Key points about water supply

- Aim to supply sufficient water for a water consumption of at least 40 litres per person per day (lpd).
- Standpost supplies should be designed for a consumption of about 40 lpd and those to house connections for 100-150 lpd.
- The maximum distance from any house to a standpost should not exceed 100m.
- Most water supply systems are arranged in a hierarchical system. Action at one level within the supply hierarchy will not have significant effects if serious deficiencies remain at another level. The first task in planning is therefore to identify any deficiencies.
- The normal minimum standard size for tertiary mains is 75mm.
- Where a 24hr/day continuous supply is not possible, designs should ensure that water mains do not pass through drains and other sources of contaminated water.
- Systems served by a single tubewell should be avoided since they will fail completely in the event of a pump breakdown.
- Provision of elevated storage will provide benefits where the supply capacity is equal to or greater than the peak daily demand. Otherwise, the first priority should be to increase supply capacity.
- Primary and secondary distribution systems should be loops. The number of sluice valves required to subdivide the system can be reduced if tertiary mains are branches.
- Sluice valves and fire hydrants should not be provided if they cannot be maintained. In practical terms, this means that it should be possible to isolate areas of 5-10 hectares rather than every branch main.

Section 4b

Water Supply

Tool W1 Water Supply: Objectives and options

Objectives

The principal objective is to provide a reliable supply of water in sufficient quantity and of adequate quality which is readily accessible to the consumers.

Water quantity

People need water principally for drinking, cooking, bathing, and laundry. The quantity of water to which people have access has perhaps the most significant effect on health. The presence of many common illnesses such as diarrhoea, dysentery, enteric fevers, infectious skin and eye diseases, and certain louse-borne infections can be reduced by improvements in personal and domestic hygiene. The availability of sufficient *quantity* of water for bathing, cleaning and laundry is thus of great importance, whereas the *quality* of this water is not especially important.

Accessibility and reliability

Improved access to and reliability of the water supply will be of particular benefit to women in terms of time saved and the potential to realise health benefits for the family through improved hygiene in the home.

The water resources and distribution systems of many towns and cities are inadequate to meet the required demand. One result of this is water rationing, which the authorities achieve by limiting the time for which water is supplied into different parts of the distribution system; some areas may only receive one hour's supply daily. From the perspective of the users, the supply is unreliable, and it is therefore important to address deficiencies in bulk supply and distribution at the city level.

The majority of low-income people collect their water from public supply points such as standposts, handpumps or shallow wells. The location and number of public supply points provided is an important factor in water supply planning. In areas where the piped water supply is unreliable, it is advisable to investigate the use of multiple sources, for example through a combination of standposts and shallow wells. Storage of water in the home helps to ensure some continuity of supply.

Water quality

Water which is collected from public supply points, such as standposts or wells, is frequently contaminated during collection and storage in the household, because of a lack of understanding of basic hygiene. Such contamination can occur even if the water issuing from the standpost is uncontaminated. Whilst the provision of bacteriologically pure water is a desirable long-term goal, it is not a prerequisite for improving existing supplies. It is widely accepted that access to increased quantities of water in conjunction with good excreta disposal and hygiene education are more important than water quality alone in achieving environmental health improvements.

Options: Sources of water

Unprotected sources

Unprotected surface water sources such as ponds, streams, ditches or canals which are seriously polluted are difficult to improve and should be abandoned at all costs.

Off-site sources

The source of mains water supply for a town or city may be either:

- surface water, which is water abstracted directly from streams, rivers and lakes; or
- groundwater, which is abstracted from the aquifers beneath the ground.

In some cases a combination of surface and groundwater sources may be used. The water is usually treated to be of potable quality, and is distributed via a network of pipes known as the ‘distribution system’. Water for low-income housing developments is commonly taken from the mains and distributed locally around the site through a system of smaller pipes to public standposts, or to individual house connections.

On-site groundwater

If groundwater of good quality exists on the site, there is no reason why it should not provide for all water requirements. However, unprotected shallow wells and springs are prone to pollution by dirty water, mud, and excreta which result from human and animal activity around the water source.

One of the best means of protecting and abstracting groundwater is to drill a borehole and cap it with a handpump to raise the water. Handpumps can be used at public supply points and for individual household supplies. If the water table is within 1 or 2 metres of ground level, the groundwater may be contaminated by seepage from open drains, sewers, and latrine pits. In such cases it is advisable to provide an alternative piped water supply which, at the very least, provides sufficient water for drinking and cooking purposes. In general, groundwater is safer from pollution when the aquifer is deep and confined.

Handpumps or shallow wells are sometimes used to supplement piped water supply which may be erratic, intermittent and generally inadequate.

Rainwater

The direct collection and use of rainwater is widely practised at an informal level by householders. A tile or sheet roof acts as the ‘catchment’, the rain is collected in gutters and led into storage vessels as shown in Figure W1. Rainwater is a useful resource which can meet at least part of the water demand at certain times of the year. Public sector intervention with a large programme is unlikely to be appropriate; communities should be made aware of the potential use of rainwater and provided with advice on how to improve their collection system.

