CHAPTER 16

# 16.Planning and Design of Regional Water Supply Systems

# CHAPTER 16: PLANNING AND DESIGN OF REGIONAL WATER SUPPLY SYSTEMS

## 16.1 Introduction

Several urban water supply schemes are combinedly planned with *enrouted* villages. In addition to this, water supply schemes for peri-urban villages need to be planned. In urban water supply schemes, a common transmission main is designed and constructed to serve villages near the transmission main. However, reliability of such schemes is low. If anything goes wrong, like a pipe bursts, the town or villages on downstream side are affected.

Historical observation has demonstrated that the water supply systems in India are not planned and designed with regard to the topography of the service areas or current and future water demands at nodes of the water system. Geographic Information Systems (GIS) is a tool that may assist design engineers to account for those critical factors. It is preferable to use GIS, along with other tools, to assess transmission routing characteristics and service area demands. The Ministry of Housing and Urban Affairs (MoHUA) published an advisory on "GIS Mapping of Water Supply and Sanitation Infrastructure" in 2020, which is available at https://mohua.gov.in/publication.php?sa=manuals-and-advisories.php.

GIS based hydraulic modelling is an essential tool for planning and designing of water supply schemes. It complements the complete planning and designing of the regional water supply components and networks considering the topography and other physical attributes. Integration of GIS with appropriate network software should be utilised, as discussed in the Chapter 12 in Part A Manual.

This chapter also proposes to adopt 100% consumer metering in urban areas for demand management, optimise pipe diameters and equalise residual heads at ESRs/tanks of urban-rural schemes.

The objective of this chapter is to present a methodology for planning, designing, and implementing of urban-rural schemes that includes towns, peri-urban and enrouted villages.

Henceforth, a combined water supply scheme for town/city, its enrouted villages and peri-urban areas shall be denoted as "Urban-Rural Water Supply Scheme".

## 16.2 Problems in Urban-Rural Areas

Presently in most of the urban and rural schemes are planned with 10 to 15 villages on a single gravity main from the Master Balancing Reservoir (MBR). The result is the reliability of the water supply in downstream villages becomes less. The design of the transmission main does not ensure equal residual head at Full Supply Levels (FSLs) of Elevated Service Reservoirs (ESRs)/Ground Service Reservoirs (GSRs). Because of this, the service reservoirs closer to the input of the system experience drawl of more water than the designed demand and hence the rest of the ESRs/ GSRs do not get adequate supply. This is true especially for peri-urban villages, which are on the periphery of the urban area. This problem gets aggravated further for the remaining villages further downstream of the long transmission main. Thus, long gravity transmission mains feeding many reservoirs in series causes inequality and unreliability. This conceptual shortcoming can be effectively overcome by the concept of Zonal Balancing Reservoir (ZBR), by properly grouping service reservoirs and providing ZBR for each group or a combined pumped ESR pressurised system. This is discussed further in

**Annexures 16.1 and 16.2** of this chapter. These annexures, i.e., case studies, show that without sacrificing economy, i.e., by keeping total cost (capital cost + capitalised cost of electricity along with O&M) minimum, it is possible to achieve the above concept of ZBRs along with limiting the number of service reservoirs to four in each direction from ZBR and thus provide water to all service reservoirs equitably and reliably.

In addition to the problems of inequality and unreliability, other problems faced are uneconomic design of pipe diameter, improper pipe material, high non-revenue water (NRW) and inequitable distribution of flow to rural households due to improper design of distribution system of village. The villages at the end of the urban-rural water supply scheme do not receive adequate and timely daily water service. These problems can be effectively resolved by proper planning and design, with the help of hydraulic modelling and GIS.

### 16.3 Concept of ZBR

After deciding the scope, the project area should be divided into subareas as per topography of each subarea. For feeding tanks in the villages of each subarea, ZBRs are located at strategic higher elevation places of the established sub areas. ZBR systems have been incorporated to increase the reliability and avoid low velocities. Transmission main network is then designed to feed these ZBRs. The ZBRs should be fed either by the gravity from MBR or by combination of a gravity/pumped pressure transmission main. For optimising cost of transmission main, adequate velocity in main stretches of transmission main are ensured and, thus, diameters are optimised. From ZBRs, water is further distributed for feeding village service tanks. Using ZBRs makes it possible to limit the number of villages to six or so on each branch of pipelines, starting from ZBR in different direction.

