gauge			

Note: GR-09 and GR-10, Bani Kinana District, P-01 and P-02 are out of scope of works.

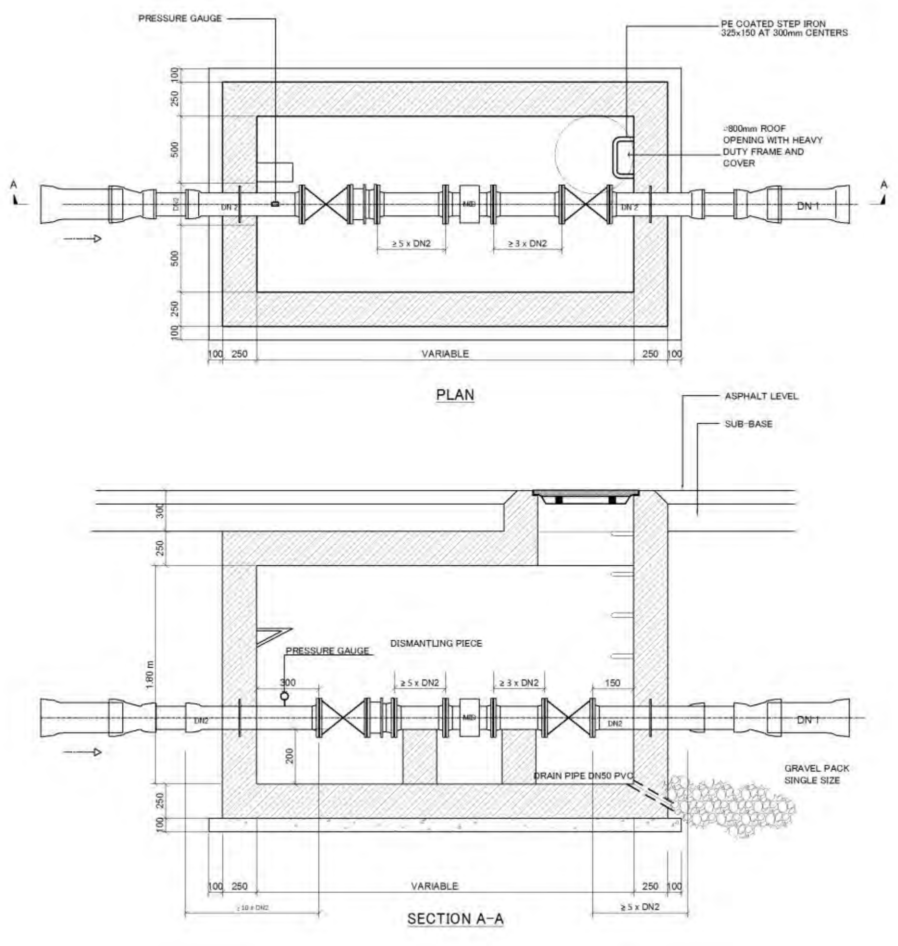


Figure 4-9 Sample Drawing of Flow Meter,

Note: This is a case that flow meter is installed individually before the flow control valve or the pressure reducing valve individually in case there is no space and etc.

4.6.5 Air Valve

Air release and vacuum valves are installed at high points on distribution pipes, 150 mm diameter and above, to vent out air from pipes during operation and allow in air into the pipeline during filling, and in case of constant rising mains having moderate slope, at a maximum distance of 750 m. Air valves are installed on a branch tee with an isolation valve for maintenance purposes. It is recommended that air valves be sized as shown in Table below.

Table 4-7 Specification of Air Valves

Pipe Diameter (mm)	Air Valve Diameter (mm)	Type	Pressure Rating	Material
150	65	Single	PN 16	Ferrum Casting Ductile
200 - 300	80	Double	PN 16	Ferrum Casting Ductile
400 - 600	100			
800	150			
> 900	200			

Air valves are installed in reinforced concrete chambers and the air valve box shall have a strong structure and such that the maintenance of the valve shall become easy.

Sample detail drawing of Air valves is shown in Figure 4-10 below.

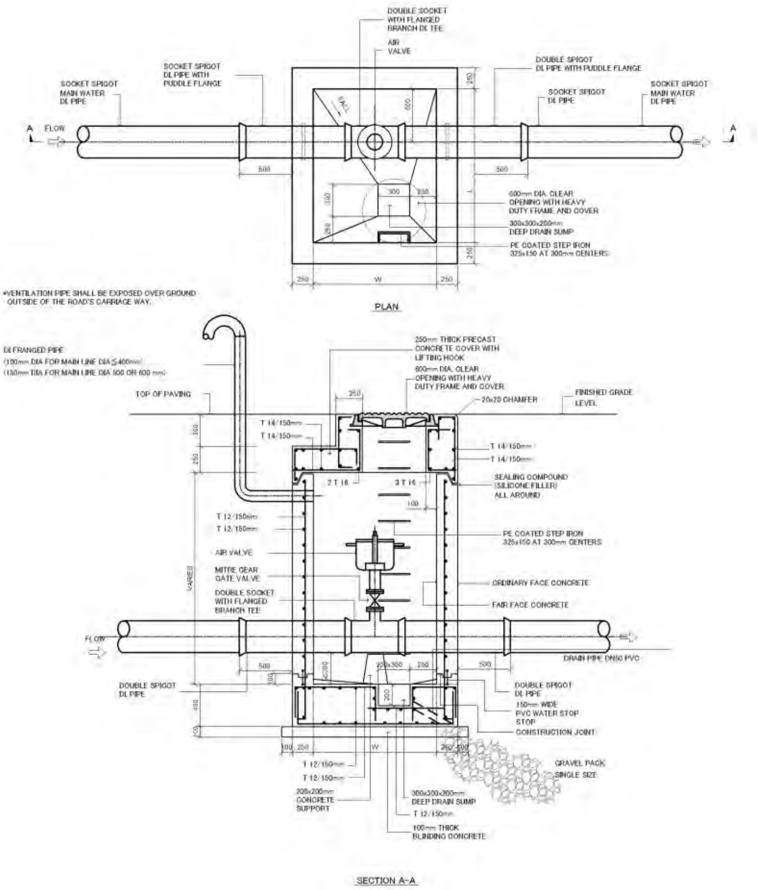


Figure 4-10 Sample drawing of Air valve

4.6.6 Drainage Facilities

Drainage facilities are provided in the neighborhood of a river, irrigation canal, a sewer etc. at a concave point of the distribution pipe.

(1) Wash-out Valves

Washout valves are normal isolation valves that are installed in conjunction with a level invert tee at the low points of main pipelines. They are used to clean the water main and also empty the main during maintenance (leak repairs). For large diameter water mains, 500 mm diameter and greater, washout installations should comprise of one isolation valve on the main line and two isolation valves on the two washout branch pipes. This installation will allow discharge of the washout water from either side of the pipe. For smaller diameter pipelines a single washout outlet shall be provided. It is recommended that the branch pipes shall be 20 to 30% of the diameter of the main pipe.

Table 4-8 Specification of Wash-Out Valves

Pipe Diameter	Type	Valve Diameter	Pressure ratings	Material
Less than 500 mm diameter	Gate valve one isolation valve on the main line	20 to 30% of the diameter of the main pipe	PN16	Ferrum Casting Ductile
500 mm diameter and greater	Gate valve two isolation valves on the two washout branch pipes			

(2) Wash-out Valve Box

Washout valves installed on 300mm diameter pipes (and greater) shall be installed in washout chambers, while those on mains smaller than 300mm diameters shall be buried directly (See Figure 4-11 and Figure 4-12).

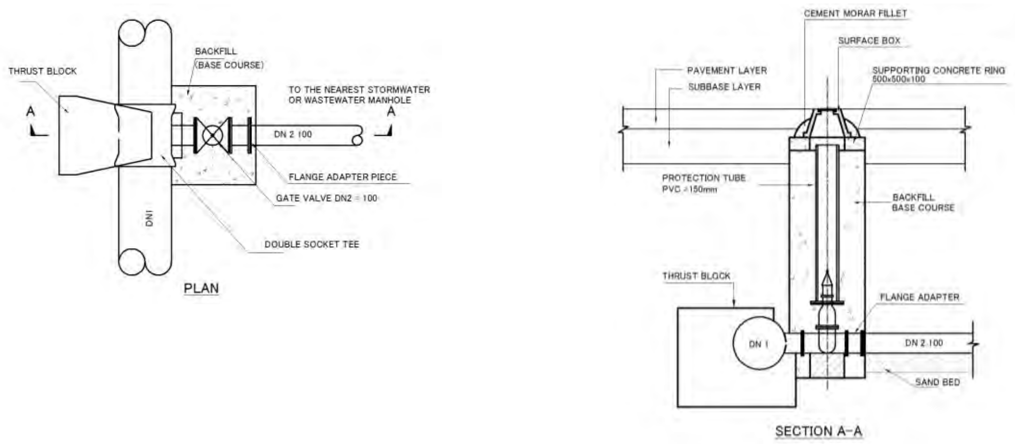


Figure 4-11 Sample of Wash-Out Valve -type1

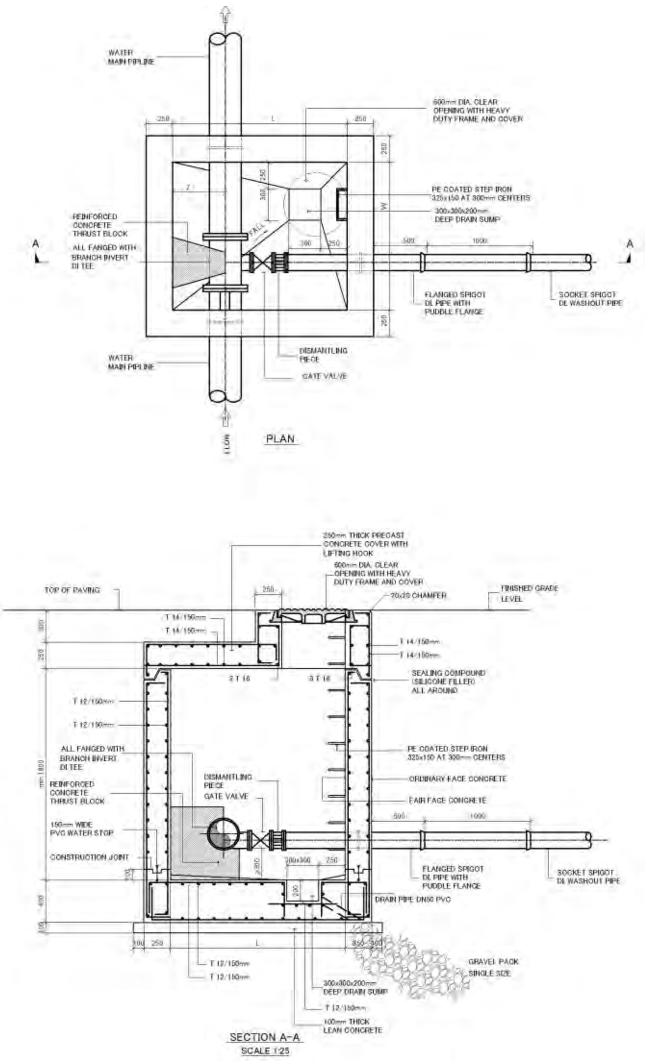


Figure 4-12 Sample of Wash-Out Valve type -2

4.6.7 Fire Hydrant

Location of fire hydrants were identified by civil defense based on their needs.Hydrants shall not be connected to pipelines less than 100 mm in diameter. Double-jet hydrant shall be mounted on a distribution main with a diameters equal and more than 150 mm (See Figure 4-13)

Hydrants may also be used for operational purposes, such as filling, draining, venting, and flushing out of the water main.

Table 4-9 Specification of fire hydrant

Pipe Diameter	Type	Pressure Rating	Material
less than 100 mm	No installation	-	-
Equal and greater than 150 mm	Double-jet hydrant	PN16	DI

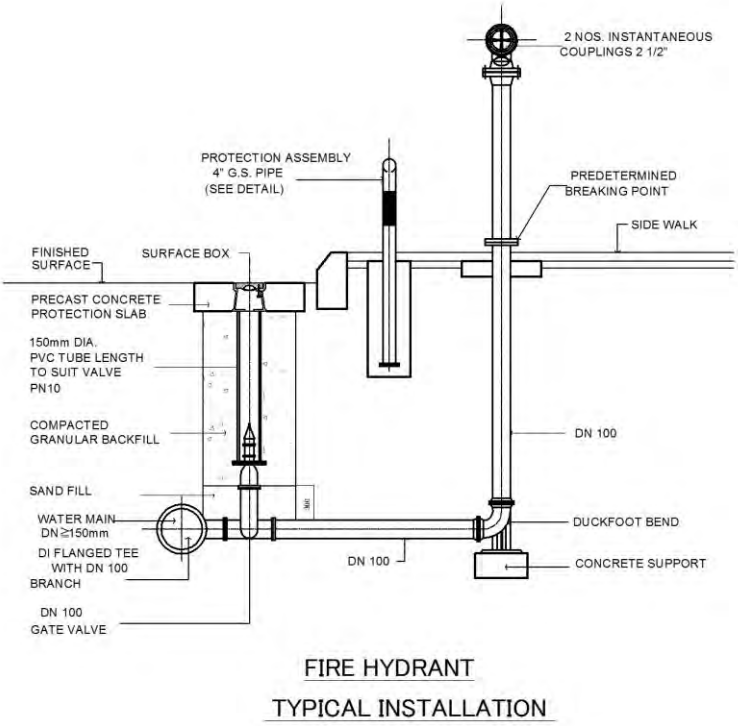


Figure 4-13 Sample drawing of fire Hydrant

5 COMPONENTS OF WORKS AND COST ESTIMATE

5.1 Proposed Works

The major components of project works include Pipeline works, Road crossing works by Trenchless technologies, pipeline ancillary works and structures, culverts and cross-drainage works, road restoration works, shifting public utilities such as electricity and telephone poles, water and sewer lines etc.

Unit rates presented in this report are composite rates that include for all the construction elements required for providing the completed works. For instance, the unit rates for pipeline works include for the earthwork excavation, supply of pipes and fittings, laying, bedding, backfilling, road reinstatement, chambers, valves, anchor/thrust blocks, dealing with existing services and disposal of materials, etc.

The major components of project include:
1. Construction of ductile iron and PE water pipelines including all required pipe appurtenances and ancillary as follows (see Table 5-1 and Figure 5-1 and Figure 5-2.).
2. Proper isolation for the proposed DMAs at the boundary.
3. Reconnect the existing water network with the new strengthening pipelines.
4. Connection to Zabdat existing reservoir.

Table 5-1 summarizes on the new strengthening pipelines by diameters and lengths for the 3 packages that was agreed in the technical committee meeting.

- Package 1 covers the western primary mains and the associated DMAs in the gravity zone.
- Package 2 covers the eastern and central primary mains and the associated DMAs in the gravity zone.
- Package 3 covers the primary mains and the associated DMAs, in the pump zone.

Table 5-1 Proposed New Strengthening Pipelines by Diameters and Lengths for 3 Packages

Package No.	DMA	125 mm	150 mm	200 mm	250 mm	300 mm	400 mm	600 mm	800 mm	1000 mm	1200 mm	Total (m)
PKG-1	GR-01,0 2, 03,0 6, 07 and 08	800	4,350	4,750	500	2,550	1,400	5,300	6,450		740	26,840
PKG-2	GR-04 and 05	100	7,310	2,150		4,580	1,530	5,320	2,500	2,450		25,940
PKG-3	P-01 and 02	4,400	7,850	2,320		570	6,200					21,340
	Total (m)	5,300	19,510	9,220	500	7,700	9,130	10,620	8,950	2,450	740	74,120

Note) The length of pipes for supplying water to GR-09, GR-10 are included in PKG-02 and PKG-01, respectively.