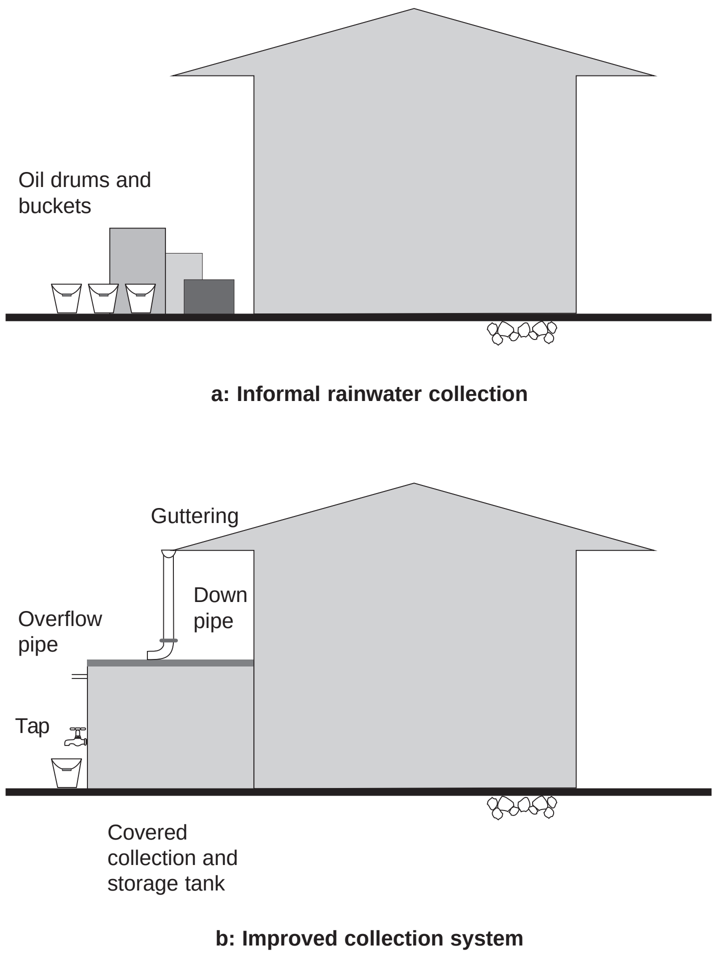


Figure W1. Household rainwater collection

Options: Levels of service

The level of service provided to a community can be defined in terms of the following:

- the quantity of water supplied per person per day;
- the quality of the water supplied;
- the continuity and pressure at which water is delivered in a piped system; and
- the number and location of water supply points.

There are three options for the distribution of water which reflect different levels of service provision for the quantity of water supplied. Note that land tenure or ownership of house/land is often an important issue governing whether supplies will be sanctioned even though users are ready to pay for the service.

Communal supply points

Water is provided at a limited number of supply points to which individuals walk to collect their water. The key point is that a clearly defined user group is essential (see Tool 9). Bathing and washing of clothes may be done at the supply point; water is carried back to the house and stored in vessels or a small tank until required. For piped water supplies, public taps are provided on standposts as shown in Figure W2**.** If groundwater is used, communal wells or handpumps are provided.

It must be ensured that there are sufficient supply points to enable users to obtain enough water and to select the location so that people do not have to walk unreasonably long distances. The definition of user groups and location of supply points are key issues for action planning.

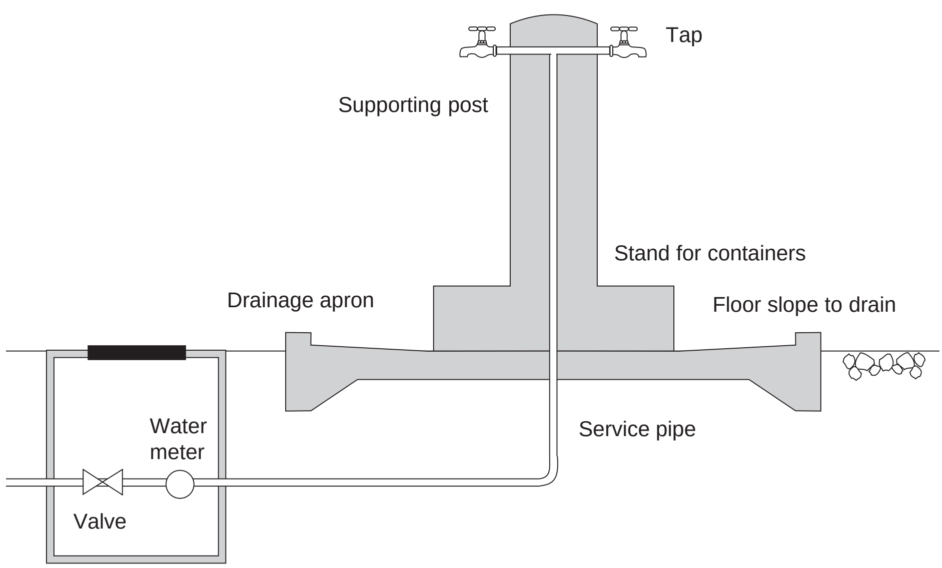


Figure W2. Standpost

Individual house supply

Each individual house has either its own private tap connected to the site distribution system, or its own open well or handpump if groundwater is used. Most households store water either in purpose-built elevated tanks, or in smaller vessels, both for convenience and in order to maintain the availability of water if the mains supply is unreliable.

Water vendors

Many people in urban areas obtain water from commercial vendors who deliver water to individual houses. This practice normally exists where the formal water supply is inadequate; water vendors are thus satisfying a need for which low-income people are often prepared to pay a high price.

Tool W2 Water Supply: Planning

The planning process for upgrading schemes will have to cover some or all of the following:

- the tertiary facilities in the area to be upgraded;
- the secondary distribution system serving the area; and
- the supply to the overall supply zone of which the area to be upgraded forms a part.

Tertiary facilities

The presence or otherwise of branch distribution mains and, where appropriate, public standpost facilities should be established from official records and from surveys on site. (Note that official records are not always accurate and should always be cross-checked). In general, any mains of 75mm and greater serving single streets and lanes can be assumed to be adequate. Similarly, a 100mm main serving up to about 100 houses should be adequate. Replacement will only be necessary if there is strong evidence that such mains are in poor condition. The presence of long house connections along the sides of a street is a good indication that no main runs along it. Existing mains should be plotted on a plan at a scale of 1:2500 or greater. The routes of proposed mains can be shown on the same plan once it has been decided whether the supply is to be to standposts or house connections. They will usually be predetermined by existing rights of way and the location of the nearest secondary mains.

Primary and secondary mains

The initial concern with regard to primary and secondary mains is to:

- determine the location of the nearest mains to the area to be upgraded; and
- establish whether they have sufficient capacity to serve the proposed scheme.

The primary/secondary system includes all mains of 150mm diameter and greater; in small systems, some 100mm mains may be included in the secondary network. The system should form a looped grid with mains spaced at intervals of about 500m. Looped systems are more flexible because they allow water to take alternative routes through the system. This means that operating pressures throughout the system are kept at a more constant level and at least a partial supply can be maintained in the event of a pipe failure.