### 16.4 Approach for Peri-urban Villages, Towns and Large Villages

Many revenue villages have boundaries in common with adjoining town/city, the village are termed as “peri-urban village”. Behavioural habits, standard of living, and, consequently, water share requirements expressed in litres per capita per day (LPCD) of the dwellers in peri-urban villages is similar to the adjoining town/city. Therefore, it is difficult to classify dwellers as villagers. In many cases, the revenue villages have developed an attachment to the adjoining town/city. The population growth is very much influenced by the rapid urbanisation of ther adjoining town/city. The influence is somewhat decreased if the dividing border is a river or water body and increases if the dividing border is a highway or proximity of railway station. If the agricultural lands are diminishing and being converted into plots for residential or commercial use, or if the cost of agricultural land is increasing substantially, this indicates that population is going to increase rapidly. All these factors need to be considered and when population needs are forecasted for design. Considering these villages as future wards of adjoining town/city and forecasting its population for immediate and ultimate stage with the method of “forecasting of future ward wise population density based on equivalent area” is recommended. The forecasting process is detailed in **Annexure 2.7** (Chapter 2) of this manual. The method mentioned is recommended to be used for assigning nodal demands and designing a distribution system thereafter.

### 16.5 Approach for Enrouted Villages

It is a common observation, in many cases, from the trunk main going to town, there are tapping points from which enrouted villages draw water. This arrangement of giving multiple tapping points lowers sustainability and hydraulic efficiency of water supply system of the town for which the project is constructed. Instead of this type of arrangement, it is recommended to provide a minimum number of ZBRs on the route of main line and feed the tanks of enroute villages from the ZBRs.

If the raw water main is designed for an urban-rural scheme, the water demand of enroute villages should also be considered while planning the transmission main through the villages.

Also, while designing an augmentation scheme of urban towns/cities, the demand of enroute villages, if they cannot be served by groundwater, surface water should be considered and integrated project should be framed. The proportionate cost for urban and rural areas shall be borne by the respective departments based on the water demand for urban and rural areas.

## 16.6 Holistic Planning of Urban-Rural Water Supply

For planning sustainable urban-rural scheme, it is necessary to adopt a holistic approach, i.e., from whole-to-part approach. This approach is depicted in Figure 16.1. This approach considers the overall situation of water availability in river basins, therefore, the river sub basins and watersheds in river basins should be considered.

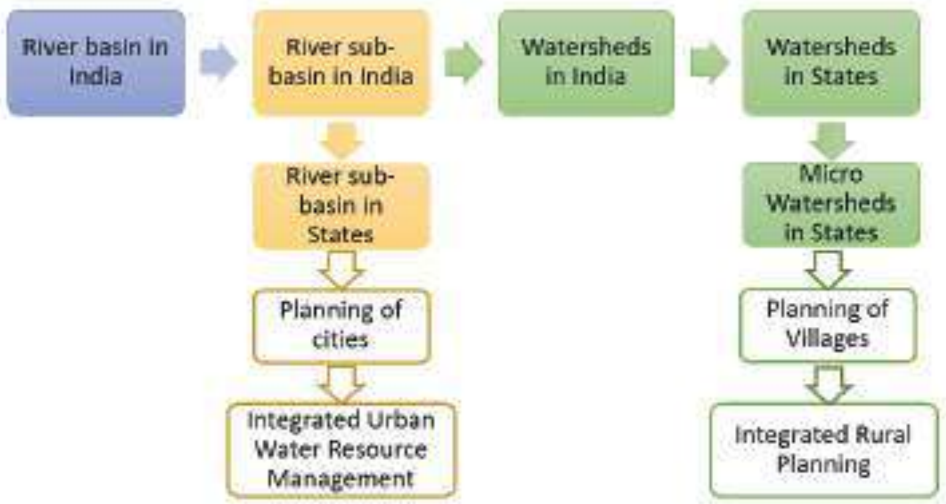


**Figure 16.1: Whole-to-Part approach**

## 16.7 Types of Urban-Rural Water Supply Schemes

There are many regions/areas in India that have acute water scarcity coupled with the 'hot spot' water quality problems like excess of total dissolved solids (TDS), hardness, chloride, fluoride, iron, nitrate, and sulphate. If we consider individual villages with such problems, the cost of standalone schemes for such villages including cost of treatment is expensive. Hence, such villages can be grouped together along with nearby urban towns and planned together to take advantage of economies of scale. Normally, in such situations, when nearby sources are not available, urban-rural is thought of with distant sources. Combined urban-rural Water Supply Schemes are categorised as follows:

a) Urban-rural with enrouted villages of cities
b) Urban-rural with peri-urban villages
c) Regional Rural Water Supply Schemes (RRWSS)