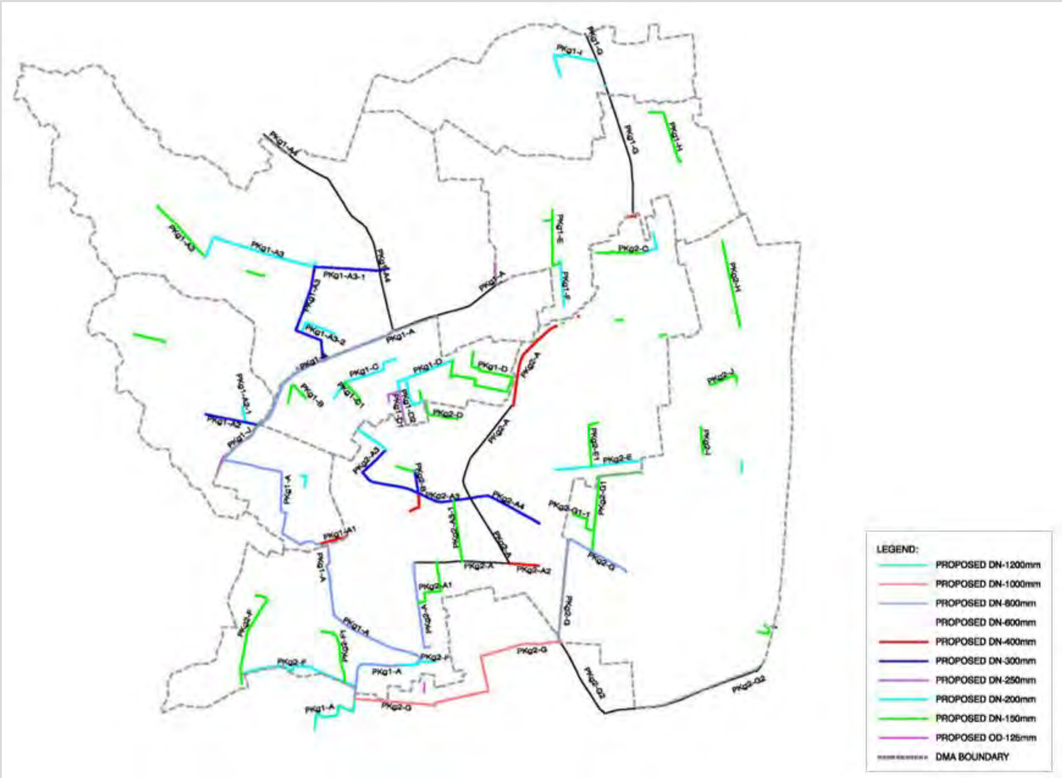


Figure 5-1 Proposed Water Pipelines within the Gravity System (Package 1&2)

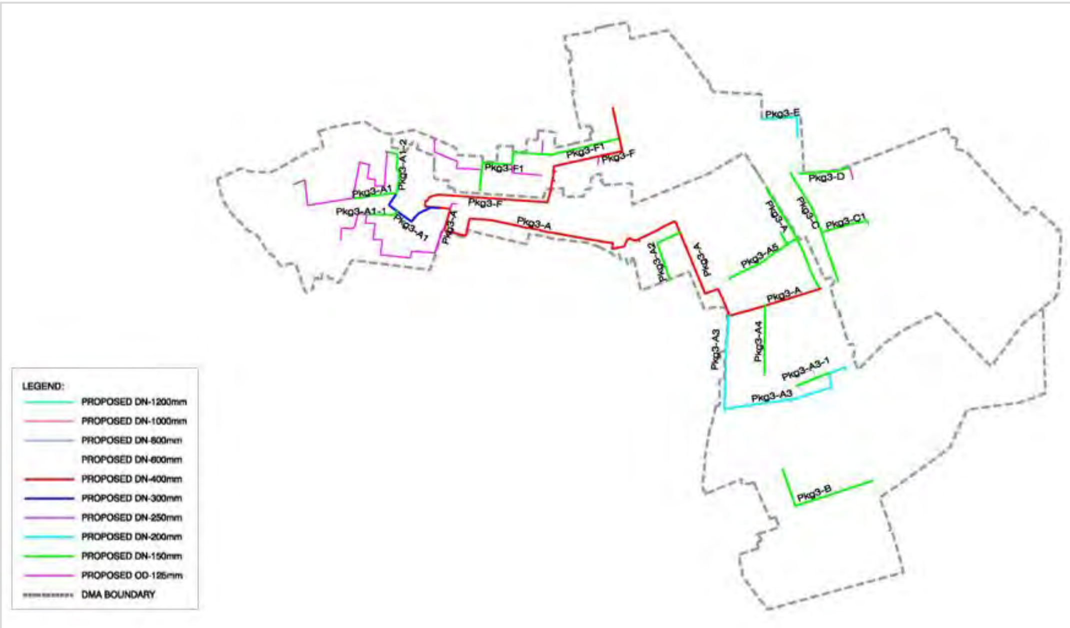


Figure 5-2 Proposed Water Pipelines within the Pumping System (Package 3)

5.2 Cost Estimate

The estimate project cost is as follow.

Table 5-2 Cost Estimate for Package 1, 2 and Package 3

Package	Total Cost (million JD)
Package 1	6.92
Package 2	6.02
Package 3	3.90
Total	16.84

6 APPENDIX

6.1 Methodology of Population allocation in the Localities and Water demand estimation in Irbid and Suburbs in the Master Plan

The basic design is planned based on JICA water MP, 2015 and the followings are excerpts on the water demand and water allocation of the Zebdat system

6.1.1 Design Population

Population of the Study Area (Irbid city and its suburbs) is estimated using the governorates' growth rates (2% per year) of DOS (Department of Statistics). Irbid city occupies large area with marked difference in the development levels within the city. The Study area includes Irbid city, Irbid suburbs within urban growth area (including localities of Aidoon, Aliah, Bait Ras, etc.), and Irbid suburbs outside of urban growth area (including localities of Al'al, As'ara, etc.). The population has also been estimated for localities of Bani Kinana Area in order to consider their demand in future, although they are out of the Study Area. The location of Irbid city and localities is shown in Figure 6-1.

(1) Population Density in Irbid City and Suburbs

As a first step, population of neighborhoods within Irbid city is estimated up to 2035 using the growth rate of Irbid Governorate, which is same for both Irbid city and its suburban localities. Locations of neighborhood within Irbid city is shown in Figure 6-2. The population densities in 2012 and 2035 based on DOS estimates are calculated. It is apparent that population densities in 10 neighborhoods located in the central part of Irbid city range from 105 to 391 persons per hectare, and are exceeding healthy environment levels considering the available infrastructures. Such abnormally high density of population in the central part of Irbid will not take place causing increased load on limited infrastructures and consequently leading to unhealthy living environments.

(2) Population Reallocation within Irbid City

Therefore, it is considered that the central area of Irbid would not be able to accept additional population and hence increased population will diffuse to suburban parts of Irbid guided by factors such as availability of infrastructure, lower prices of land, etc. The "Irbid 2030: Greater Irbid Area plan" (see Figure 6-3) prepared by the Ministry of Municipal Affairs (hereinafter called as city master plan) includes planned population density in Irbid city and its suburbs which has been set considering sound living environment and development of city and its suburbs. The city master plan is used as a guide for future population distribution in the Irbid city and its suburbs. Ten (10) neighborhoods located in the central part of Irbid are defined as "residential stable" areas in the city master plan. Population growth in these 10 neighborhoods is not encouraged and, consequently, future population in these neighborhoods is considered same as the existing population.

Population in the remaining 35 neighborhoods, defined as "residential intensification" area, is estimated using the population density in the city master plan. As a result, the adopted population in Irbid city in 2035 is 389,310, which is lower than DOS population (486,360). This is shown in Table 6-1 and Figure 6-2

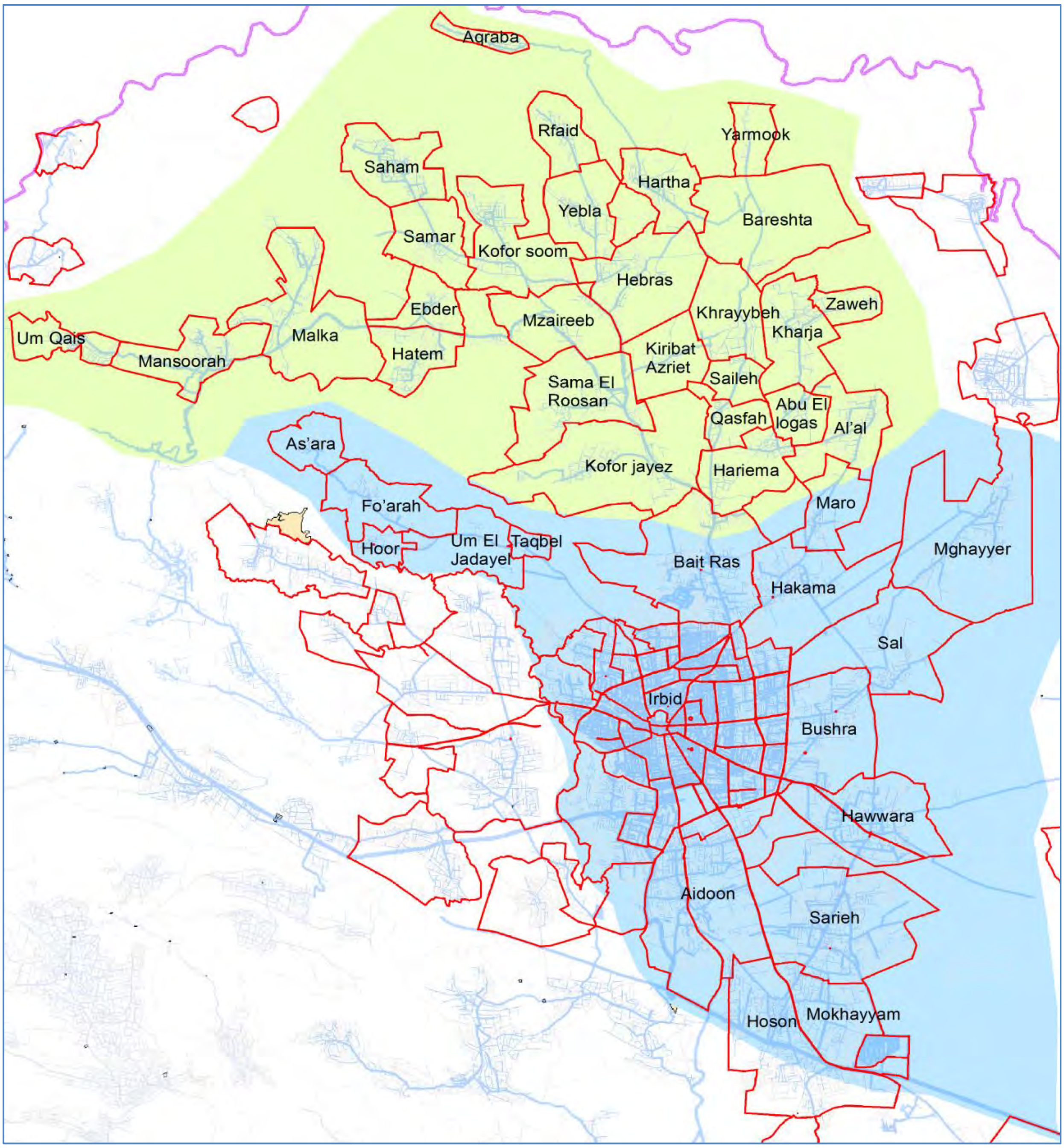
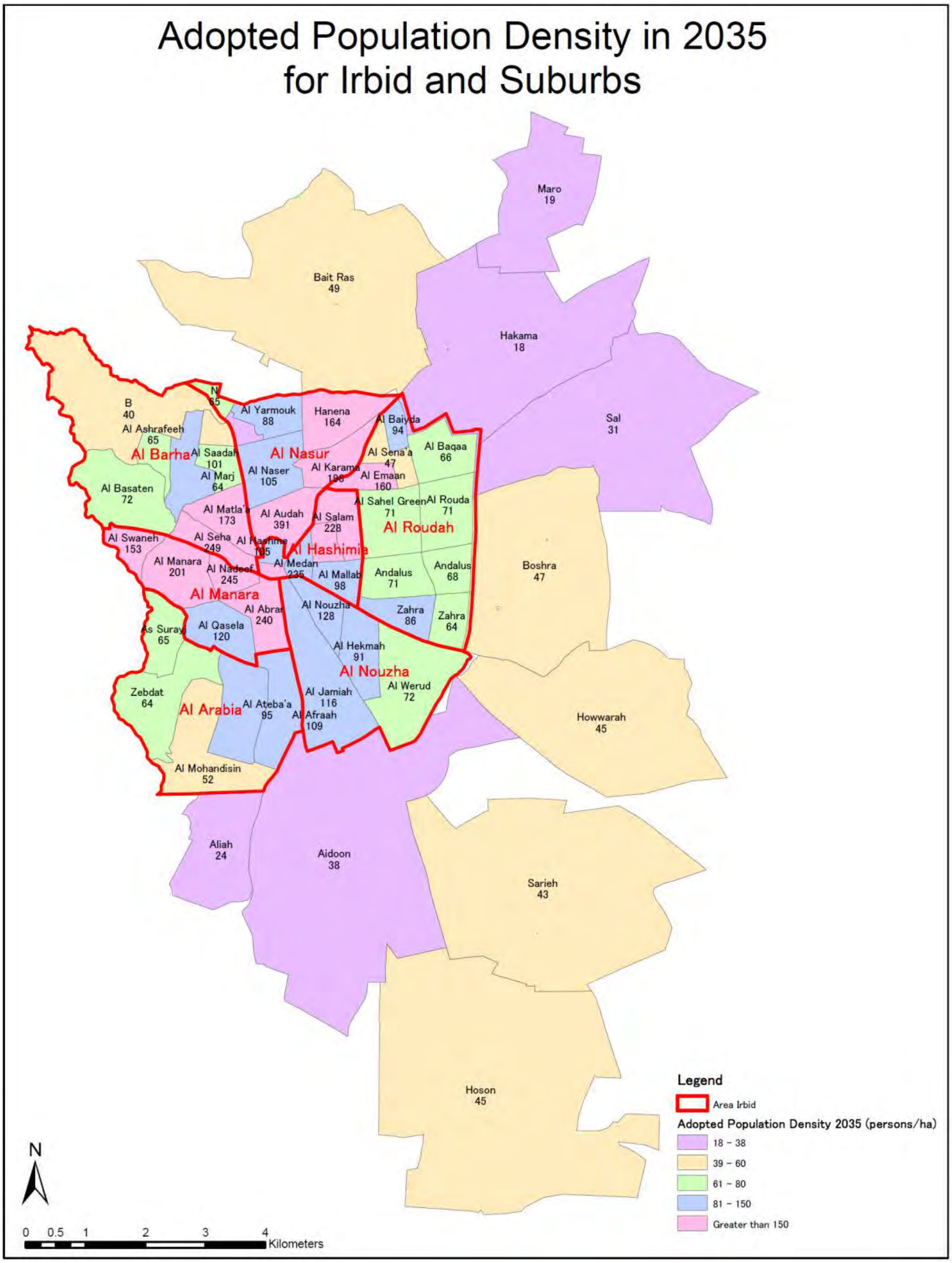


Figure 6-1 Irbid City and Localities in Its Suburbs (Study Area) and Bani Kinana District

Note：blue shade - Irbid City and its Suburbs Area, yellow-green shade- Bani Kinana District