For small schemes, which are close to an existing secondary main, the adequacy of supply can be checked by measuring the pressure of supply in the main at the point where the connection to the new scheme will be made. The pressure measurement should be made at a time of maximum demand, normally around 0800 hours. The supply can be assumed to be adequate if the pressure head in the main is at least 10 metres above the highest point in the area to be served by the proposed scheme. If this is the case, detailed design of the scheme may commence without further consideration of overall planning issues.

For larger schemes and where pressure in the mains indicates problems with the supply, analysis of the primary/secondary distribution system will usually be required. The sizes and locations of existing primary/secondary mains

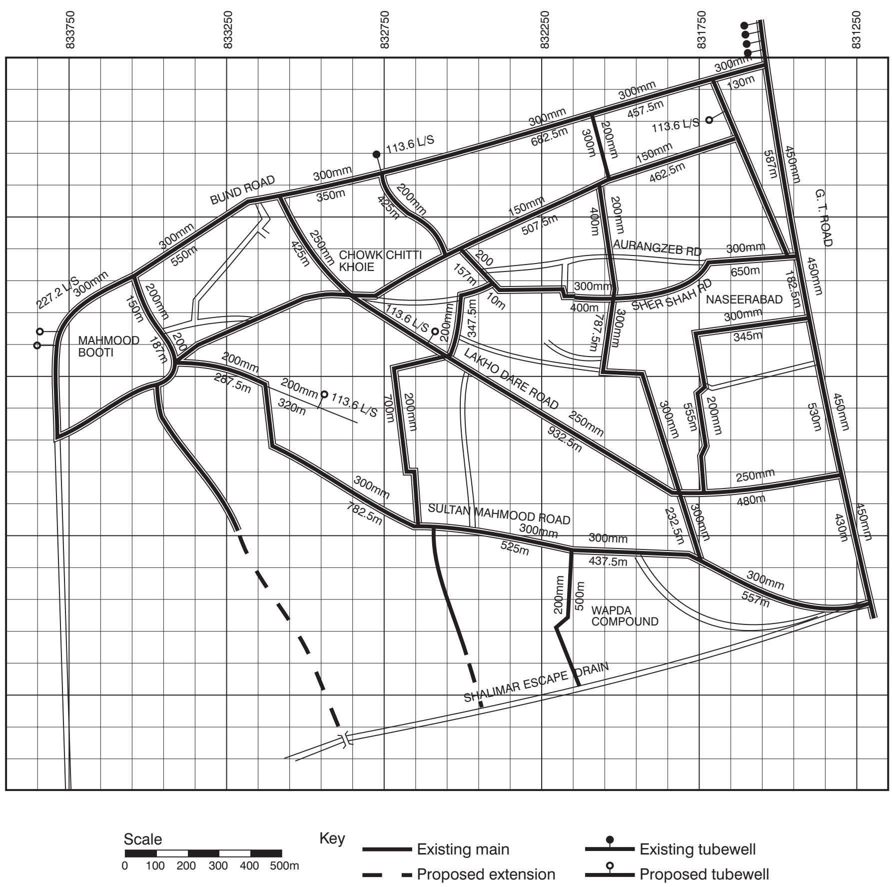


Figure W3. Secondary distribution system in North-East Lahore

should be established and plotted at a scale of between 1:2000 and 1:5000 so that any missing links in the system can be identified. Where there is no existing system, it will be necessary to decide the routes to be followed by the primary/secondary mains. As far as is possible, these mains should follow through roads and it should be recognised that the irregular layouts of many informal areas will mean that the grid will not be particularly regular. Figure W3 shows the main grid for the North East Lahore Upgrading Area.

The proposed primary/secondary grid must be analysed to confirm that it is adequate to serve its supply area. An introduction to analysis methods is given later in the section on detailed design.

Adequacy of existing supply

In order to assess the adequacy of the existing supply it is necessary to have information on the extent of the supply area, the availability of water to supply that area, the design population and any industrial, commercial or institutional demands for water in the area.

Extent of supply area to be considered

For centralised systems, the supply area considered should be that covered by one supply zone or easily isolated sub-zone as shown in Figure W4. Information on the extent of supply zones can be obtained from the operating authority. Where the existing supply is from a number of tubewells, each serving its own distribution system, it is possible to consider each system separately. However, it is preferable to consider the possibility of combining several such systems together so that there is the option of providing back-up supply when one tubewell is not operating. As a general rule, there should be at least three tubewells per supply zone. On the other hand, there is little point in excessive centralisation of systems which rely on separate tubewell sources. Figure W5 gives an example of a system supplied by local tubewells.