### 16.7.1 Design Approach for Enrouted Villages of Urban Scheme

A typical urban-rural scheme with enrouted villages is shown in Figures 16.2 and 16.3. The components of urban-rural schemes are source, transmission main from source to WTP, transmission main from WTP to MBR, transmission main from MBR through a zonal meter to the villages, transmission main continuing from the village to ESRs beyond the villages to ESRs in the operation zone, and Operation Zone ESRs into the OZ distribution system as shown in Figure 16.2. The rest of the components for a ZBR approach are shown in Figure 16.3.

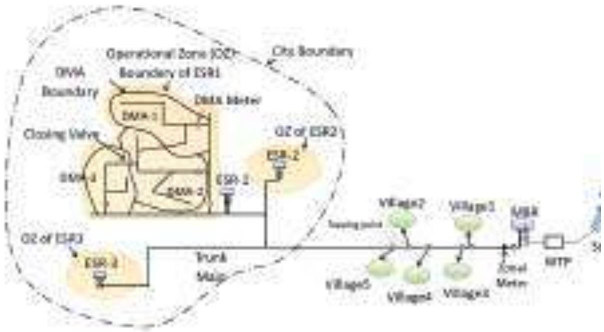

**Figure 16.2: A typical urban-rural scheme with enrouted villages with tapping points (not recommended)**

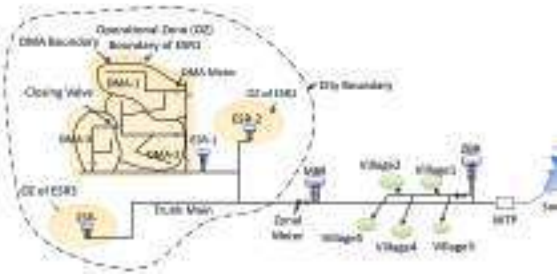

**Figure 16.3: A typical urban-rural with enrouted villages with ZBR (recommended)**

Figure 16.2 shows water supply arrangement to the enrouted villages through direct tapping points from the trunk main. This arrangement results in excessive residual head at FSLs of ESRs by which village ESRs can draw many times more water than they are designed for. Moreover, this arrangement of giving multiple tapping points lowers sustainability and hydraulic efficiency of water supply system of the town for which the project is constructed. Thus, water supply of the town and villages on downstream side is affected. Therefore, this type of arrangement should be discouraged, and an arrangement shown in Figure 16.3 is recommended in which the water supply to the enrouted villages is through the ZBR.

### 16.7.2 Design Approach for Peri-Urban Villages of Urban Scheme

Urban-rural schemes with peri-urban villages are of two types: (i) Common source along with city and (ii) separate source.

i. Common Source: A typical urban-rural with peri-urban villages scheme with common source for both urban and rural areas is shown in Figure 16.4. In this type, source for both the city and the enrouted villages is common.
ii. Separate Source: Urban-rural with peri-urban villages with separate sources for urban and rural areas is shown in Figure 16.5.

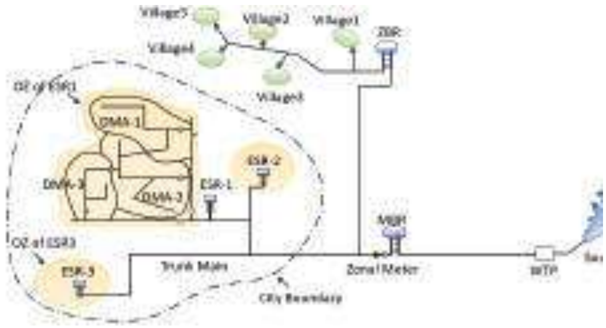

Figure 16.4: A typical urban-rural with peri-urban villages with common source

Figure 16.5: A typical urban-rural with peri-urban villages with separate sources

### 16.7.3 Design Approach for Regional Rural Water Supply Schemes (RRWSS)

The configuration of RRWSS is shown in Figure 16.6. In this type of configuration, water from WTP is distributed radially by locating ZBRs at central and at strategic locations of groups of, villages so that every pipeline from ZBR can serve a group of minimum number of villages.

A typical RRWSS with rural villages is shown in Figure 16.6. In this case, pipelines from ZBR are designed for catering water supply of a group of minimum number of villages (three to four villages) by placing ZBR at key strategic locations.