Source: JICA Study Team

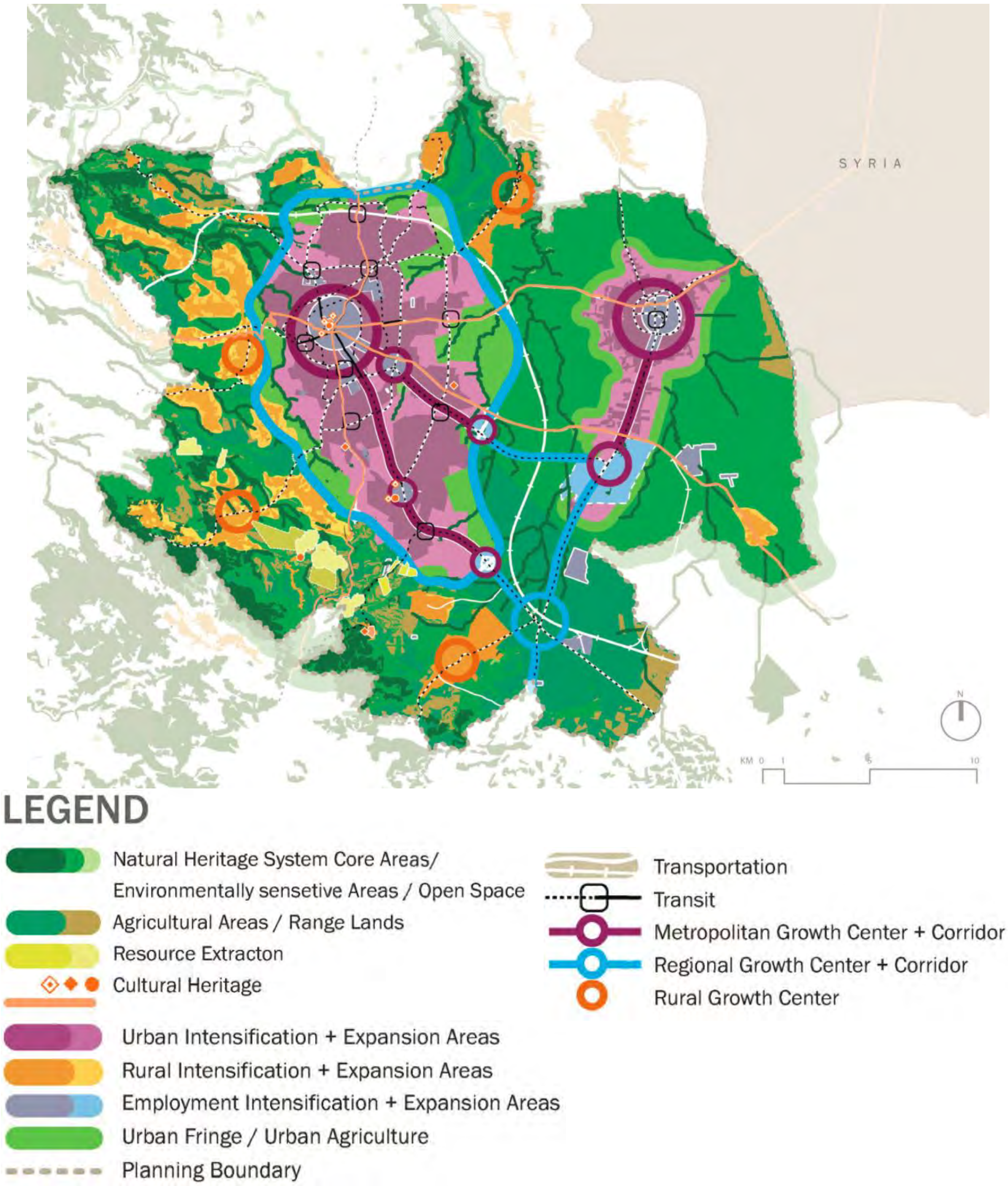
Note: Number in cells (locality and neighborhood) is population density in persons per hectare.

Figure 6-2 Population Density in Irbid City and Suburbs in 2035

(3) Population Reallocation to Irbid Suburbs

The remaining population of the DOS estimates of Irbid city for 2035 is re-allocated to peri-urban or suburban localities within Greater Irbid "urban growth area" (see Figure 6-3) such as localities of Hawwara, Sarieh, Aidoon, Hoson, Bait Ras, etc. The infrastructure in these suburban localities are developing at fast pace and existing population density is still very low, thus capable of accommodating increased population in sustainable manner. The total of the DOS population in 2035 of these suburban localities (229,273) and the remaining population from Irbid city (97,050) is redistributed to these suburban localities in proportion of their calculated population using city master plan density. Consequently, the population in these suburban localities is a) corresponding DOS population (using population growth rate of 2.0 %) plus b) re-allocated population from Irbid city. Hence, the total population of Irbid and its suburbs calculated in this Study remains same as in case of DOS estimates and the population distribution gets fairer with due consideration to avoiding population overload in central Irbid.

The calculated population and population density of each neighborhood in Irbid city, its suburban localities and a Bani Kinana and outside of urban growth area is shown in Table 6-1.



Source: Irbid 2030: Greater Irbid Area Plan of MOMA

Figure 6-3 Residential Intensification and Expansion Areas in Irbid, Ramtha and Its Suburbs

6.1.2 Water Demand Estimation

Estimated demand in all localities and neighborhoods in the Study Area (Irbid and its suburbs) including Bani Kinana is shown in Table 6-1 based on estimated population and the per capita consumption.

Table 6-1 Population and Average Water Demand in Irbid City, Suburbs and Bani Kinana District

Area/Locality	Neighborhood	2012 Population (person)	2035 Population (person)	2012 (MCM/y)	2035 (MCM/y)
Irbid City					
Al Arabia, Irbid City	Al Afraah	11,917	11,917	0.63	0.60
	Al Ateba'a	5,730	11,868	0.30	0.59
	Al Mohandisin	6,300	9,717	0.33	0.49
	As Surayj	217	4,992	0.01	0.25
	Zebdat	3,585	10,561	0.19	0.53
	Sub-total	**27,752**	**49,055**	1.47	**2.46**
Al Barha, Irbid City	Al Ashrafeeh	2,196	2,308	0.12	0.12
	Al Basaten	4,498	11,768	0.24	0.59
	Al Herafeyeen West	158	997	0.01	0.05
	Al Marj	1,610	2,687	0.09	0.13
	Al Matla'a	12,990	12,990	0.69	0.65
	Al Saadah	7,497	8,446	0.40	0.42
	Al Seha	13,147	13,147	0.70	0.66
	No Name	--	12,453	-	0.62
	Sub-total	**42,096**	**64,796**	2.23	**3.24**
Al Hashme, Irbid City	Al Hashme	2,732	2,732	0.14	0.14
	Al Jamee	1,433	1,730	0.08	0.09
	Al Mallab	3,895	4,512	0.21	0.23
	Al Medan	6,822	6,920	0.36	0.35
	Al Salam	13,977	14,272	0.74	0.71
	Al Tall	1,044	1,908	0.06	0.10
	Sub-total	**29,903**	**32,074**	1.58	**1.62**
Al Manara, Irbid City	Al Abrar	19,224	19,224	1.02	0.96
	Al Manara	21,481	21,481	1.14	1.07
	Al Nadeef	8,904	8,904	0.47	0.45

Area/Locality	Neighborhood	2012 Population (person)	2035 Population (person)	2012 (MCM/y)	2035 (MCM/y)
	Al Qasela	10,212	10,397	0.54	0.52
	Al Swaneh	5,191	7,201	0.27	0.36
	Sub-total	**65,012**	**67,207**	3.44	**3.36**
Al Nasur, Irbid City	Al Audah	32,581	32,581	1.72	1.63
	Hanena	15,617	17,089	0.83	0.85
	Al Herafeyeen East	486	648	0.03	0.03
	Al Karama	13,256	13,814	0.70	0.69
	Al Naser	10,871	10,871	0.58	0.54
	Al Yarmouk	4,242	5,511	0.22	0.28
	No Name	-	1,206	-	0.06
	Sub-total	**77,053**	**81,720**	4.08	**4.08**
Al Nouzha, Irbid City	Al Jamiah	12,025	13,591	0.64	0.68
	Al Nouzha	6,896	6,896	0.36	0.34
	Al Hekmah	6,784	7,562	0.36	0.38
	Al Werud	6,525	14,292	0.35	0.71
	Sub-total	**32,230**	**42,341**	1.71	**2.11**
Al Roudah, Irbid City	Andalus	-	4,015	-	0.20
	Andalus	5,532	5,643	0.29	0.28
	Al Baqaa	2,413	6,340	0.13	0.32
	Al Baiyda	2,844	2,943	0.15	0.15
	Al Emaan	4,982	6,215	0.26	0.31
	Al Rouda	5,009	7,684	0.27	0.38
	Al Sahel Green	6,028	8,011	0.32	0.40
	Al Sena'a	796	2,174	0.04	0.11
	Zahra	-	3,707	-	0.19
	Zahra	5,374	5,385	0.28	0.27
	Sub-total	**32,978**	**52,117**	**1.75**	**2.61**
Sub-total		**307,024**	**389,310**	**16.25**	**19.47**
Irbid Suburbs within Urban Growth Area					
Greater Irbid Municipality	Aidoon	22,767	48,819	0.92	1.85
	Aliah	532	5,197	0.02	0.20
	Bait Ras	22,078	50,036	0.89	1.90

Area/Locality	Neighborhood	2012 Population (person)	2035 Population (person)	2012 (MCM/y)	2035 (MCM/y)
	Bushra	13,936	32,175	0.56	1.22
	Hakama	9,093	14,404	0.37	0.55
	Hawwara	15,622	31,955	0.63	1.21
	Hoson	25,093	65,633	1.02	2.49
	Maro	3,578	6,046	0.14	0.23
	Sal	8,505	24,699	0.34	0.94
	Sarieh	23,532	47,359	0.95	1.80
Sub-total		**144,736**	**326,323**	**5.86**	**12.39**
Total		**451,760**	**715,633**	**22.11**	**31.86**
Irbid Suburbs outside of Urban Growth Area					
Greater Irbid Municipality	Locality				
	Al'al	5,343	8,464	0.22	0.32
	As'ara	1,188	1,882	0.05	0.07
	Fo'arah	4,062	6,435	0.16	0.24
	Kofor Jayez	3,818	6,048	0.15	0.23
	Mghayyer	10,625	16,831	0.43	0.64
	Mokhayyam Azmi Mufte (Hoson camp)	20,353	32,241	0.82	1.22
	Teqbel	612	969	0.02	0.04
	Um El-Jadayel	1,083	1,716	0.04	0.07
	Sub-total	**47,084**	**74,586**	**1.89**	**2.83**
Bani Kinana District					
Bani Kinana District	Hariema	4,522	7,163	0.18	0.27
	Kharja	5,283	8,369	0.21	0.32
	Abu El-Loqas	1,549	2,454	0.06	0.09
	Aqraba	3,070	4,863	0.12	0.19
	Bareshta	214	339	0.01	0.01
	Ebder	2,838	4,496	0.11	0.17
	Hartha	4,916	7,787	0.20	0.30
	Hatem	6,629	10,501	0.27	0.40
	Hebras	4,374	6,929	0.18	0.26
	Hoor	2,432	3,852	0.10	0.15
	Kherbit Azrit	930	1,473	0.04	0.06

Area/Locality	Neighborhood	2012 Population (person)	2035 Population (person)	2012 (MCM/y)	2035 (MCM/y)
	Khrayybeh	1,747	2,767	0.07	0.11
	Kofor Soom	8,377	13,270	0.34	0.50
	Malka	7,784	12,330	0.32	0.47
	Mansoorah	4,404	6,976	0.18	0.26
	Mzaireeb	1,466	2,322	0.06	0.09
	Rfaid	2,532	4,011	0.10	0.15
	Saham	7,226	11,447	0.29	0.43
	Saidoor	1,810	2,867	0.07	0.11
	Samar	3,852	6,102	0.16	0.23
	Soom	6,311	9,997	0.24	0.38
	Qasfah	882	1,397	0.04	0.05
	Saileh	871	1,380	0.04	0.05
	Sama El-Roosan	3,487	5,524	0.14	0.21
	Um Qais	4,811	7,621	0.19	0.29
	Yarmook	1,034	1,638	0.04	0.06
	Yebla	4,564	7,230	0.18	0.28
	Zaweh	1,047	1,659	0.04	0.06
	Sub-Total	**98,962**	**156,764**	**3.98**	**5.95**
Total Outside of Urban Growth Area and Bani Kinana District		146,046	231,350	5.87	8.78
Grand Total		597,806	946,983	27.98	40.64
Summary					
Study Area					
Irbid City		**307,024**	**389,310**	**16.25**	**19.47**
Within Urban growth area		**144,736**	**326,323**	**5.86**	**12.39**
Outside of Urban Growth Area		**47,084**	**74,586**	1.89	2.83
Sub-total		**498,844**	**790,219**	**24.00**	**34.69**
Outside of Study Area					
Bani Kinana		**98,962**	**156,764**	**3.98**	**5.95**
Total		**597,806**	**946,983**	**27.98**	**40.64**

Note:

1. Irbid city and its suburbs within and outside of Urban Growth Area in Greater Irbid Municipality are the Study Area. Bani Kinana District is outside of Study Area but connected with distribution network of the Study Area.
2. Andalus and Zahra are each divided into 2 with the same names based on the map received from the Irbid Municipality office.

3. One area each in Al Barha and Al Naser are with "No Name". These areas are located in the north-western corner of Irbid city and in the map provided by both the Irbid Municipality and DOS, there does not exist any name for this area. Also, DOS did not have population estimate for this area.
4. Source: Prepared by JICA Study Team

6.1.3 Water Sources and Supplemented Water

Networks in the Zebdat system is connected with networks in Bani Kinana district. Therefore, in order to plan for the distribution facilities in Irbid and its suburbs, Bani Kinana district shall be included and supplemented water amount from external sources are calculated by locality using local (internal) water sources and estimated water demand in each locality.

The estimated average water demand for Case A and Case B (in 2035) and fixed amount of internal sources same as current amount in each locality are shown in Table 6-2 and required supplemented water supplied to Irbid city and its suburbs and localities in Bani Kinana district are calculated in the same table. The estimated average water demand and external source allocation to localities are shown in Figure 6-4 (Case A for reduced water demand) and Figure 6-5 (Case B for water demand in 2035). In addition, water transfer amount to each locality in Case A and Case B are presented in Figure 6-6 and Figure 6-7, respectively.