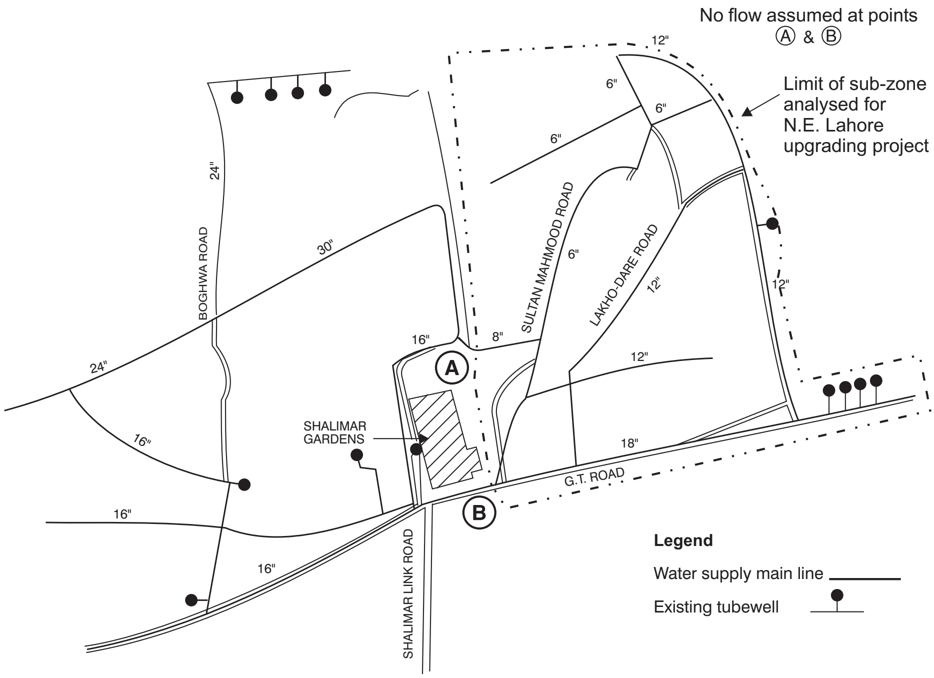


Figure W4. Subdivision of water supply zone for initial planning purposes

There may be operational advantages in delivering water from tubewells direct to an elevated reservoir from which water can gravitate into supply. This will allow water to be chlorinated at a single point for each zone rather than at individual tubewells and will thus allow much greater control over the chlorination process. The possibility of providing such a system should be considered at the planning stage, since although it may not be possible to implement it in the short term, it may affect the extent of the supply area to be considered.

Existing supply capacity

Estimates of the amount of water supplied should ideally be based on the results of metering, either at the point at which the water enters a zone from the larger system or of the discharges from individual tubewells. Unfortunately, there are few bulk meters on water supplies at present and rough estimates may be all that is possible. The introduction of bulk metering should be a priority wherever it is not already present. Where there are no bulk meters, approximate supply estimates may be obtained from information on the rated capacity of tubewells and water treatment facilities. However, such information should be treated with caution as the actual capacity will not always be the same as the rated capacity.

Population

Information on the present and future population of the supply area and the per-capita water demand are required to calculate the domestic demand for water. In developed areas, the population can be obtained by multiplying the number of housing units by the average household size. The former can be obtained from physical surveys and the latter from social surveys. Further information on calculating populations is given in Annex 1**.**

Industrial, commercial and institutional demands

At the planning stage, information should be obtained on the water demand from any large industrial, commercial or institutional premises within the supply area. It will not normally be necessary to make specific allowance for the demand from small workshops, shops and local primary schools. Further information on industrial, commercial and institutional demands is given in Annex 1.

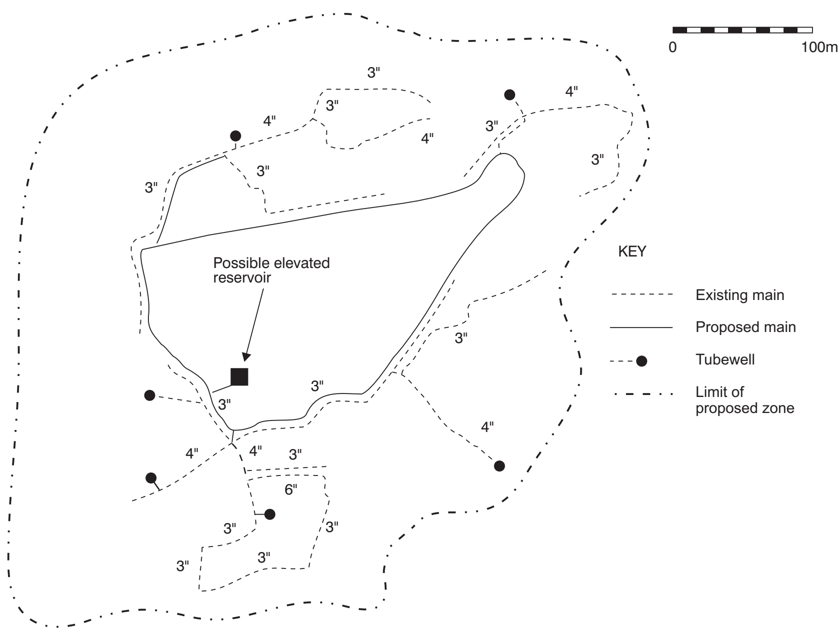


Figure W5. Local tubewell-based systems combined into one

Assessment of existing per-capita supply

In predominantly residential areas, the average amount of water provided per-capita in a day is given by q_d where:

$$q_d = Q_d \times 1000/P$$

in which q_d is in litres, Q_d is the total amount of water supplied per day in m^3 and P is the population. Where the supply is from tubewells or other sources that do not operate full time, it may also be useful to work out the maximum rate of per-capita supply, given by q_h where:

$$q_h = Q_h \times 1000/P$$

in which Q_h is the maximum rate of supply in m^3/hr. If the ratio $24Q_h/Q_d$ is much greater than 1, it suggests that there is scope for increasing the level of service by increasing the periods of supply.

Where there are significant industrial, commercial or institutional demands, the per-capita demand should be based on a modified supply figure from which these non-domestic demands have been deducted.

Decisions on levels of service

Type of connections

The existing average daily per-capita supply provides a guide to the type of connections to be provided in an upgrading scheme. In general, house connections will be preferable to standposts where q_d is 100 lpd or more. Where it is less than about 50 lpd, extensions to the system should probably be to standposts in the first instance. The choice will also be affected by the expectations of the beneficiaries which will in their turn be influenced by the existing situation. For instance, it is unlikely that public standposts alone will be appropriate where many plots already have handpumps drawing palatable groundwater from a shallow aquifer. However, there will be many situations in which it will be necessary to provide some public standposts to supply water to those people who cannot afford house connections. In recently developed areas, the best strategy may be to provide public standposts in the first instance while recognising that increasing numbers of house connections will be made over time. In such areas, it may be advisable to design primary and secondary mains for the demand from house connections even though standposts are provided initially.

Continuity of supply

Where the existing supply is provided for very limited periods, it will be unrealistic to expect a continuous supply in the near future. Where the existing supply is provided for more than about 15 hours per day, the possibilities for providing a continuous supply should be investigated.