Figure 16.6: A typical RRWSS with Rural Villages

The distribution system for the above categories and peri-urban villages is recommended to be designed by dividing it in hydraulically discrete operational zones (OZs). A case study of RRWSS is discussed in **Annexure 16.2**.

## 16.8 Design Parameters

The design parameters presented here are for all the three types of urban-rural schemes which are:

a) Urban-rural with enrouted villages of cities
b) Urban-rural with peri-urban villages
c) RRWSS

Design parameters of intake works, design period, and population forecast of urban component is mentioned in Table 2.7 of the Chapter 2 in Part A of this manual.

### 16.8.1 Population Forecast of Village

Two cases are possible: (i) Census data is not available and (ii) Census data is available.

(i) Census data is not available: Population forecast of village shall be made as per Jal Jeevan Mission Guidelines.

(ii) Census data is available: The forecasted population for immediate and ultimate stage should be computed. From the census data, at least for the last three decades, forecasted population with well-known methods of arithmetic increase method, incremental increase method and geometrical increase method should be computed. Generally arithmetic increase method or incremental increase method may be considered depending on the nature of the village(s). However, local body may take the decision for further review in case there are other developmental activities, as below:

a) The villages, which are on the existing highway, and which are expected to be on proposed highway, proposed railway station, proposed industries, near the industrial belts, expected or existing sugar factories or food processing units, proposed economic corridor, etc., grow at much faster rate than the computed by above-described methods of averaging.
b) Due to establishment of the above factor, where the growth in the last census has already occurred, the computation by the above method shows much higher forecast and needs to be attenuated realistically.

If the rate of growth is decreasing, the decreasing rate growth forecasting method, as stipulated in Chapter 2, shall be adopted.

### 16.8.2 Ward Wise Distribution of Forecasted Population

If the present population of a town or a large village exceeds 5000, it is first forecasted for intermediate (15 years from the base year) and ultimate (30 years from the base year) stages. Then this population should be distributed ward wise by forecasting population density for intermediate and ultimate stages. This method is described at length in **Annexure 2.7** in Chapter 2 of this Part A manual.

## 16.9 Testing Pressure of Transmission mains

Field testing of pressure pipes: Field test pressure shall be a maximum of:

- 1.5 times maximum sustained operating pressure;
- 1.5 times maximum pipelines static pressure;
- Maximum sustained operating pressure plus maximum surge pressure (in case of pumping mains);
- Sum of the maximum pipeline static pressure and the maximum surge pressure, subject to a maximum equal to the work test pressure for any pipe fitting incorporated;
- Testing pressure in accordance with the provisions of IS of relevant pipe material used.

## 16.10 Air Valves on Transmission Main

Air valves shall be installed at summits in the lines and at changes in grade to steeper slopes in line. Otherwise, in long horizontal stretches, it should be installed at a minimum interval of 500 metres. L-section of transmission mains shall be prepared at an interval of 50 metres. However, the interval of 30 metres shall be adopted when variations in ground levels are more. Effective diameter of air valve shall be 1/4 to 1/5 of the internal diameter of the pipeline (Ref IS: 14845-2000).

Air valve may be fixed on the shafts so that their hydraulic efficiency increases. At the location of air valves, a suitable flanged T shall be provided and, on that flange, with help of flanged pipe, the shaft of suitable height above ground shall be provided. On top of flange, the air valve shall be fixed. The proper height above ground is necessary so that miscreants cannot tamper the ball of air valve. Because of the sizable height, leakage can be observed from a considerable distance, allowing for a timely repair. Tee of air valve should be embedded in concrete block so that the shaft remains stable and is not easily disturbed by miscreants and stray animals. Another advantage of this type of arrangement is that there's no need for a cage to protect the air valve.

## 16.11 Break Pressure Tank (BPT)

The design is included in section 6.14 in Part A of this manual.

## 16.12 Per Capita Supply at Consumer End (LPCD)

Per capita supply shall be as follows:

(a) City/town: As per Table 2.7 in Part A, Chapter 2.

(b) Rural part: As per operational guidelines for the implementation of Jal Jeevan Misson-2019, Ministry of Jal Shakti, the service level of potable drinking water supply should be at least 55 LPCD. States may enhance the same to higher level depending on availability of drinking water sources for which additional financial resources that may be required, will be met by the state government or local community or donors. In addition to this, cattle troughs may be constructed to provide drinking water to livestock especially in hilly terrain, or drought prone and desert areas. It is necessary to reserve water for domestic needs from multi-purpose reservoirs/storages in consultation with concerned agencies/departments.