Table 6-2 Average Water Demand, Internal Water Sources and Required Supplemented Water from External Sources for Case A and B in Irbid Area

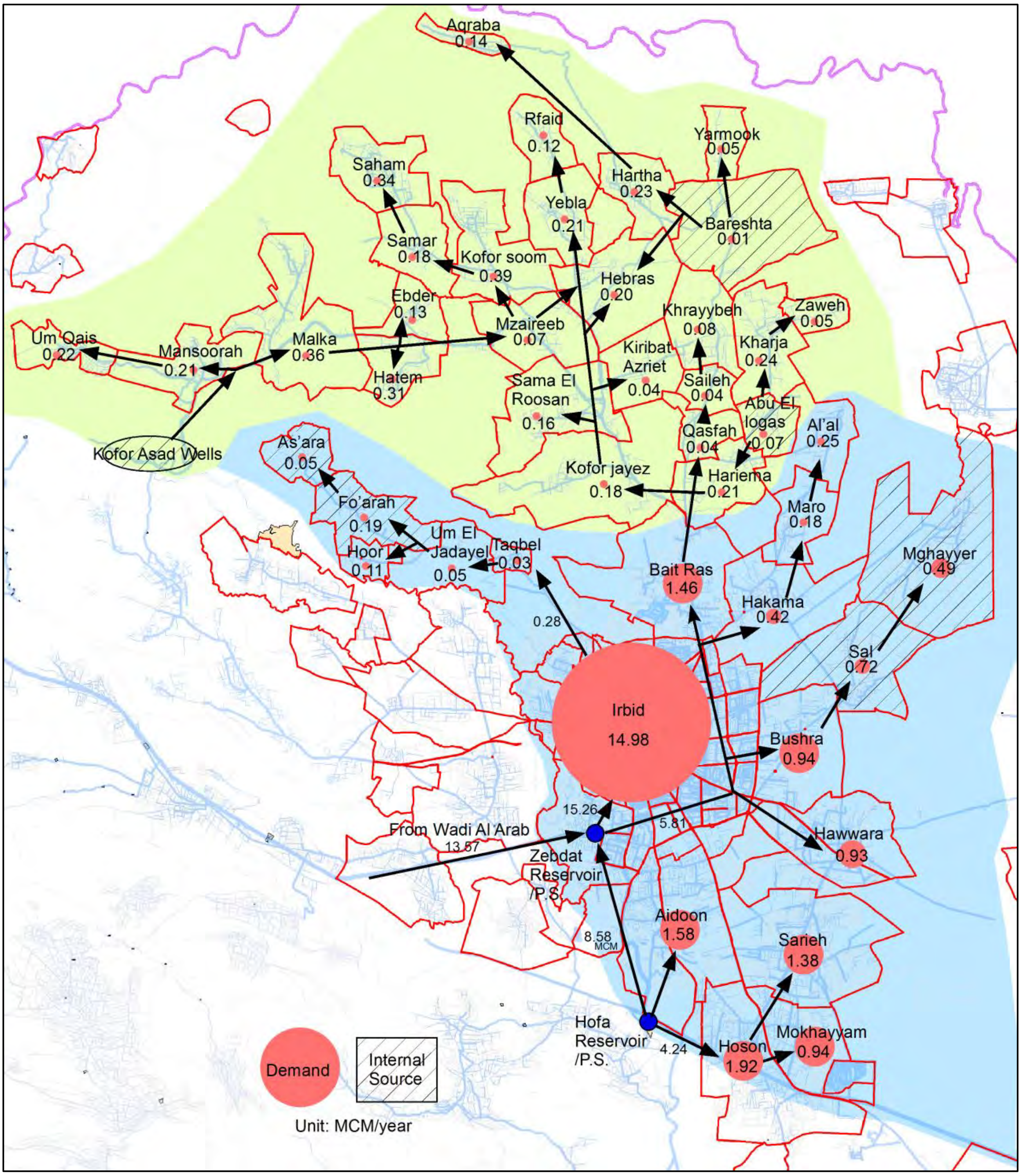
Unit: (MCM/year)

Area	Locality	Both Cases	Allocation in 91 MCM/y (Case A)		Allocation in 121 MCM/y (Case B)	
		Internal source	Water Allocation (reduced average water demand)	Supplemented from External Sources	Average Water Demand in 2035	Supplemented from External Sources
Irbid City	**Irbid City**	**0.00**	**14.98**	**14.98**	**19.47**	**19.47**
Irbid Suburbs within Urban Growth Area	Aidoon	0.00	1.43	1.43	1.85	1.85
	Aliah	0.00	0.15	0.15	0.20	0.20
	Bait Ras	0.00	1.46	1.46	1.90	1.90
	Bushra	0.00	0.94	0.94	1.22	1.22
	Hakama	0.00	0.42	0.42	0.55	0.55
	Hawwara	0.00	0.93	0.93	1.21	1.21
	Hoson	0.00	1.92	1.92	2.49	2.49
	Maro	0.00	0.18	0.18	0.23	0.23
	Sal	0.30	0.72	0.42	0.94	0.64
	Sarieh	0.00	1.38	1.38	1.80	1.80
	Suburb-total	**0.30**	**9.53**	**9.23**	**12.39**	**12.09**
Irbid Suburbs Outside of Urban	Al'al	0.00	0.25	0.25	0.32	0.32
	As'ara	0.02	0.05	0.03	0.07	0.05

Area	Locality	Both Cases	Allocation in 91 MCM/y (Case A)		Allocation in 121 MCM/y (Case B)	
		Internal source	Water Allocation (reduced average water demand)	Supplemented from External Sources	Average Water Demand in 2035	Supplemented from External Sources
Growth Area	Fo'arah	0.13	0.19	0.06	0.24	0.11
	Kofor Jayez	0.00	0.18	0.18	0.23	0.23
	Mghayyer	0.02	0.49	0.47	0.64	0.62
	Mokhayyam Azmi Mufte	0.00	0.94	0.94	1.22	1.22
	Um El-Jadayel	0.00	0.05	0.05	0.07	0.07
	Teqbel	0.00	0.03	0.03	0.04	0.04
	Sub-Total	**0.17**	**2.18**	**2.01**	**2.83**	**2.66**
Bani Kinana District	Hariema	0.00	0.21	0.21	0.27	0.27
	Kharja	0.00	0.24	0.24	0.32	0.32
	Abu El-Loqas	0.72	0.07	-0.65	0.09	-0.63
	Aqraba	0.00	0.14	0.14	0.19	0.19
	Bareshta	0.61	0.01	-0.60	0.01	-0.60
	Ebder	0.00	0.13	0.13	0.17	0.17
	Hartha	0.00	0.23	0.23	0.30	0.30
	Hatem	0.00	0.31	0.31	0.40	0.40
	Hebras	0.00	0.20	0.20	0.26	0.26
	Hoor	0.00	0.11	0.11	0.15	0.15
	Kherbit Azrit	0.00	0.04	0.04	0.06	0.06
	Khrayybeh	0.00	0.08	0.08	0.11	0.11
	Kofor Soom	0.00	0.39	0.39	0.50	0.50
	Malka	0.00	0.36	0.36	0.47	0.47
	Mansoorah	0.00	0.21	0.21	0.26	0.26
	Mzaireeb	0.00	0.07	0.07	0.09	0.09
	Rfaid	0.00	0.12	0.12	0.15	0.15
	Saham	0.00	0.34	0.34	0.43	0.43
	Saidoor	2.21	0.08	-2.13	0.11	-2.10
	Samar	0.00	0.18	0.18	0.23	0.23
	Soom	0.00	0.29	0.29	0.38	0.38
	Qasfah	0.00	0.04	0.04	0.05	0.05

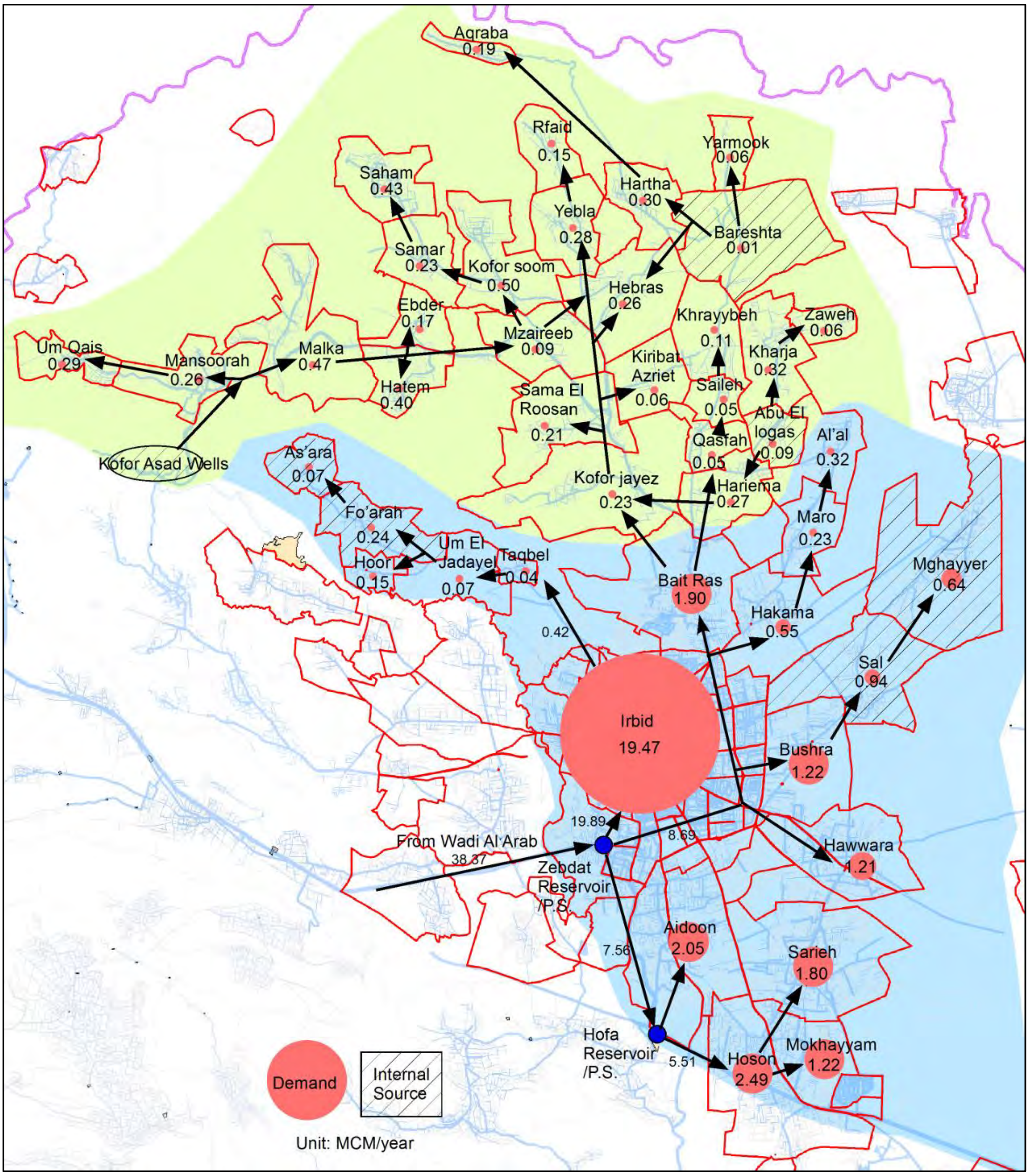
Area	Locality	Both Cases	Allocation in 91 MCM/y (Case A)		Allocation in 121 MCM/y (Case B)	
		Internal source	Water Allocation (reduced average water demand)	Supplemented from External Sources	Average Water Demand in 2035	Supplemented from External Sources
	Saileh	0.00	0.04	0.04	0.05	0.05
	Sama El-Roosan	0.00	0.16	0.16	0.21	0.21
	Um Qais	0.00	0.22	0.22	0.29	0.29
	Yarmook	0.00	0.05	0.05	0.06	0.06
	Yebla	0.00	0.21	0.21	0.28	0.28
	Zaweh	0.00	0.05	0.05	0.06	0.06
	Sub-Total	**3.54**	**4.58**	**1.04**	**95**	**2.41**
Total		**4.01**	**31.27**	**27.26**	**40.64**	**36.63**

Source: JICA Study Team



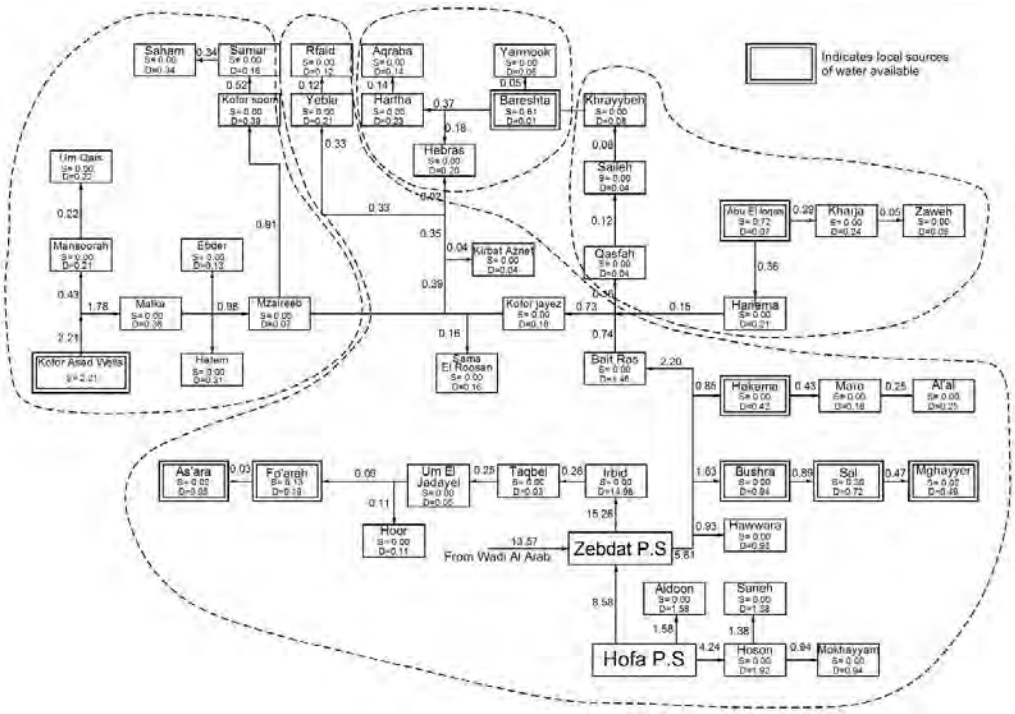
Source: JICA Study Team

Figure 6-4 Water Demand in Localities in Case A (91 MCM/y)



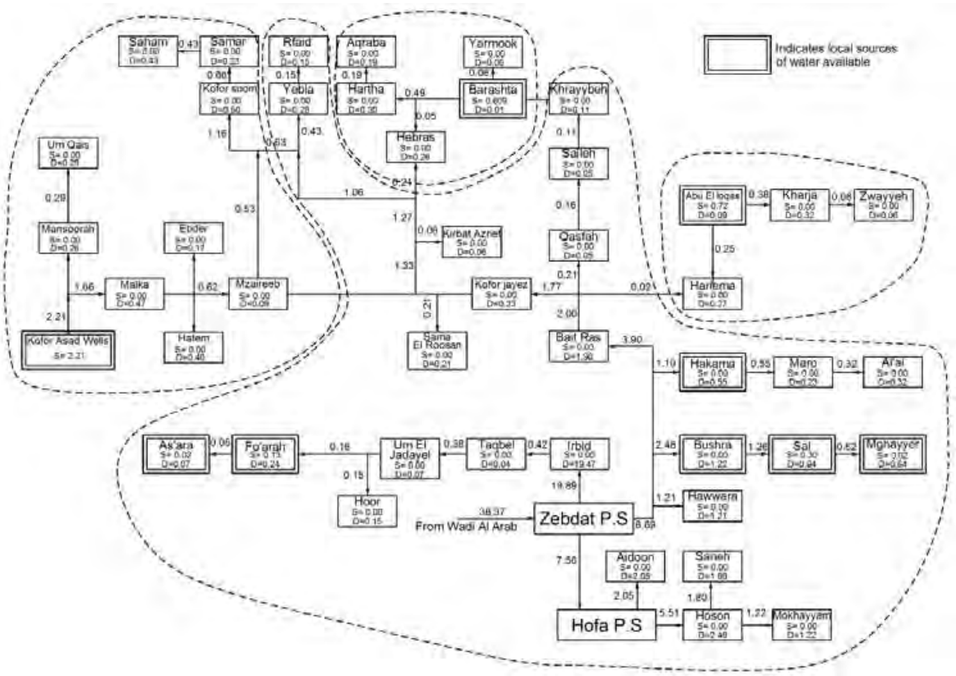
Source: JICA Study Team

Figure 6-5 Water Demand in Localities in 2035 (121 MCM/y)



Note: S=Local Supply, D=Demand in Locality, Unit=MCM/year

Figure 6-6 Internal Source (Local Supply) and Water Transfer in Reduced Demand (91 MCM/y) in Irbid



Note: S=Local Supply, D=Demand in Locality, Unit=MCM/year

Figure 6-7 Internal Source (Local Supply) and Water Transfer in 2035for Full Demand (121 MCM/y)

6.2 Water Allocation in the Northern Governorates

Figure 6-8 Water Allocation and Water Supply in Irbid Case 91mcm

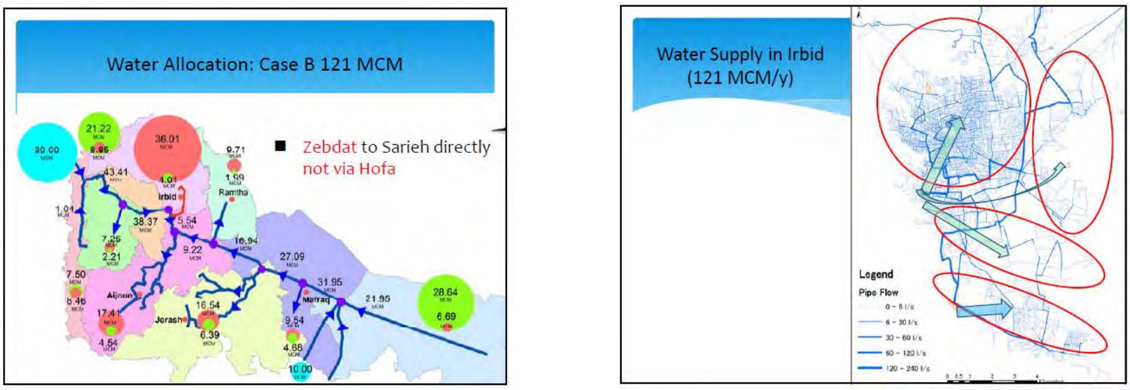


Figure 6-9 Water Allocation and Water Supply in Irbid Case 121 MCM

Source: MP

6.3 Pipeline Material Selection

6.3.1 Description

In order to select the most appropriate material for the pipeline, the following materials have been evaluated:

- Ductile Iron
- Mild Steel
- Galvanized Iron
- Un-plasticized Polyvinyl Chloride (uPVC)
- Polyethylene

The following paragraphs provide a summary of the review of pipeline materials carried out during this study, and give the background to the selection of the recommended materials for each of the pipeline systems.