Where separate supply systems are served by single tubewells, the possibility of combining the systems and staggering the shut down periods for tubewells should be considered. This should reduce the periods when there is no supply although problems of low pressure will still occur if the combined supply capacity is inadequate. In the longer term, there could be operational advantages in linking the tubewells via separate supply mains to a central elevated tank from which water would gravitate to supply. This would allow water to be chlorinated at a single point for each system rather than at individual tubewells.

Design per-capita consumption

The design per-capita consumption should be decided in the light of the intended levels of service. Typical values will be:

- 30-50 lpd for standpost supplies; and
- 100-150 lpd for house connections with a near continuous supply.

Where possible, the figures should be based on metered consumptions for an area similar in character to the project area but with a good water supply.

Where the supply is only provided for limited periods, a figure of less than 100 lpd may have to be assumed for house connections, at least in the short term.

Additional bulk supply and storage facilities

The design consumption figures are used to calculate the bulk supply and storage capacities required. The maximum amount of water required in a day is given by Q where:

$$Q = P\{c \times f_d + w\}/1000$$

where Q is in cubic metres per day;
P is the design population;
c is the per-capita water consumption in litres per day;
f_d is the peak day factor, i.e. the peak daily demand divided by the average daily demand;
w is the per-capita allowance for leakage in litres per day.

In most informal areas, it will not be necessary to make additional allowance for industrial, commercial and institutional demands.

The value of $\mathbf{f_d}$ will typically be around 1.1 while **w** can be taken to be 25-40% of **c**, depending on the expected level of maintenance. An additional allowance for wastage at the tap, equal to about 25% of **c** should be made for supplies from standposts.

For systems with limited amounts of high level storage, water must be supplied to the system at rather higher rates to cater for variations in demand over the day. The relationship between supply capacity, the peak daily requirement for water (Q) and the storage capacity is shown in Figure W6. The peak daily water requirement figure used should include allowance for leakage and wastage.

The priorities for action will depend on the capacity of production facilities relative to demands, the level of provision of storage facilities and the operating regime. These factors are inter-dependent and their combined effect must be analysed. However, the following basic rules can be used to make preliminary decisions:

- where water is provided for less than about 6 hours in a day, the priority should be to extend the period of supply;
- where no elevated storage is available, little is to be gained by pumping into supply during night-time periods of low demand;
- where the supply capacity is less than about 75% of Q, the priority should be to increase supply; and
- in other cases, the ratios of existing supply capacity to Q and available storage capacity should be calculated and plotted on Figure W6. If the point is below the line, possible upgrading strategies are represented graphically by the range of projections to between points (a) and (b) on the line.

Storage may be provided either in centralised elevated reservoirs or in small tanks located on-plot. Small on-plot tanks can be constructed by individuals and community initiatives should therefore seek to encourage their use where preliminary analysis has shown that provision of storage will bring benefits. Tanks may be located on roofs and should typically have capacities in the range 500-1000 litres. (As a rough guide allow 100 litres per person).

Where centralised elevated reservoirs or storage tanks are to be provided, their location will be influenced by topography. In general the best locations will be at the highest points within their supply areas. However, all other things being equal, they should be located as close to the centre of their supply areas as possible. Analysis of capital and running costs is required to determine the most economic combination of increased production capacity and storage. Such analysis is beyond the scope of the present manual.

Water may be delivered to elevated reservoirs via supply mains that are completely separate from the distribution system or through mains that form part of the distribution system. The former system is more expensive but allows greater control over the quality of water delivered to the consumer. This is because all water has to pass through the reservoir and so there will not be large variations in the length of time that the water is in the system. This means that chlorination levels are relatively easy to control. Where water is supplied to the reservoir via the distribution system, some areas will be served from the reservoir at times and directly from the source at other times. This means that the length of time that the water is in the system will vary and this in turn will affect the residual chlorine concentration. Despite this disadvantage, a combined supply/distribution system will often be the only option in the short term where funds are limited.

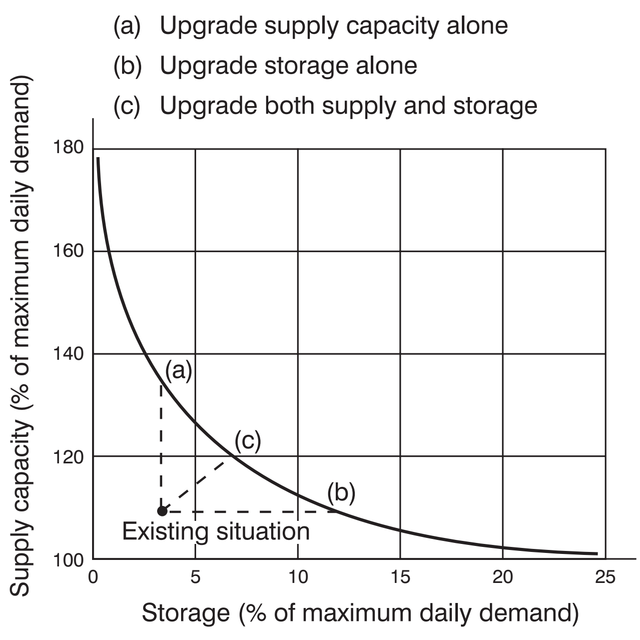


Figure W6. Relationship between required supply and storage capacites

Annex 1

Information required for overall planning and design

Population

An estimate of the existing population in an area can often be obtained from census data, which will normally be available for individual wards. For the detailed calculation of future population, population densities can be obtained by multiplying the average housing density in different areas by an estimate of the average household size. Calculations for the former should allow for development of presently undeveloped plots. The best procedure will be to calculate densities in representative fully developed areas and apply the figures thus obtained to all similar areas within the supply area. The present average household size can be obtained from analysis of social survey results. Some increase with time will be appropriate, typically 10-20% over a 30 year design period.

Per-capita consumption

Typical per-capita consumption figures have already been given in the main text. Per-capita demands in areas with house connections vary widely, depending on the continuity and pressure of the supply and the opportunities for using water on-plot. Demands tend to be much higher where houses have gardens which require watering. The maximum average per-capita demand in informal areas is unlikely to exceed about 200 lpd and may be much lower where supply is intermittent. If possible, design figures should be based on the results of metering studies on houses already receiving a good water supply. Some care is required when conducting such studies since water meters tend to over-record when there is air in the system due to a discontinuous supply.