## 16.13 Capacity of MBR and ZBR

The storage capacity of MBR for Urban area shall be designed for three hours of ultimate demand & for combined a Urban & Rural as well as for Rural the storage capacity shall be three hours of ultimate demand. However, ULBs are free to carry out the capacity of MBR based on the mass curve.

The storage capacity of zonal balancing reservoir in rural areas shall be designed for 2 hours capacity of the ultimate demand of the service tanks under its command area.

## 16.14 Losses

Breakdown of losses is shown in Figure 16.7.

(i) Losses in WTP towards washing of filters, etc. = 3%


**Figure 16.7: Breakup of losses**

(ii) Losses in distribution = 10%

(iii) Losses in raw water main up to WTP 1% + losses in pure water up to ESRs 1%, i.e., total 2%. This is correct and adequate for normal expanse of urban-rural scheme. But when urban-rural comprises of many villages, then losses need to be considered as under.

Expanse, i.e., length from the source to farthest village via WTP is more than 20 km, then total loss should be considered at the rate of 1%, instead of 2%, per 10 km.

### 16.15 Hours of Pumping and express feeder of electricity

Express electricity feeder from its source of at least 11 KV substation is necessary to be provided for urban-rural scheme. It should be provided at head works, WTP, and at sumps provided for pumping to ZBRs where total operative HP is 50 or more at any of these pumping stations. Where the operative HP is less than 50, the express electricity feeder should also be provided but it can be from reliable source of electricity and need not be from 11 KV substation. The cost of these feeders should be included in the total cost of urban-rural scheme.

For rural part of the scheme, hours of pumping may be 16 to 20, depending on the availability of quality electric supply, whereas the urban and peri-urban part of the urban-rural scheme should be designed for 22 hours pumping.

### 16.16 Peak Factor

(a) Water distribution networks of urban-rural schemes: A peak factor of 2.5 irrespective of population should be adopted in urban areas and a peak factor of 3 irrespective of population should be adopted in rural areas.

(b) Pumping/Transmission mains: In urban-rural schemes, if power availability is 24 hours, the peak factor may be considered as 1, and if power availability is 16 to 20 hours, the peak factor may be considered as 1.5 to 1.2, depending on the specific circumstances.

### 16.17 Consumer meters

100% metering is necessary for urban-rural schemes to sustain the O&M of the system.

#### 16.17.1 Water Tariff – Tool for Demand Management

For demand management and for enforcing social justice, instead of flat rates, volumetric tariff with a telescopic rate structure is mandatory for towns and villages.

This is required for controlling demand and hence, it is an important tool for demand management. As every family is to be supplied water through house connection, i.e., no public stand-posts, quantum of first slab of telescopic structure should be such designed so that the urban/rural poor can get drinking water at an affordable price, i.e., this slab is to be subsidised accordingly.

Quantum of subsequent slab should be so designed so that the middle-class persons get an incentive for decreasing their consumption. At the same time, this slab should not be too costly to poor to maintain minimum hygiene standards. Quantum of subsequent slab/slabs for higher consumption shall be such priced that it becomes penalty for luxurious consumption.

### 16.17.2 Strategy for Solving Metering Problem

Problems in metering need to be solved instead of simply dispensing with meters. The following should be the strategy:

a) The cost of meters also needs to be reduced by research and by large scale production.
b) Include cost of household meters alone in the project cost. The details regarding cost recovery and replacement of meters after warranty period can be seen in the Metering Policy mentioned in section 13.2 in Part A of this manual.

## 16.18 Bulk Metering

Bulk metering at head work, inlet, and outlet of WTP, inlets of ZBRs, inlets of ESRs are essential for supply management.

## 16.19 Minimum Diameter of Pipe

For urban and peri-urban areas, the minimum internal diameter of primary pipes shall be 100 mm for plain area and 80 mm for hilly areas. For secondary pipes in small lanes of hilly areas for facilitating with the HSC pipes, the diameter shall be between 32-63 mm as per the local conditions. For other rural areas, the minimum diameter of pipe shall be outer diameter of 63 mm in plain areas and 50 mm for hilly areas.