(1) Ductile Iron

Ductile Iron (DI) pipes are extensively used for water transmission and distribution networks, and there is a long history of their service and performance. Standard pipes of Class K9 have safe working pressures of 40 bars for 300-mm pipes rising to 60 bars for 65-mm pipes. The pipes may be jointed by conventional spigot and socket joints, restrained spigot and sockets joints, or flanged joints. Standard pipes can be available in various lengths i.e. 3.0, 6.0 or 12.0 metres in length, which makes the handling fairly simple. Jointing and pipe laying can be accomplished by relatively unskilled labour. The ductile iron pipes are rigid and thus the quality of the pipeline bedding can be lower than that required for other materials.

The standard joints allow joint deflections of 5 degrees for pipes of 65 to 300 mm and of 4 degrees for pipes of 350 mm and greater (refer to manufacturer recommendations) . With standard joints, the joint rotation can accommodate local settlements, but the standard joint offers no restraint to pipe movement resulting from static or dynamic thrusts, therefore, anchor blocks are needed to restrain the pipes at bends and tees.

For protection against corrosion, the pipes are cement mortar lined internally, and bitumen and metallic zinc coated externally. Standard modern day practice is to wrap the pipes in loose polyethylene sheathing to provide additional protection in aggressive soils. Care must be taken during handling and pipe laying activities in order not to damage the internal and external protection systems.

(2) Mild Steel

Mild Steel (MS) is an established pipeline material that has been used extensively in the water, gas, oil and process industries. There is a wide range of diameters, pressure classes and specifications.

Mild Steel pipes are available in long lengths and usually have welded joints, which results in a reduction of the number of pipe restraints required, as thrust can be transmitted along the welded pipeline. High quality site welding requires a high level of control, skilled welders and welding equipment.

Mild Steel pipes are susceptible to corrosion both internally and externally. Although there is a considerable service history of protecting welded steel pipelines by cathodic protection methods, these measures require regular monitoring and maintenance.

The pipes may be bitumen coated externally, cement mortar lined or epoxy coated. External coatings are usually reinforced bitumen sheathing or polyethylene wrapping. Internal bitumen linings are no longer approved for drinking water mains in some countries, and either cement mortar or epoxy linings tend to be used in recent designs.

As with most welded joints, damage to coatings at joints is a concern. For smaller diameter pipes, it is difficult to enter the pipe after welding in order to make good the internal lining.

(3) Galvanized Iron

Galvanized Iron (GI) pipes are generally manufactured in diameters ranging from 13 mm to 150 mm. These pipes have been widely used in the water distribution systems, especially in house connection lines and in plumbing systems.

The pipes are screw jointed, simple to install and do not require highly skilled fitters. The standard length of the pipes is 6 m and on-site cutting and forming screw joints are simple using portable equipment.

Galvanized iron pipes are susceptible to corrosion in aggressive soil conditions if the galvanizing layer is damaged or is not up to the standard. Because of the general concern with regard to the durability of the these pipes for use in water distribution systems, newly developed materials such as uPVC and PE have started to replace these pipes in new water distribution systems. Moreover, experience with GI pipelines in Sana'a proved that under the prevailing soil conditions, the durability of these pipes does not recommend them for further consideration.

(4) Un-plasticized Polyvinyl Chloride

Un-plasticized Polyvinyl Chloride (uPVC) pipes are available in a range of diameters and can be manufactured to withstand pressures up to 16 bars. The pipes are lightweight and are easily handled and laid in trenches.

The uPVC pipes used in water distribution networks are usually spigot and socket pipes, jointed by sealing gaskets. The joints are not self -anchored and thrust blocks are required at bends and tees.

The pipes are corrosion resistant and have acceptable resistance to normal trench bedding stresses. However, in certain circumstances where the pipes are expected to stand empty without internal pressure for long periods of time, their structural capabilities to withstand soil and traffic load conditions could become susceptible.

Care must be taken with handling of uPVC pipes because they are subject to ultra-violet degradation on prolonged exposure to direct sunlight. In the example of the application in certain location, all pipelines will be buried and extended exposure to heat and direct sunlight is not expected to be a concern.

(5) Polyethylene Pipes

Polyethylene (PE) pipes are available in a range of diameters and, within reason, can be designed for specific pressure ratings. Installation costs are usually lower than that of other materials because of the long lengths with welded joints. The frictional resistance is usually low contributing to better hydraulic conditions.

The small diameter PE pipes are very flexible and are delivered in coils of lengths up to 100 meters, which allows for out of trench jointing and faster pipe laying. The pipes are corrosion resistant and have long durability qualities. However, the pipes require quite stringent bedding conditions, there is some evidence of susceptibility to cyclic pressure variation and the pipes are particularly susceptible to negative pressures during surge conditions or when the pipes are expected to stand empty without internal pressure for long periods of time.

(6) **Comparison of Pipe Materials**

Having listed the benefits and limitations to candidate pipeline materials above, they are now assessed against a range of issues that are relevant to the performance of the water network. A Multi Criteria Assessment (MCA) comparison is used which comprises the following stages:

- Identification of criteria for material assessment;

- Weighting of assessment criteria to reflect their importance to overall outcome
- Comparative scoring of different materials against each criteria

The end result of the MCA comparison is recommended pipe materials for the water network.

6.3.2 Criteria for Assessment

Criteria for assessment in the MCA process are intended to reflect the most important issues that govern the suitability of a particular pipe material for the water network.

The following criteria have been identified (in no particular order):

6.3.3 Procurement

(1) Locality of pipe manufacturer and supplier

A local supplier of pipes may be beneficial to the Client in terms of delivery timelines and future supply of parts.

Use of local facilities also benefits the local market and helps grow local knowledge and expertise.

(2) Local Manufacturer

The availability of local manufacturing facilities has the potential to reduce transport costs and time, ensure local support in the event of technical queries or favourable support if an urgent need for material arises. However, it is important to ensure all certification and accreditation is applicable to the local facility and not a parent or JV partner’s facility.

(3) Lead Time

The time it takes to receive pipes on site from the date of placing an order varies for different pipe materials. Plastic pipes tend to have shorter lead times than metal pipes as the most plastic pipes are locally manufactured.

6.3.4 Installation and Handling

(1) Pipe storage

Plastics (such as Polyethylene and PVC) may be subjected to UV degradation if stored in direct sunlight and insufficient chemical stabilisation is included in the raw material. Differential thermal expansion may affect Ductile Iron pipes if their temperature is allowed to exceed certain thresholds and this can induce weakness in the pipe material.

(2) Construction Period

Many aspect of construction period are taken into account in the installation costs but there are some benefits to the Client with projects that can be completed over a shorter timeframe so it is worth considering as a metric in its own right. In aggressive ground condition DI will need additional protection, which will add to the construction period.

(3) Resistance to Handling and Installation Damage

The stiff and structurally robust pipe materials such as Steel, Ductile Iron and Polyethylene are more tolerant of poor or incorrect handling and installation damage as they have thick and strong pipe walls although damage to linings or coatings would be an essential for steel and Ductile Iron.

However, some of the materials being considered such as uPVC are less tolerant of handling mistakes. uPVC is also a rigid thin walled plastic pipe and, while less susceptible to failure through damage during handling, is susceptible to damage through exposure to ultra-violet light, over loading during stacking and during installation.

(4) Susceptibility to Installation Defects

PE pipe is fusion jointed on site and a successful weld should be free from dust and dirt and be completed at a set temperature. This pipe material is more susceptible to poor construction practices during installation than DI or uPVC.

(5) Health and Safety Issues with Pipe Installation and Maintenance

In comparison to other materials welding joints in steel pipelines and to a lesser extent polyethylene pipelines carry inherent health and safety risks to contractors and operations staff responsible for the repair of mains. However, these risks are relatively minor when compared with other health and safety risks associated with pipeline installation including trench collapse, trips, falls and vehicle – personnel interaction.

6.3.5 Weighting of Assessment Criteria and Basis of Sensitivity Analysis

As stated above, each of the assessment criteria identified must now be weighted to reflect their relative importance to the overall suitability of a candidate pipe material.

To assist in this weighting, the criteria are grouped as follows:

Pipe Procurement

- Locality of pipe manufacturer and supplier
- Lead time

Handling and Installation

- Pipe storage
- Construction Period
- Resistance to handling and installation damage
- Susceptibility to installation defects (inadequate backfill, poor welds etc)
- Health and safety issues with pipe installation

Costs

- Supply Cost of pipe
- Installation Cost of Pipe
    - Ease of Installation
    - Requirement for bedding

- Trench Width
- Pipe Shoring
- Civil Works

A matrix of group weightings has been used as follows, which produces a set of scores for the pipe materials for varying financial and technical weightings. This allows the sensitivity of technical and financial weightings to be assessed.

Table 6-3 Matrix of Group Weightings - Technical and Financial Weightings

Group	Weight of Factor	Criterion	DI	PE	uPVC	GI	Steel
Procurement	5%	Locality of pipe manufacturer and supplier.	3%	4%	3%	2%	2%
	5%	Local Manufacturer	2%	4%	3%	2%	2%
	5%	Lead Time	3%	4%	4%	2%	2%
Sub Total	15%		8%	12%	10%	6%	6%
Installation and Handling	10%	Pipe storage	8%	9%	7%	7%	7%
	10%	Construction Period	9%	10%	9%	8%	8%
	10%	Resistance to Handling and Installation Damage	8%	9%	6%	7%	6%
	5%	Susceptibility to Installation Defects	3%	3%	2%	2%	2%
	5%	Health and Safety Issues with Pipe Installation and Maintenance	3%	3%	2%	2%	2%
Sub Total	40%		31%	34%	26%	26%	25%
Cost	20%	Supply Cost of pipe	15%	18%	16%	14%	13%
	25%	Installation Cost of Pipe	20%	22%	19%	14%	13%
Sub Total	45%		35%	40%	35%	28%	26%
Grand Total	100%		74%	86%	71%	60%	57%

6.4 Proposed Water Distribution Network- Model and Data Tables

A CD-ROM containing hydraulic model in EPANET format is enclosed.

6.5 Surge Analysis

6.5.1 Gravity system

WATER HAMMER ANALYSIS REPORT -1

PURPOSE: Study of water hammer phenomenon caused by the closing of inlet valve at the end point of No.16.

METHOD: Characteristic Method by Computer Simulation

1. BASIC CONDITIONS

1-1) Basic Conditions

1) Service: Water distribution (G-01)
2) Rated capacity (Q): 85.835 m^3/min
3) Valve closing period for inlet valve at the end point of No.16: 60 sec

1-2) Pipeline

1) Pipe material: Ductile cast iron pipe
2) Pipe diameter (D): 1,200～400 mm
3) Pipe thickness (t): 19.5～8.5 mm
4) Value of K/E: 0.0127
5) Pipeline length (L): 11,490 m
6) Loss co-efficient (C): 110
7) Wave speed (a) $a=1425/(1+K/E \times D/t)^{0.5}$: 1,068～1,128 m/sec

1-3) Initial Operating Conditions

1) Flow condition: Refer to below table.
2) Zebdat reservoir water level: 631.00 m (HWL)
3) Discharge pressure level at the end point of No.16: 606.16 m (WL)
4) Actual head (Ha): -24.84 m (WL-HWL)

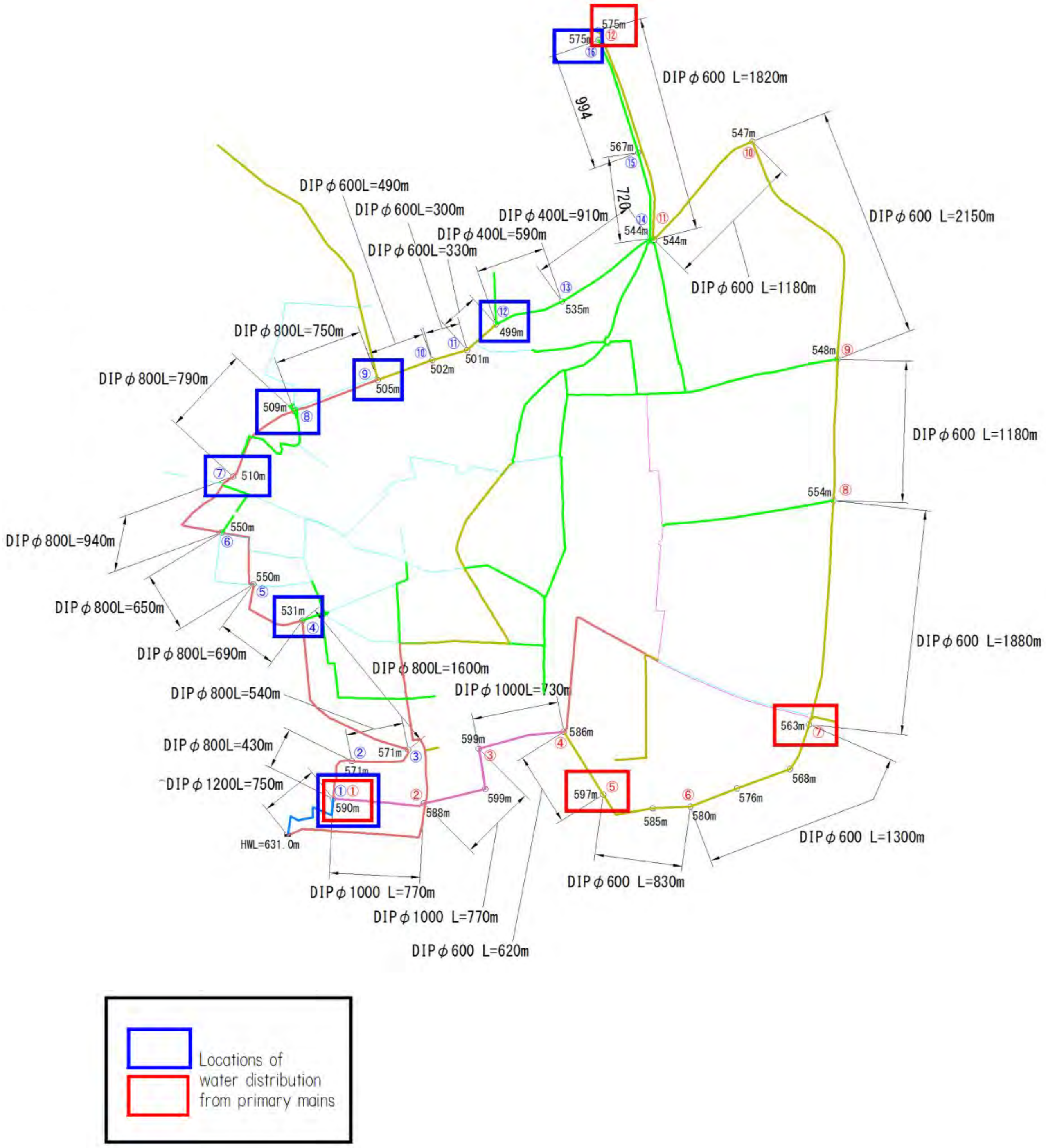


Figure 6-10 Water Hammer Analysis Pipelines (Gravity system REPORT -1)