Industrial, commercial and institutional demands

Most areas to be upgraded contain small businesses, shops and facilities such as schools and health centres. In some places, industries will be situated within or adjacent to upgrading areas. Allowance must be made in design for the water demand from such premises.

In general, small workshops and commercial premises do not use a lot of water and can be treated as standard housing units for design purposes. Typical standard allowances for the demand from schools and clinics are 45 lpd and 350-500 l per bed per day respectively. Where possible, information should be obtained from metered records.

Where large factories are present within the design area, their water use should be considered individually. Bear in mind that some factories will have their own sources of water and will not draw large quantities from the public system. Large users will usually be metered and historic information on their consumption should be available from metered records. This information should be used in design, adjusted as necessary to accommodate plans for increased consumption in the future.

Fire demands

Separate allowance for fire fighting demands is not required in most low income areas. Any fire hydrants should be on primary and secondary mains, ideally of 150mm dia. and over, which should normally be capable of carrying the required flow of 15 litres per second to any fire hydrant at a residual pressure head of 4 metres.

The total daily water demand is the sum of the domestic, commercial and institutional demands. Provision for fire demand should not be included in the total.

Peak demands

Demand for water varies through the year, reaching a peak during hot dry periods. A daily variation is superimposed on this gradual variation as water demand peaks in the morning and falls to a minimum at night. The normal design procedure is to apply peak factors to the average demands in order to determine maximum demands.

The peak day factor, defined as the ratio of the maximum daily demand to the average daily demand, is used in the design of production and storage facilities and bulk supply mains. When unconstrained, its magnitude depends on climatic factors and the requirement for seasonal uses such as garden watering. However, peak consumption is often constrained by the capacity of the supply system. In the absence of site specific information, a value of 1.1 may be taken for typical informal areas.

The peak hour factor is used in the design of primary and secondary distribution mains. It may be defined as the ratio of the maximum hourly demand to either the maximum or average daily demand. In this manual, it is related to the average daily demand. Its magnitude depends on a number of factors, including the number of houses served, the relative number of house connections and standposts, and the extent to which houses, commercial and industrial premises have their own water storage facilities. For the design of a primary/secondary distribution system with a continuous or near continuous supply, a factor of 2.5 should be taken if local data is not available.

Where water is supplied for less than about 12 hours per day, peak factors are likely to be higher. Where local data is not available, the peak hour factor in such situations may be taken as 30/N where N is the number of hours supply during the day.

The peak hour factors given above apply to areas with house connections. People who rely on standposts have to queue for their water and at peak times all standposts are in continuous use. The capacity of the distribution system for a standpost supply can therefore be calculated if the number of standposts and the quantity of water discharging from each standpost are known.

Peak hour factors vary with the population served, the smaller the supply area, the larger is the peak factor. For this reason factors for tertiary mains are much higher than those given above for primary/secondary systems. In practice, it is better to calculate the peak flows in tertiary mains directly using probability theory. Suggested figures for design obtained from probability based analysis have been given in the section on the design of tertiary mains in tool W3.

Leakage and wastage

Leakage from the distribution system must be allowed for when calculating flows. Even in well maintained systems, it is likely to be 15-20% of the total supply. In the absence of local data, the figure used for design should be realistic, bearing in mind the age of existing elements of the system and the likely level of maintenance. Typical allowances for leakage will be in the range 25-40% of the average daily demand.

The term wastage is used here to refer to water wasted within the consumer‘s premises. Causes of wastage include leaking pipes and broken taps. If there is significant wastage, the apparent per-capita consumption will be increased.

The application of peak factors to this apparent average per-capita consumption will lead to over-design since wastage is more or less continuous and does not peak with peak demand. Where high levels of wastage are suspected, either the design per-capita consumption figure should be adjusted downward or the peak hour factor should be reduced.

Tool W3 Water supply: Design

General approach to distribution system design

When water flows through distribution mains, pressure head is lost because of friction. The object of design is to distribute head-losses between primary, secondary and tertiary mains and house connections so that the pressure at taps never falls below a minimum level. In practice, this is done by:

- specifying a minimum allowable head in the primary/secondary distribution system; and
- specifying maximum allowable head-losses in tertiary mains and connections.

For low-rise areas where there are few if any taps above ground floor level, the minimum head allowed in the primary/secondary system should be 10m. Where there are houses with taps at higher levels, an additional 3m should be allowed for each floor to which water has to be supplied. Note that these figures are in relation to the highest ground levels in the area served by the mains and not to the ground levels along the mains themselves.

Suitable maximum head-loss values in tertiary mains and connections are 3m and 2m respectively, leaving a minimum of 5m head above ground level available at the tap.

Details of design methods and rules for tertiary mains, house connections and standposts are given in the following section. An introduction is then given to the analysis and design of primary/secondary systems.

Design of tertiary mains

Tertiary mains may run through from one part of the main grid to another or they may be dead ends. Although the latter will provide marginally lower pressures, it reduces the number of valves necessary to subdivide the system and therefore has some operational advantages.

Many water supply agencies specify a minimum main diameter of 75mm but this is larger than required for hydraulic purposes for tertiary mains. Pipes in conventional materials such as asbestos cement and ductile iron are not manufactured in sizes smaller than 75mm but it is possible to use smaller diameter plastic and galvanised steel (GI) pipes for tertiary mains. The required diameter can be related to the number of houses served in accordance with the following guidelines:

1. For mains supplying house connections	
No. of houses	Diameter (mm)
12	38
20	50
40	75
100	100
200	150

2. For mains supplying standposts		
Flow (litres per sec)	No. of taps served	Diameter (mm)
1	3	38
2	6	50
5	15	75

For larger systems which serve only standposts, the mains should be designed on the assumption that all taps are open.