## 16.20 Design of Raw and Treated Water Mains up to tank

### 16.20.1 Pumping Mains

a. Raw water: Pumping Mains are designed with well-known method of economical diameters. In this method, the logic is based on the minimisation of total cost which comprises of costs of pumping main, cost of pumping machinery and capitalised cost of pumping expenditure based on consumption of electricity. For this exercise, instead of taking subsidised cost of electricity, the actual unit cost of electricity needs to be considered.

b. Clear water: Optimisation of pipes is discussed in Part A, Chapter 6 (Transmission of Water). While carrying out the exercise, when pipe diameter decreases, velocity increases and frictional loss (m/km) also increases, which in turn, increases the HP and pumping expenditure. By iterative process, the optimised diameter is thus computed. In short, the guiding tools are velocity (m/s) and head loss gradient (m/km) in the pipeline.

The design of pumping main, which pumps water to multiple service reservoirs, is discussed in the Part A, Chapter 6.

### 16.20.2 Gravity Mains

The same tool of optimisation of pipes, i.e., velocity (m/s) and head loss gradient (m/km) needs to be used in the design of diameters of gravity mains as vividly and as prudently as it is used in the design of pumping mains.

Normally, diameters, lengths, pipe material, LSL of MBR, FSL, and demands of ESRs are fed as data that the software uses to analyse the data and computes the residual head at the inlets (FSLs) of each ESR to be served by that MBR.

All pipelines from source to ESRs shall be laid on all-season roads and branch roads to WTP, MBR and ESRs shall be provided in the project along with its cost.

### 16.21 Residual Nodal Head in distribution system

(a) It shall be as per Table 2.7 of Part A, Chapter 2 for the cities.
(b) For peri-urban areas, the minimum residual head shall be 15 m.
(c) Jal Jeevan Mission allowed use of stainless steel flow control valve (FCV) to control flow and pressures in house service connection. As this FCV reduces the residual pressure at ferrule, the residual pressure in village schemes that use such FCV shall be 12 m.
(d) However, for village schemes that are not using such FCVs, residual pressure shall be 7 m.

### 16.22 Capacity of ESR

Capacity for ESRs of urban-rural schemes shall be as per the Table 2.7 of Part A, Chapter 2.

### 16.23 Fire Requirement

(a) Urban part: It shall be as per the Table 2.7 of Part A, Chapter 2.
(b) Enrouted villages: It shall be same as per (a) above, however, the value of population (P) shall be considered as population (in thousands) of the ultimate stage (30 years) of the villages under jurisdiction of each ZBR

Water for extinguishing fire outbreak in villages should be stored in ZBRs.

### 16.24 Number and Location of Isolation Valves

It shall be as per the Table 2.7 of Part A, Chapter 2. For enabling effective breakdown maintenance of leaky pipes in distribution system, isolation valve at appropriate locations should be provided in adequate number to isolate the network. As-built drawing showing the locations of isolation valves that should be readily available to maintenance staff.

### 16.25 Control valves

Control valves such as pressure reducing valve (PRV) and flow control valve (FCV) are vital for equitable distribution of water and equal terminal pressures.

### 16.26 Pipe Material

Distribution system – Provide metallic and/ or non-metallic pipes as per the site and service conditions.

Raw/treated water pumping mains, transmission mains and feeder mains, are the arteries of water supply projects and should be laid with metallic pipe having internal lining. If non-metallic pipes are proposed, they shall be duly justified.

Gravity transmission mains, inside and outside city areas, should be based on economical size of the gravity mains. The metallic pipes shall be preferred. If non-metallic pipes are proposed, they shall be duly justified.

## 16.27 Laying of Pipelines

Minimum cover of 0.9m is recommended, however cover should be provided as per the respective BIS code for different pipe materials & suiting to the local field conditions. Laying of pipe shall be as per procedure for laying given in Part A, Chapter 11. In colder region (like Ladakh, J&K, etc.) the pipes have to be provided with thermal insulation.

## 16.28 Flow Computation

Flow can be computed using Hazen-Williams method or Darcy-Weisbach method.

## 16.29 Hydraulic Model for urban-rural scheme

It is described in the Part A, Chapter 12 (Service Reservoir and Distribution System).

## 16.30 Designing of distribution system

It is described in the Part A, Chapter 12 (Service Reservoir and Distribution System). However, operation zones and district metered areas (DMAs) are discussed as below:

### 16.30.1 OZ and DMAs for Urban and Peri-Urban Areas

**Operational zone (OZ)** should be hydraulically discrete, and each OZ is the jurisdiction of each ESR/GSR to serve water supply. Performance of distribution of water depends on size of OZ of ESR/GSR or its jurisdiction. A typical concept of OZ of urban-rural scheme is shown in Figure 16.8. The OZ is subdivided in district metering areas (DMAs).