2. CALCULATION OF BASIC DATA

Pipe Section		Intake capacity	Flow capacity	Pipeline diameter	Pipeline length	C value	Flow velocity	Loss head	Dynamic level	GL	Static level	Hydraulic level
		m^3/min	m^3/min	mm	m	-	m/sec	m	m	m	m	m
Zebdat	1	32.06	85.84	1,200	750	110	1.26	1.07	629.93	590.00	41.00	39.93
1	2		53.77	800	430	110	1.78	1.86	628.07	571.00	60.00	57.07
2	3		53.77	800	540	110	1.78	2.33	625.74	571.00	60.00	54.74
3	4	5.01	53.77	800	1,600	110	1.78	6.91	618.83	531.00	100.00	87.83
4	5		48.77	800	690	110	1.62	2.49	616.35	550.00	81.00	66.35
5	6		48.77	800	650	110	1.62	2.34	614.00	550.00	81.00	64.00
6	7	4.91	48.77	800	940	110	1.62	3.39	610.61	510.00	121.00	100.61
7	8	22.60	43.86	800	790	110	1.45	2.34	608.27	509.00	122.00	99.27
8	9	12.77	21.26	800	750	110	0.71	0.58	607.69	505.00	126.00	102.69
9	10		8.50	600	490	110	0.50	0.28	607.41	502.00	129.00	105.41
10	11		8.50	600	300	110	0.50	0.17	607.24	501.00	130.00	106.24
11	12	6.55	8.50	600	330	110	0.50	0.19	607.05	499.00	132.00	108.05
12	13		1.95	400	590	110	0.26	0.16	606.88	535.00	96.00	71.88
13	14		1.95	400	910	110	0.26	0.25	606.64	544.00	87.00	62.64
14	15		1.95	400	730	110	0.26	0.20	606.44	567.00	64.00	39.44
15	16	1.95	1.95	400	1,000	110	0.26	0.27	606.16	575.00	56.00	31.2

3. FIGURES FOR WATER HAMMER RESULTS

Refer to the attached drawing

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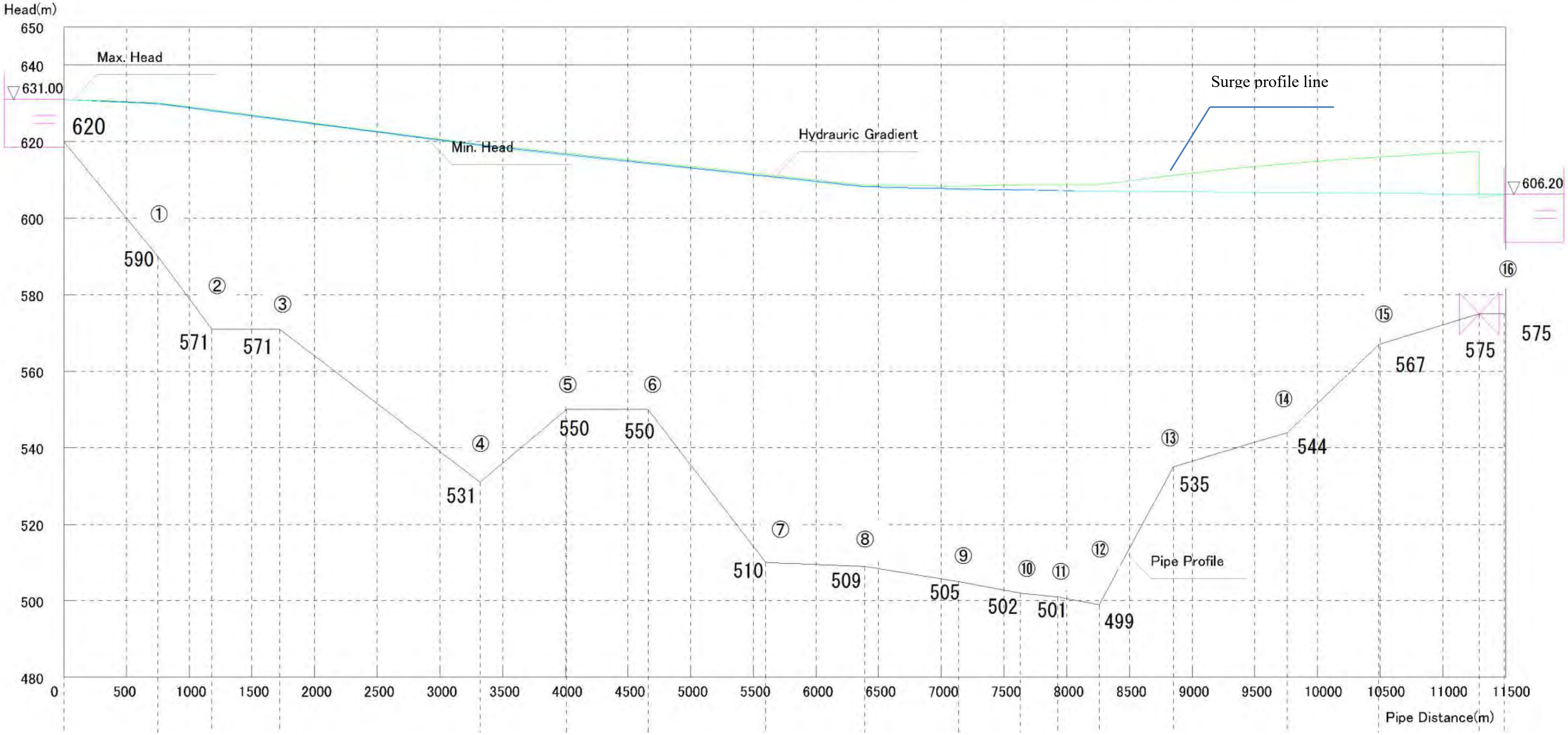

Figure 6-11 Water Hammer Results (Gravity system REPORT -1)

4. CONCLUSION

The calculation results for water hammer phenomena in pipeline are shown in the attached drawing consisting of the pipeline profile, hydraulic gradient line, maximum and minimum pressure lines.

From this drawing, pressure rise between point No.11 and point No.16 is observed. However, maximum pressure is within the allowable pressure of the pipeline.

WATER HAMMER ANALYSIS REPORT-2

PURPOSE: Study of water hammer phenomenon caused by the closing of inlet valve at the end point of No.12.

METHOD: Characteristic Method by Computer Simulation

1. BASIC CONDITIONS

1-1) Basic Conditions

1) Service: Water distribution (G-02)
2) Rated capacity (Q): 68.714 m^3/min
3) Valve closing period for inlet valve at the end point of No.12: 60 sec

1-2) Pipeline

1) Pipe material: Ductile cast iron pipe
2) Pipe diameter (D): 1,200～600 mm
3) Pipe thickness (t): 19.5～11 mm
4) Value of K/E: 0.0127
5) Pipeline length (L): 13,980 m
6) Loss co-efficient (C): 110
7) Wave speed (a) $a=1425/(1+K/E \times D/t)^{0.5}$: 1,068～1,095 m/sec

1-3) Operating Conditions

1) Flow condition: Design capacity
2) Flow capacity (QT): 68.714 m^3/min
3) Zebdat reservoir water level: 631.00 m (HWL)
4) Discharge pressure level at the end point of No.12: 599.74 m (WL)
5) Actual head (Ha): -31.26 m (WL-HWL)

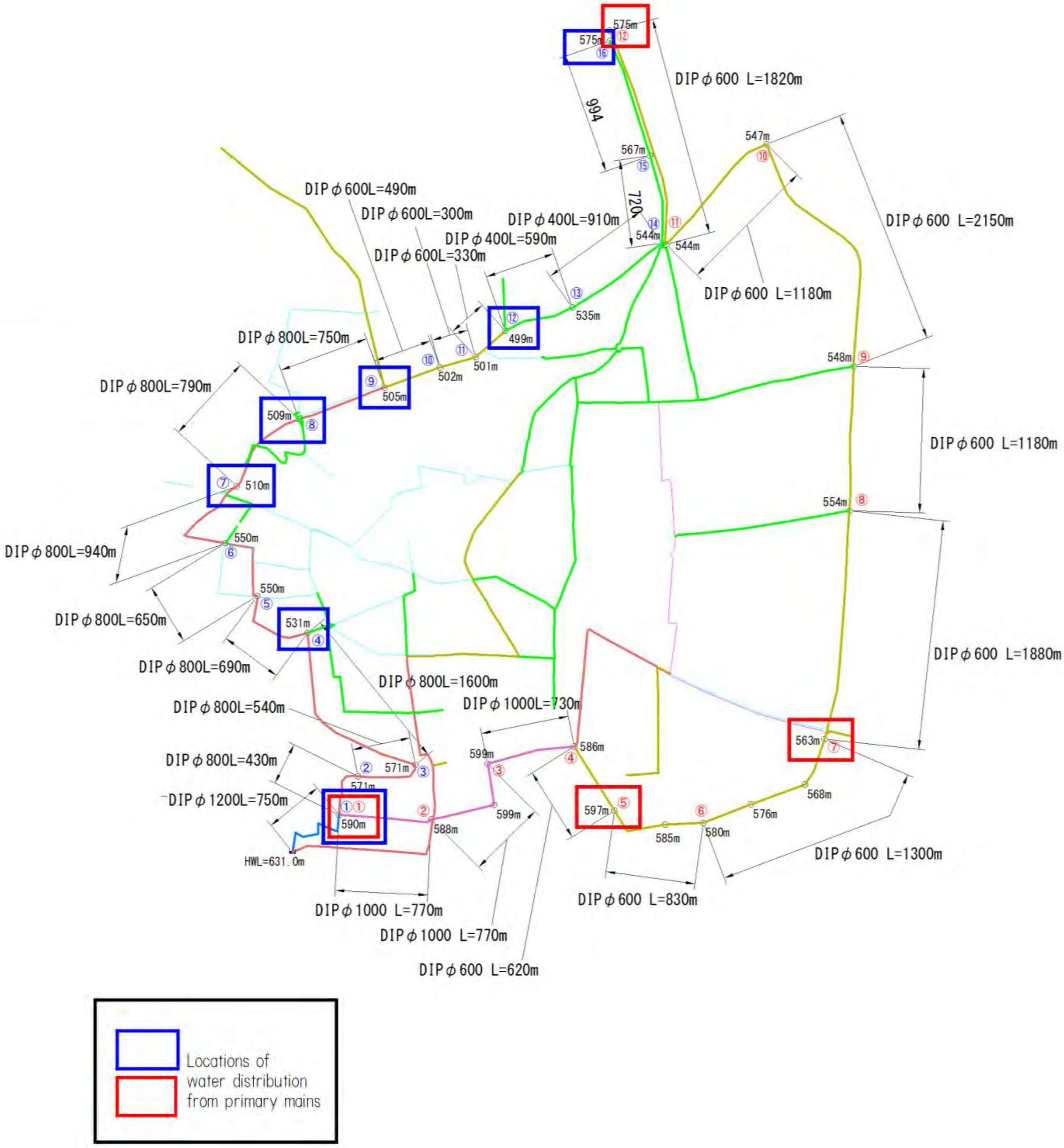

Figure 6-12 Water Hammer Analysis Pipelines (Gravity system REPORT -2)

2. CALCULATION OF BASIC DATA

Pipe Section		Intake capacity	Flow capacity	Pipeline diameter	Pipeline length	C value	Flow velocity	Loss head	Dynamic level	GL	Static level	Hydraulic level
		m^3/min	m^3/min	mm	m	-	m/sec	m	m	m	m	m
Zebdat	1	32.06	68.71	1,200	750	110	1.01	0.71	630.29	590.00	41.00	40.29
1	2		36.65	1,000	770	110	0.78	0.55	629.74	588.00	43.00	41.74
2	3		36.65	1,000	770	110	0.78	0.55	629.19	599.00	32.00	30.19
3	4		36.65	1,000	730	110	0.78	0.52	628.67	586.00	45.00	42.67
4	5	12.09	36.65	600	620	110	2.16	5.35	623.32	597.00	34.00	26.32
5	6		24.56	600	830	110	1.45	3.41	619.90	580.00	51.00	39.90
6	7	8.83	24.56	600	1,300	110	1.45	5.35	614.55	563.00	68.00	51.55
7	8		15.73	600	1,880	110	0.93	3.39	611.16	554.00	77.00	57.16
8	9		15.73	600	1,180	110	0.93	2.13	609.03	548.00	83.00	61.03
9	10		15.73	600	2,150	110	0.93	3.88	605.15	547.00	84.00	58.15
10	11		15.73	600	1,180	110	0.93	2.13	603.02	544.00	87.00	59.02
11	12	15.73	15.73	600	1,820	110	0.93	3.28	599.74	575.00	56.00	24.74

3. FIGURES FOR WATER HAMMER RESULTS

Refer to the attached drawing.

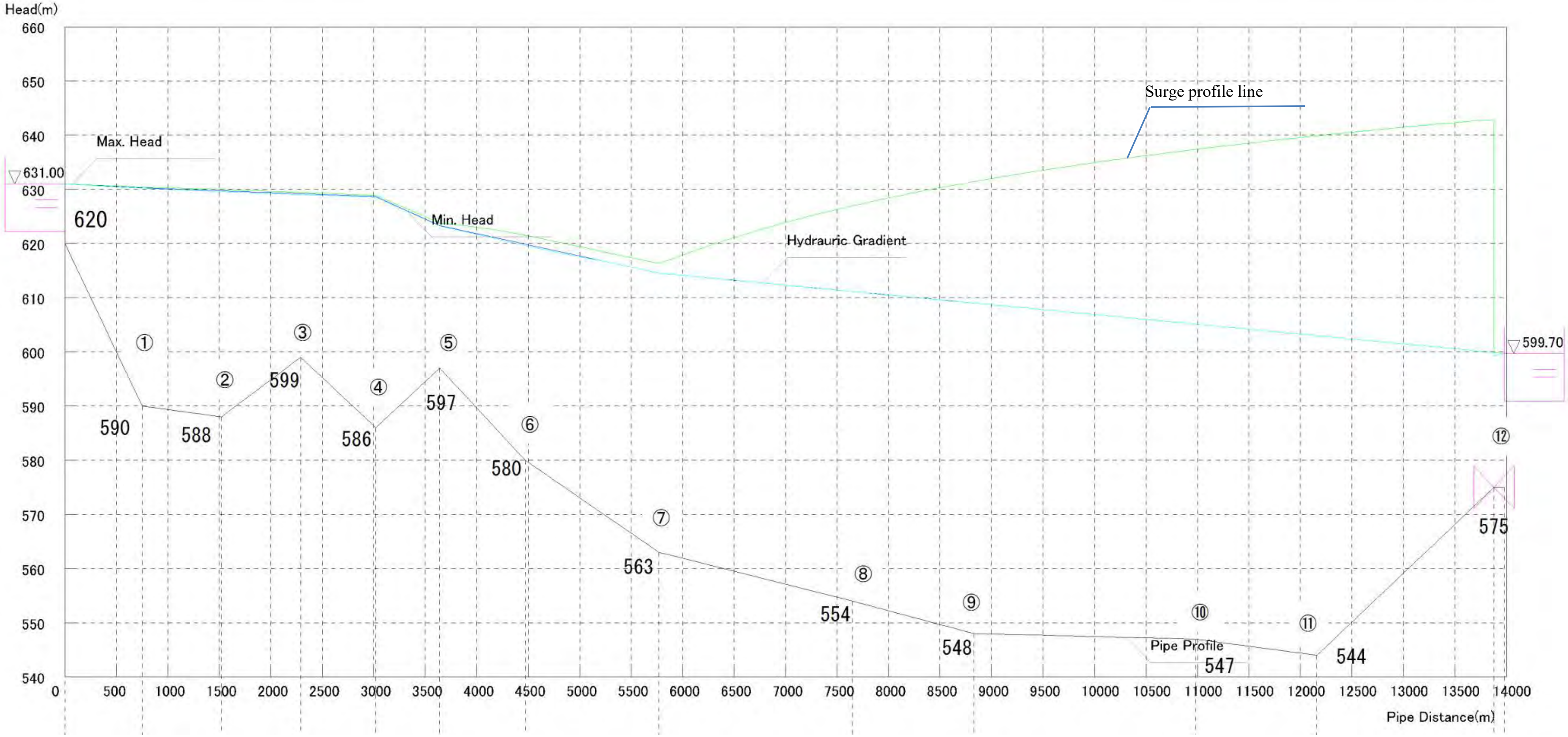

Figure 6-13 Water Hammer Results (Gravity system REPORT -2)

4. CONCLUSION

The calculation results for water hammer phenomena in pipeline are shown in the attached drawing consisting of the pipeline profile, hydraulic gradient line, maximum and minimum pressure lines.