House connections

Assuming an allowable head-loss of 2m in the connection, a 12mm pipe is adequate for house connections up to about 10m in length. A 20mm pipe will be adequate for connections up to 100m in length. These figures are for single connections. 20mm pipes should be used for connections serving two houses.

Public standposts

The basic decisions to be made when designing for supply from public standposts are:

- how many taps are required; and
- where should these taps be located.

Number of taps required

Defining and establishing user groups is the key activity. In addition, we must also consider some basic design issues to ensure that there are a sufficient number of taps to fulfil the requirements. Factors include: the flow rate from the tap; the time for which standposts operate each day; the population served; and the per-capita water consumption.

The flow rate of water delivered by the tap depends upon both the size and make of the tap and the available head, (that is, the water pressure in the distribution pipe immediately upstream of the tap). The flow rates delivered by the most common types of tap for different values of available head are shown in Figure W7. A reasonable first estimate is to assume a minimum available head of 5 metres at the standpost. Standard half-inch and three-quarter inch taps deliver about 600 and 1000 litres per hour (0.17 and 0.27 litres per second) respectively at this pressure. In general, it is preferable to use three-quarter inch taps for standposts. For continuous use and allowing 25% wastage at the tap, the flow from a three-quarter inch tap will be sufficient to fill about 40 containers, each having a volume of 20 litres, in one hour.

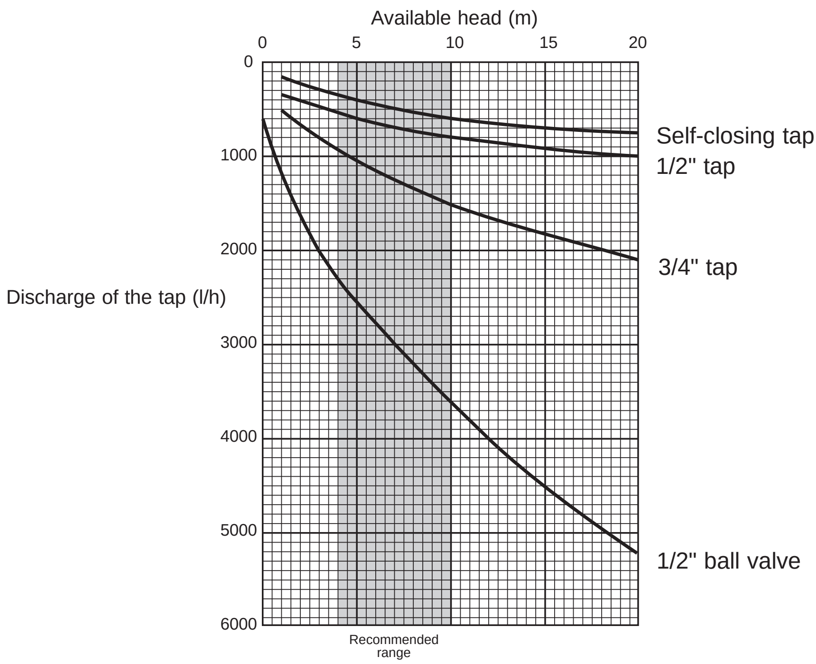


Figure W7. Discharge rates from standpost taps

Assuming a per-capita water consumption of 40 lpd, a single three-quarter inch tap would supply enough water for 240 people if operated continuously for 12 hours each day. In fact, the tap will only be used continuously at periods of peak demand and the number of people served by a single tap should be limited to 125. Where water is supplied to the standpost for 6 hours or less during the day, the number of people served by a single tap can be calculated from the formula:

$N = T \times D/(1.25 \times c)$
where N is the number of people served by a single tap;
T is the number of hours during which water is supplied each day;
D is the tap discharge in litres per hour;
c is the per-capita consumption in litres per day.

More than one tap should be provided at each standpost as the additional cost is negligible compared with the benefits from reducing the queuing time. The World Health Organisation recommends that there should not be more than 250 people served by several taps on a single standpost. The area in hectares which can be served by one standpost is equal to (nN/P) where n is the number of taps on the standpost and P is the population per hectare.

In less densely populated communities, the distance from the household to the standpost is likely to limit water use. All houses should be within 200 metres of a standpost. However, if plot sizes are very large and the housing density is correspondingly low, a standpost system may be grossly inefficient and it might be cheaper to provide house connections and meter the water consumption.

At public water supply points, considerable quantities of wastewater result from spillage and leakage; the standpost or handpump should be provided with an apron as shown on Figure W2 (see Tool W1) draining to a soakaway or drain in order to prevent insanitary conditions from developing. The design should be carried out with the aid of the community; their customs and habits in respect of water collection and use must be accommodated. For example, if people wish to bathe at the standpost, then a large paved and drained apron should be provided to enable them to do so.

Primary/secondary system design

Full consideration of the design of main reticulation systems is beyond the scope of this manual and only the main steps in design are listed below. These steps are:

- decide the system layout (see Tool W2);
- produce a simplified version of the system, removing smaller mains and any short lengths of main between junctions which are close to each other;
- define the pressures and supply rates at supply points (service reservoirs, tubewells and take-off points from trunk mains);
- define nodes at all supply points and at intervals throughout the system, including all junctions between mains;
- divide the area served by the system into sub-areas centred on these nodes and calculate the peak water requirement for each area, including allowance for leakage;
- define the maximum ground level in each sub-area together with ground levels and heads at supply points and minimum water levels in reservoirs;
- assign sizes to mains and analyse the system using an appropriate method. (Hardy-cross or a computer programme such as the LOOP programme distributed by the World Bank). Head-losses may be calculated from design charts or by the expression, adapted from the Hazen Williams formula:

$$h_f = 10.9(Q/C)^{1.85}L/D^{4.87}$$

where h_f is the head-loss in length L metres;
C is Hazen Williams coefficient;
D is the pipe diameter in metres; and
Q is the discharge in cubic metres per second.

Typical values of C for various pipe materials are as follows:

asbestos cement	140
uPVC	140-150
new cast-iron	130
old cast-iron	80

A headloss chart of uPVC pipe is given in Figure W8.