**DMA:** DMA is a hydraulically discrete subdivision of a large network, created by closing of isolation valves interconnecting the surrounding network and thus isolating area. DMA receives water from bulk pipeline coming from ESR and supplies continuous water through 100% metering of consumers.

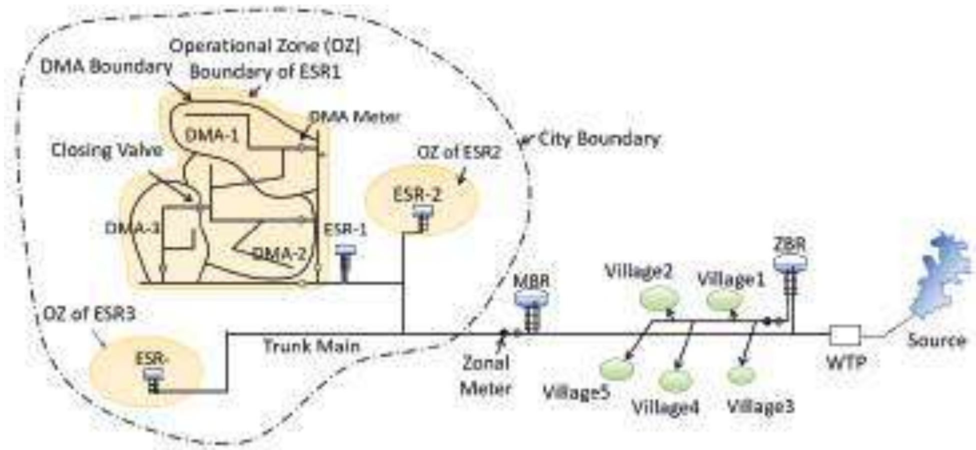


Figure 16.8: A typical urban-rural explaining concept of OZ and DMA

The design criteria for OZ and DMA, along with the detailed design procedure of distribution system, is explained in Part A, Chapter 12 (Service Reservoir and Distribution System).

### 16.30.2 For enrouted villages and RRWSS

Each village shall be considered as individual operation zone for which one service tank is supplying water. If the size of the village is big enough (more than 500 to 3000 connections in plain areas and 500 to 1500 connections in hilly areas), aDMA shall be considered, as given in Part A, Chapter 12.

## 16.31 Design OF Transmission Mains of Urban-Rural

Detailed design procedure of transmission main is discussed in Part A, Chapter 6 (Transmission of Water).

## 16.32 Solar Water Pumping Systems

Due to the pumping systems, energy consumption represents the biggest part of recurring energy expenses in the drinking water & sewerage sector—sometimes up to 70%, impacting the O&M sustainability. Erratic availability of power / voltage may lead to potential damage or reduced lifespan of the pumps. In terms of reaching the absolute poorest, this service delivery model should include the affordable water price & include subsidies to support most marginalized households where required. Hence an alternative solution for sustainable energy supply should be sought in the field of Renewable Energy Sources (RES). Among the renewable energy sources, solar energy is the most widely used source in water & sewerage sector, as such availability of solar resources are abundance in most part of the country. The economic benefits and performance of Solar Photovoltaic Systems depend strongly on the global irradiation of the geographic location where the system is installed and local climatic & environmental parameters also have an impact. Solar Energy Systems requires negligible maintenance & with no recurring power expenses except regular check-ups hence it is considered an appropriate alternative solution. Water Supply System has to meet water needs constantly at required level of reliability over the whole planning period. While planning water supply systems, conjunctive use of solar – powered water system will be explored to reduce the recurring energy cost of water supply & sewerage systems. Reduction of conventional energy use and $CO_2$ emissions in the urban water supply system must be achieved without compromising the water needs of all users.

The available options can be:

1) Stand-alone System – for small systems,
2) Hybrid System – can be operated with solar energy during the sunny hours only. Possible energy bills saving can be in between 40-50%
3) Grid Tied System with net metering basis – Solar energy so generated, to be transmitted to the grid possible energy saving can be plus 90%.