From the drawing, pressure rise between point N0.6 and point No.12 is observed. However, maximum pressure is within the allowable pressure of the pipeline.

6.5.2 Pumping system

WATER HAMMER ANALYSIS REPORT-3

PURPOSE: Study of water hammer phenomenon caused by the trip of all operating pumps.

METHOD: Characteristic Method by Computer Simulation

1. BASIC CONDITIONS

1-1) Main Pump

1) Pump service: Water distribution (P-01)
2) Pump type: Centrifugal volute pump
3) Number of installed pumps: 2 sets
4) Number of operating pumps: 1 set
5) Rated pump capacity (Q): 8.82 m^3/min
6) Rated pump total head (HT): 50 m
7) Rated speed of rotation (N): 1,460 min-1
8) Pump shaft power (P): 110 kW

1-2) Motor and GD^2(Moment of inertia)

1) Motor output: 110 kW
2) Motor type: Squirrel cage induction
3) Motor voltage: 400 V
4) Motor frequency: 50 Hz
5) Number of pole: 4 P
6) Motor GD^2: 3.00 kg-m^2
7) Pump GD^2: 6.00 kg-m^2
8) Fly-wheel GD^2: 40.00 kg-m^2

1-3) Check Valve

1) Valve bore: 300 mm
2) Valve type: Ordinary check valve

1-4) Pipeline

1) Pipe material: Ductile cast iron pipe
2) Pipe diameter (D): 400 mm
3) Pipe thickness (t): 8.5 mm
4) Value of K/E: 0.0127
5) Pipeline length (L): 4,110 m
6) Loss co-efficient (C): 110

7) Wave speed (a) $a=1425/(1+K/E \times D/t)^{0.5}$: 1,128 m/sec

1-5) Operating Conditions

1) Flow condition: Design capacity
2) Flow capacity (QT): 8.82 m^3/min
3) Zebdat reservoir water level: 631.00 m (HWL)
4) Discharge pressure level at the end point of No.9: 671.50 m (WL)
5) Actual head (Ha): 40.50 m (WL-HWL)

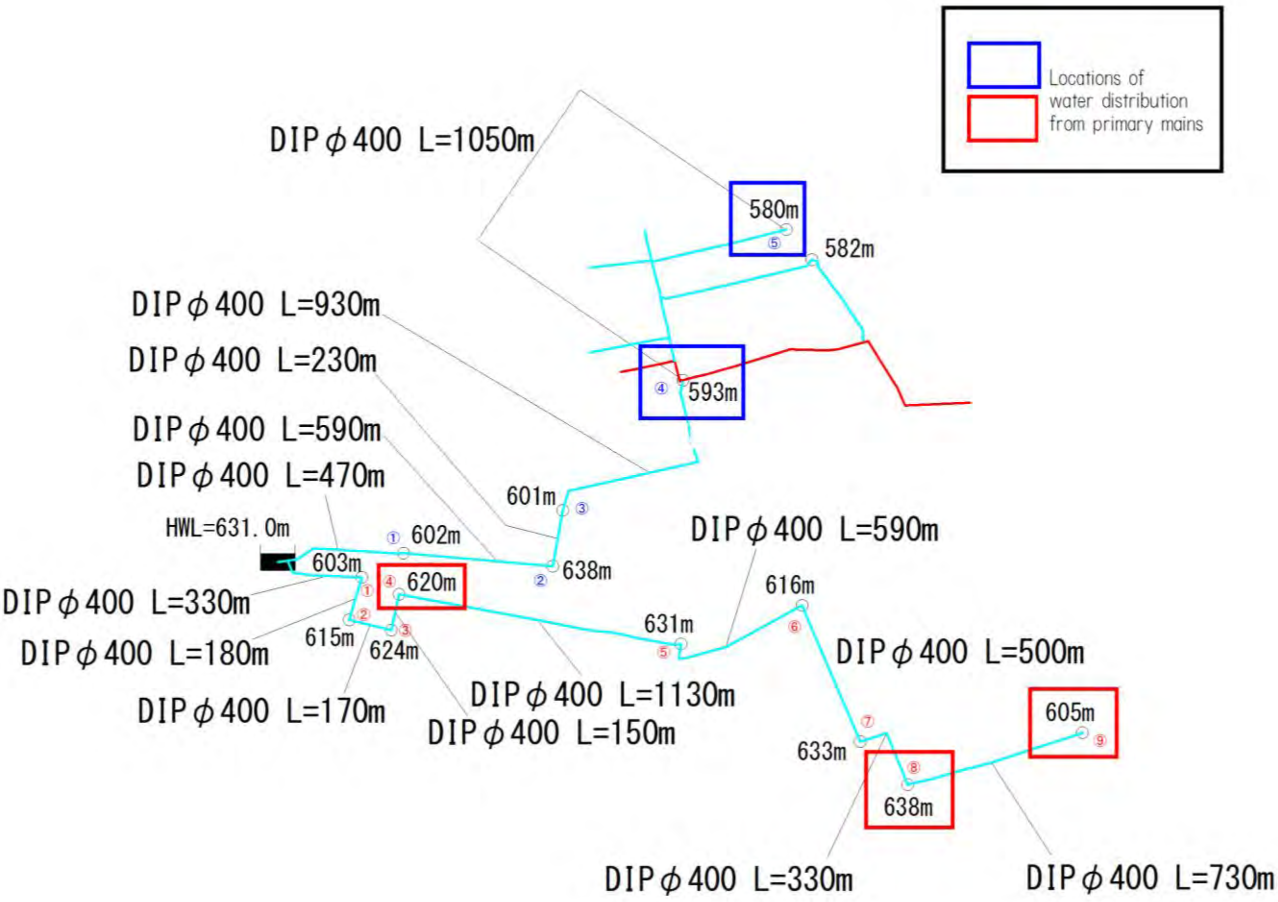

Figure 6-14 Water Hammer Analysis Pipelines (Pumping system REPORT -3)

2. CALCULATION OF BASIC DATA

Pipe Section		Intake capacity	Flow capacity	Pipeline diameter	Pipeline length	C value	Flow velocity	Loss head	Dynamic level	GL	Static level	Hydraulic level
		m^3/min	m^3/min	mm	m	-	m/sec	m	m	m	m	m
Zebdat	1		8.82	400	330	110	1.17	1.47	679.53	603.00	78.00	76.53
1	2		8.82	400	180	110	1.17	0.80	678.73	615.00	66.00	63.73
2	3		8.82	400	170	110	1.17	0.76	677.97	624.00	57.00	53.97
3	4	2.94	8.82	400	150	110	1.17	0.67	677.30	620.00	61.00	57.30
4	5		5.88	400	1,130	110	0.78	2.38	674.92	631.00	50.00	43.92
5	6		5.88	400	590	110	0.78	1.24	673.68	616.00	65.00	57.68
6	7		5.88	400	500	110	0.78	1.05	672.63	633.00	48.00	39.63
7	8	2.94	5.88	400	330	110	0.78	0.69	671.93	638.00	43.00	33.93
8	9	2.94	2.94	400	730	110	0.39	0.43	671.51	605.00	76.00	66.51

3. CALCULATION CASE

Following two cases of the calculation for without counter-measures and with counter-measures (flywheel and air valve) are carried out.

Case 1: Pump GD^2 + Motor GD^2: 9.00kg-m^2
Case 2: Pump GD^2 + Motor GD^2 + Flywheel GD^2: 49.00kg-m^2

4. FIGURES FOR WATER HAMMER RESULTS

Refer to the attached drawing for Case 1 & 2.

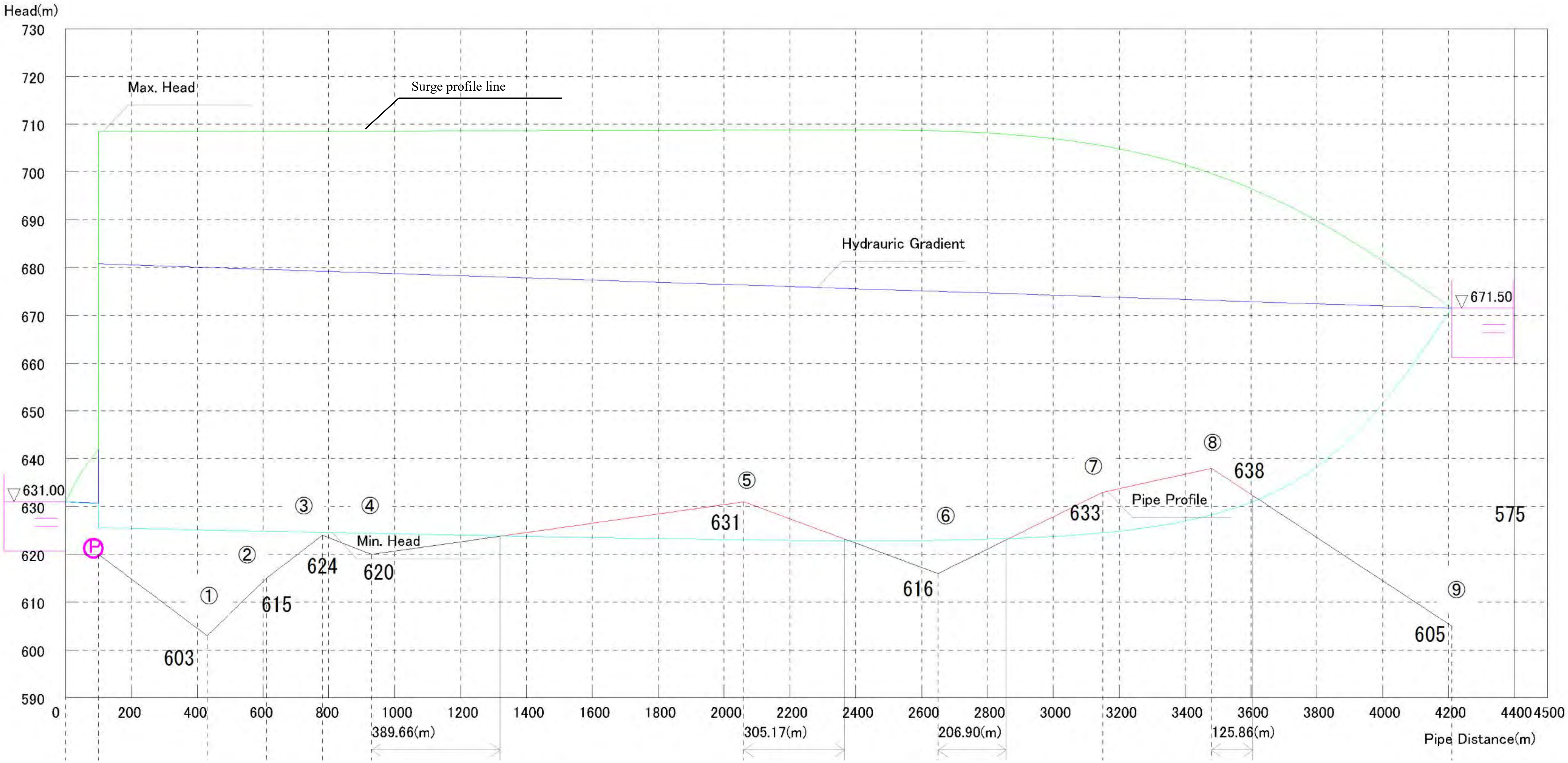

Figure 6-15 Water Hammer Results (Pumping system REPORT -3) Case 1: Pump GD^2 + Motor GD^2: 9.00kg-m^2

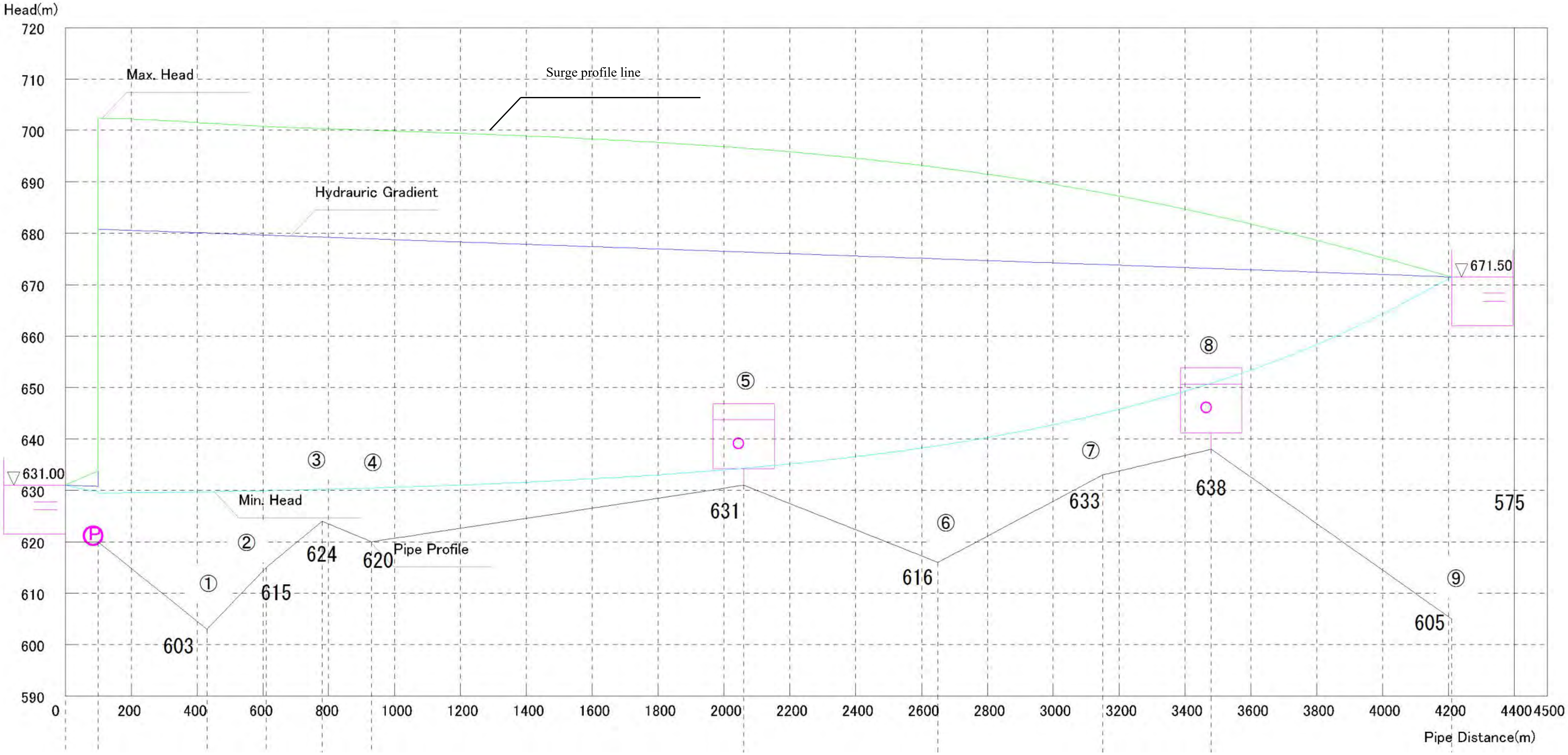

Figure 6-16 Water Hammer Results (Pumping system REPORT -3) Case 2: Pump GD^2 + Motor GD^2 + Flywheel GD^2: 49.00kg-m^2

5. CONCLUSION

The calculation results for water hammer phenomena in pipeline are shown in the above drawing consisting of the pipeline profile, hydraulic gradient line, maximum and minimum pressure lines.

In case of Case 1, negative pressure is observed and when it is over -10m, water column separation might be occurred in the pipeline. After the column separation, water will be rejoined and abnormal pressure might be generated and pipeline might be damaged finally. Therefore, countermeasures must be necessary in order to prevent the negative pressure generation.

In case of Case 2, as a result of adopting the fly-wheel, negative pressure is not observed in the pipeline.

And also, maximum pressure is within against allowable pressure of the pipeline.

Accordingly, it is recommended to install the fly-wheel (GD^2 = 40 kg-m^2).

WATER HAMMER ANALYSIS REPORT-4

PURPOSE: Study of water hammer phenomenon caused by the trip of all operating pumps.

METHOD: Characteristic Method by Computer Simulation

1. BASIC CONDITIONS

1-1) Main Pump

1) Pump service: Water distribution (P-02)
2) Pump type: Centrifugal volute pump
3) Number of installed pumps: 2 sets
4) Number of operating pumps: 1 set
5) Rated pump capacity (Q): 2.68 m^3/min
6) Rated pump total head (HT): 30 m
7) Rated speed of rotation (N): 1,460 min^{-1}
8) Pump shaft power (P): 30 kW

1-2) Motor and GD^2(Moment of inertia)

1) Motor output: 30 kW
2) Motor type: Squirrel cage induction
3) Motor voltage: 400 V
4) Motor frequency: 50 Hz
5) Number of pole: 4 P
6) Motor GD^2: 0.70 kg-m^2
7) Pump GD^2: 0.90 kg-m^2
8) Fly-wheel GD2: 15.00 kg-m^2

1-3) Check Valve

1) Valve bore: 200 mm
2) Valve type: Ordinary check valve

1-4) Pipeline

1) Pipe material: Ductile cast iron pipe
2) Pipe diameter (D): 400 mm
3) Pipe thickness (t): 8.5 mm
4) Value of K/E: 0.0127
5) Pipeline length (L): 3,270 m
6) Loss co-efficient (C): 110
7) Wave speed (a) $a=1425/(1+K/E \times D/t)^{0.5}$: 1,128 m/sec

1-5) Operating Conditions

1) Flow condition: Design capacity
2) Flow capacity (QT): 2.68 m^3/min
3) Zebdat reservoir water level: 631.00 m (HWL)
4) Discharge pressure level at the end point of No.5: 659.76 m (WL)

5) Actual head (Ha): 28.76 m (WL-HWL)

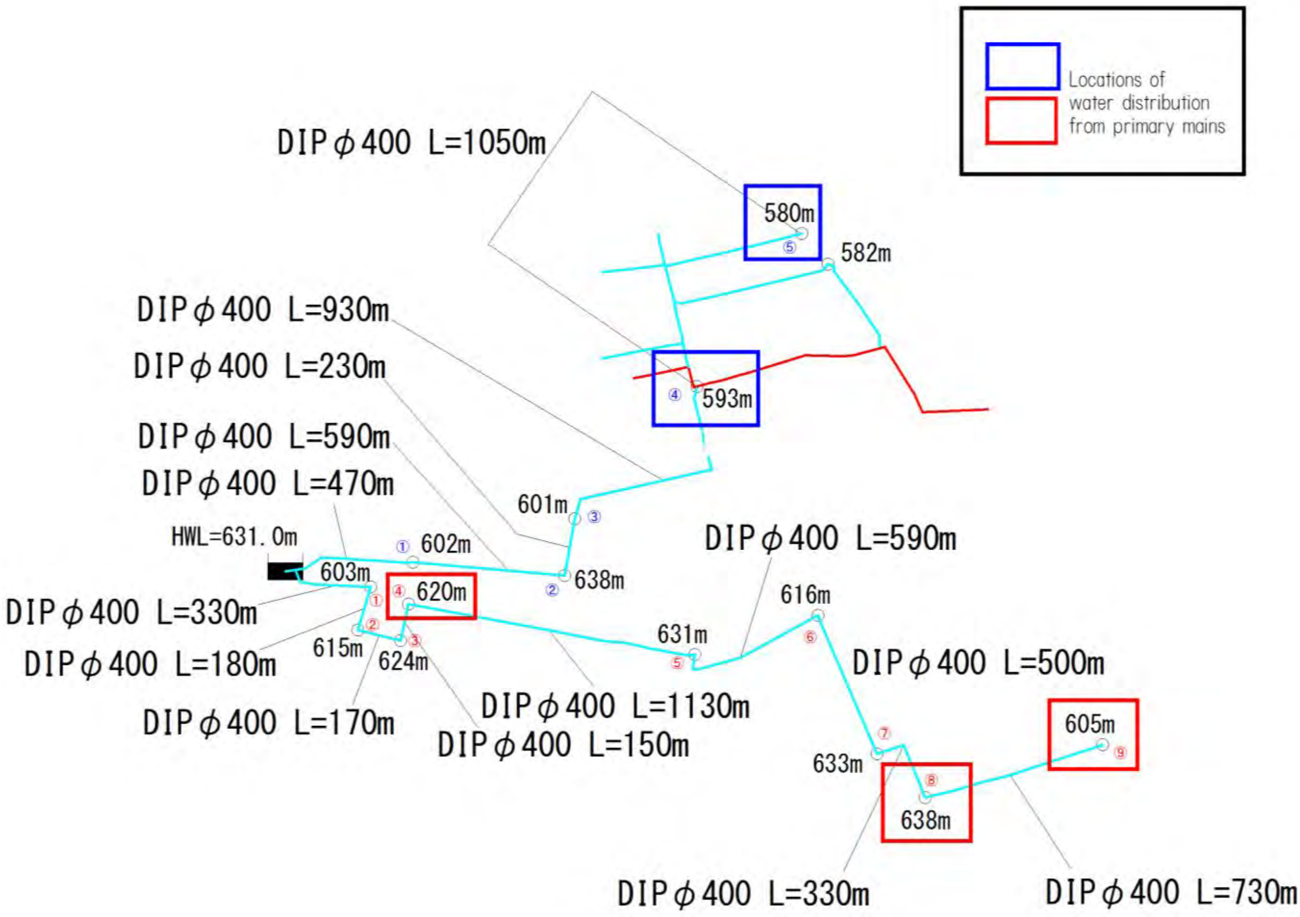

Figure 6-17 Water Hammer Analysis Pipelines (Pumping system REPORT -4)

2. CALCULATION OF BASIC DATA

Pipe Section		Intake capacity	Flow capacity	Pipeline diameter	Pipeline length	C value	Flow velocity	Loss head	Dynamic level	GL	Static level	Hydraulic level
		m^3/min	m^3/min	mm	m	-	m/sec	m	m	m	m	m
Zebdat	1		2.68	400	470	110	0.36	0.23	660.77	602.00	59.00	58.77
1	2		2.68	400	590	110	0.36	0.29	660.48	638.00	23.00	22.48
2	3		2.68	400	230	110	0.36	0.11	660.37	601.00	60.00	59.37
3	4	1.34	2.68	400	930	110	0.36	0.46	659.91	593.00	68.00	66.91
4	5	1.34	1.34	400	1,050	110	0.18	0.14	659.76	580.00	81.00	79.76

3. CALCULATION CASE

Following two cases of the calculation for without counter-measures and with counter-measures (flywheel and air valve) are carried out

Case 1: Pump GD^2 + Motor GD^2: 1.60kg-m^2
Case 2: Pump GD^2 + Motor GD^2 + Flywheel GD^2: 16.60kg-m^2

4. FIGURES FOR WATER HAMMER RESULTS

5. Refer to the attached drawing for Case 1 & 2.

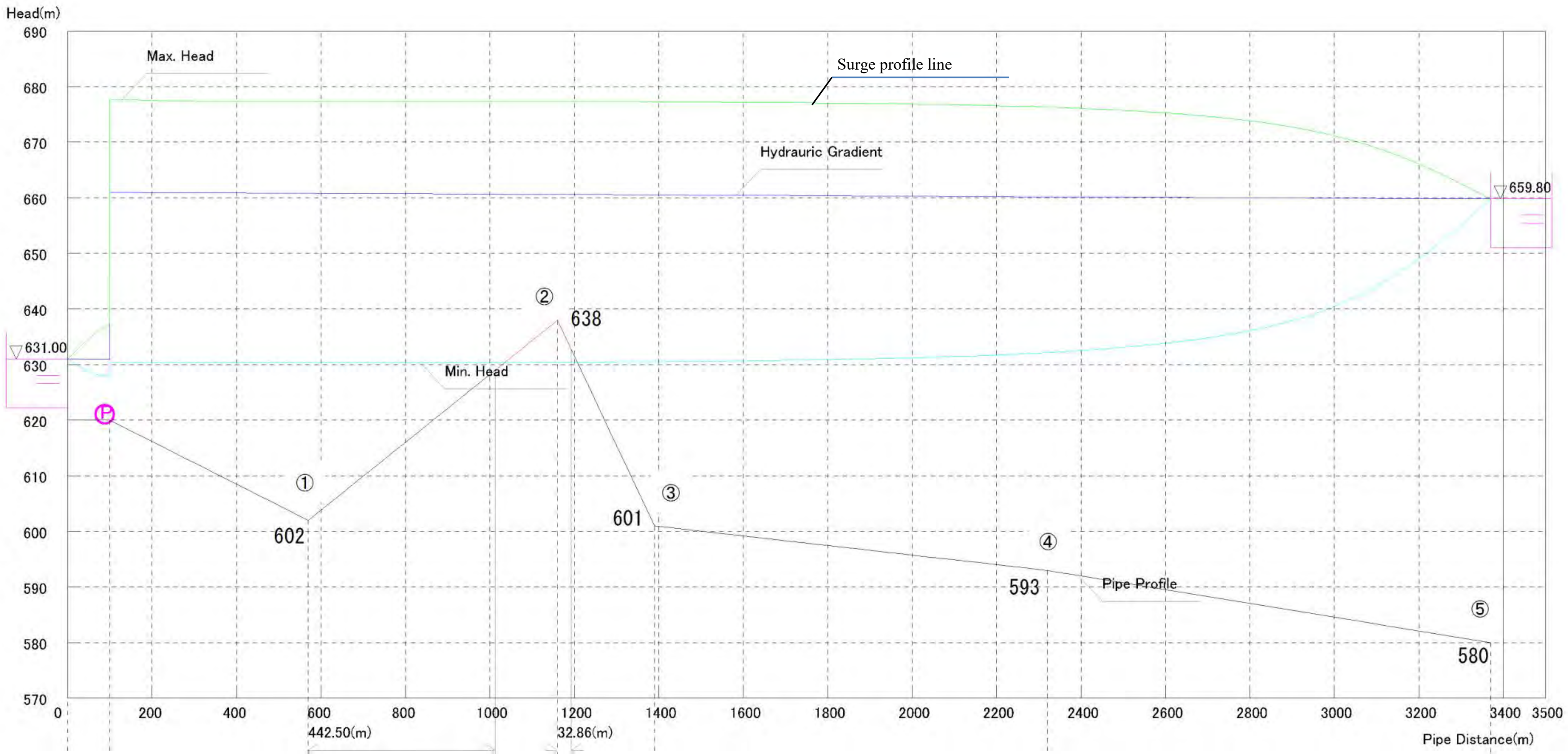

Figure 6-18 Water Hammer Results (Pumping system REPORT -4) Case 1: Pump GD^2 + Motor GD^2: 1.60kg-m^2

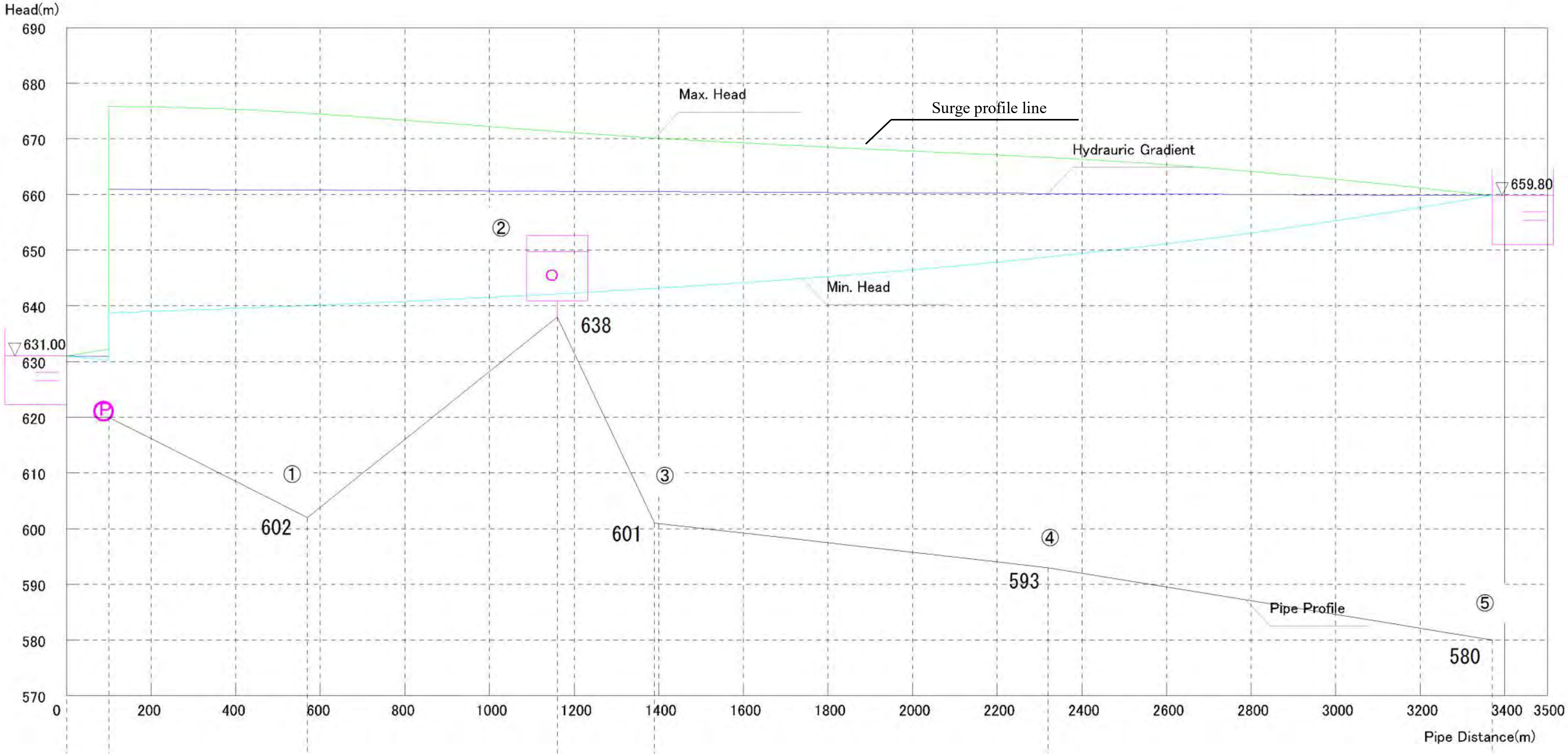

Figure 6-19 Water Hammer Results (Pumping system REPORT -4) Case 2: Pump GD^2 + Motor GD^2 + Flywheel GD^2: 16.60kg-m^2

5. CONCLUSION

The calculation results for water hammer phenomena in pipeline are shown in the above drawing consisting of the pipeline profile, hydraulic gradient line, maximum and minimum pressure lines.

In case of Case 1, negative pressure is observed and when it is over -10m, water column separation might be occurred in the pipeline. After the column separation, water will be rejoined and abnormal pressure might be generated and pipeline might be damaged finally. Therefore, countermeasures must be necessary in order to prevent the negative pressure generation.

In case of Case 2, as a result of adopting the fly-wheel, negative pressure is not observed in the pipeline.

And also, maximum pressure is within against allowable pressure of the pipeline.

Accordingly, it is recommended to install the fly-wheel (GD^2 = 15 kg-m^2).