The grid tied systems can be located either on-site or distant locations subject to availability of land. For the urban & regional water supply & sewerage schemes, Hybrid / Grid tied system / both in combination can be considered as per techno-economic feasibility analysis based on the site specific conditions & requirements. Hence optimal system sizing & selection (various components i.e. Pump, Photovoltaic array, Inverter, transformers etc.) can be carried out in consideration of lean period insolation, available sunny days over the year & local environmental conditions in consideration with techno-economic viability. Possible installation options are:

Fig No. 1

Fig No. 2

Fig No. 3

Fig No. 4

Fig No. 5

Fig No. 6

Figure 16.9 (1 to 6): Possible Installation Options

Key design requirements are as follows

- Data Collection – Geographic Location, Design Period, Designed Water Demands, Lean Period Total Dynamic Head, Site Specific Sunny Days & Worst Month Peak Sunshine Hour
- Design Process –
  1) Pump Electrical Energy

     Energy in kW = $\left[\frac{Q*TDH}{102*\eta}\right] PSH$

     Where Q = Flow rate (LPS); TDH = Lean period Total Dynamic Head; q = Combined Efficiency of Pump & Motor (as per manufacturer); PSH = Peak Sunshine Hour

     <u>Note:</u> Pump can also be designed using available softwares
  2) Array Sizing for standalone System (AS in kWp) = EE *(1 + Losses in percentage)
  3) Array Sizing for Grid Tied System (AS in kWp) = [Annual energy requirement / (No. of sunny days X Lean month PSH)] X (1 + Losses in percentage)

**Example –**

**A. Off Grid Stand Alone System**

**Given Data:**

Design Population — 1000; Water Supply Level — 65 LPCD; Total Design Head — 60 m; Peak Sunshine Hour — 5 hours; Wire to water efficiency — 58%; Water Density — 1000 (kg/m$^3$); Specific Gravity of Water — 9.81(kga/s$^2$); Solar Panel Array Losses — 40%

**Calculation:**

**Water Demand (Q) = 65 m$^3$/day;**

Energy in kW= $\left[\frac{65*1000*60}{(3600*24)*102*0.58}\right]5 = 3.81$

Pump Electrical Energy (EE in kW) = 3.81 (5.1 Horse Power — commercial available 5 HP) Array Sizing in kW = 5.65 kW considering radiation uncertainties

**B. On Grid –Grid Tied (Net Metering Basis) System**

**Given Data**: Mardanpur Group Water Supply Scheme Block Budhni; District: Sehore; Capacity - 25.65 MLD

Operating Horse Power - 1240 HP; Pumping Hours - 22; Average Peak Sunshine Hour - 5.5 hours; Power Factor - 0.96; Sunny Days – 300; Solar Panel Array Losses – 40%

**Calculation**:

Array Sizing in kW = [(HP * 0.746) * Pumping Hours * 365] * (1+ Losses in percentage)

Power Factor * 300 * PSH

Required Array Sizing = 6565.21 kW; Land Requirement @ 6 sqm/kW = 39390 sqm

Payback Period – 7 years; Sufficient Land is available at treatment plant site.

Note: Present cost of production of water is costlier than the production of water with the installation of solar system.

**C. On Grid –Grid Tied (Net Metering Basis) Hybrid System**

**Given Data**: Bhopal – Kolar Water Supply Scheme; Capacity – 162 MLD; Horse Power - 3000 HP; Pumping Hours – 23 hours

Required Array Sizing 16107.69 kW

Note: In this case due to limited availability of land, 6000 kW system can be installed.

- Installation Requisite – Direction true south; Orientation Site's geographical Latitude; Shadow free area; sufficient land available for installation & also future expansion; No HT line passing over & above Solar Array.

Figure 16.10: Solar Installation

To enhance the solar yield an appropriate technically feasible & cost effective tracking system is to be provided such as motionless stationary tracking system. Higher sizing of panels is recommended to take care of solar radiation uncertainties as per site specific needs (10-20%). Regular washing & cleaning mechanism of the PV modules is mandatory i.e. for achieving the optimal power generation as per design over full planning period. To ensure solar system performance, IoT enabled measurement & monitoring system shall be the integral part as per site specific needs in consideration with Annexure no. I of “Specification for Photovoltaic Water Pumping System” dated 22.03.2023 issued by Ministry of New & Renewable Energy, GoI. For bigger water supply systems possibility for PPP mode can be explored.

The planning period for the solar photovoltaic systems can be adopted as 15 years in-line with pump design life. As per needs later on solar panel array can be further augmented. Energy yield is dependent on efficiency of the solar modules hence quality of solar modules should be ensured as per MNRE guidelines. Decision making key requirements for adoption of solar energy system in urban water supply schemes – availability of land; technical feasibility; financial viability; life cycle cost analysis etc.

The solar water pumping system shall be considered after comparing the financial feseability of the conventional energy and solar energy sources by taking into account capital cost, O&M cost, land availability and other local conditions.