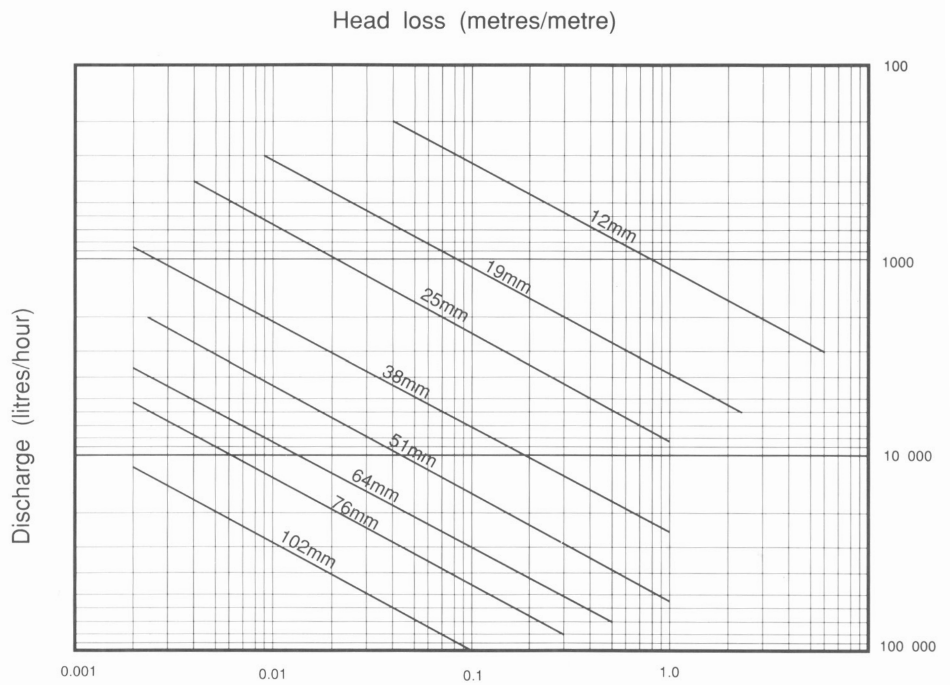


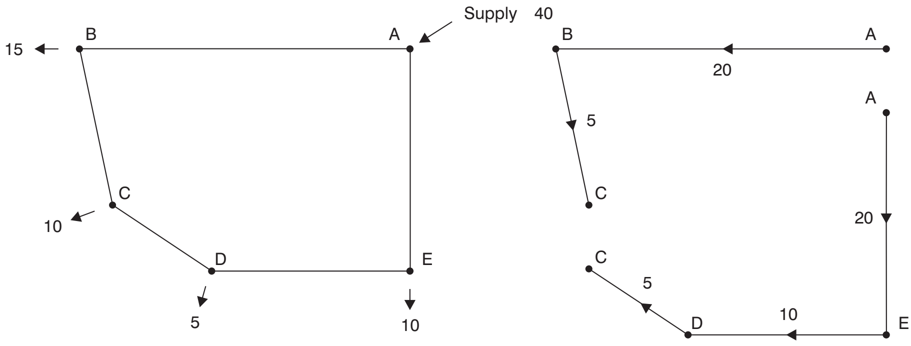
Figure W8. Headloss in uPVC pipes

- add additional mains and/or alter the main sizes as necessary to obtain at least the minimum allowable pressure head at all points in the system.

Further details of the method outlined above can be found in standard text-books. It involves fairly difficult calculations if a computer is not available. The following procedure can be adopted to give a rough approximation for fairly simple systems:

- sketch a plan of the system, showing the location of water demands;
- assume breaks in mains to eliminate loops and convert the system to a series of branches; the breaks should be located so that demands are roughly divided in relation to the capacity of mains;
- assign demands at nodes and proceed to analyse the system.

A simple example of the method is illustrated in Figure W9.



(a) Nodes, showing supply/demand in litres per second

(b) Network split down, showing assumed flows in each pipe

(c) Analyse as two branched systems as follows:

- Assume pipe diameters
- Calculate h_f in each pipe from Hazen Williams
- Check : i) $h_{f_{AB}} + h_{f_{BC}} = h_{f_{AE}} + h_{f_{ED}} + h_{f_{DC}}$
  ii) Residual heads at all nodes are within the range specified
- If these checks are not satisfied, alter the pipe diameters and recalculate h_f

Figure W9. Simplification of looped system for calculation purposes

The elimination of loops means that flows and hence head-losses in all pipes can be calculated directly, removing the need for complex iterative calculations. The calculation process is thus greatly simplified. The procedure will tend to overestimate flows in some mains and should be used with caution.

Pipe materials

There are many different materials that may be used for pipes in water distribution systems. Whilst each has its own advantages and disadvantages, in practice it is local availability and cost which usually dictates the material used.

For mains of 75mm diameter and greater, materials used include: ductile iron; asbestos cement (AC); and different types of plastic pipe, the most common of which is known as uPVC. Asbestos cement and uPVC are cheaper and easier to handle than ductile iron and are manufactured in many countries. An important consideration is the availability of fittings; problems arise if the fittings necessary to make repairs and future connections are not available. Some care is needed when using uPVC pipes since they will tend to fail if laid in contact with sharp stones, bricks and other hard materials.

Pipes are classified in terms of the working pressure for which they are designed. Class B pipes, which are intended for a maximum working pressure of 60 metres (6 bars), will usually be appropriate for upgrading schemes.

Galvanised steel (GI), uPVC and medium density polyethylene (MDP) are used in tertiary distribution mains. GI mains are sometimes used in sizes greater than 75mm. Their threaded joints are easy to make and GI pipes are therefore more suitable for use in community managed schemes than other types. However, they are liable to rust and therefore have a much shorter life than other types of pipe. Some increase in life can be achieved by protecting the outer face of the pipe with bitumen. GI pipes of 50mm or less may be laid above ground along pedestrian lanes, providing care is taken to ensure that they do not cause obstructions across doorways and rights of way.

At present MDP has to be imported into many countries. The smaller diameters are provided in rolls that can be unwound on site, reducing the need for connections to a minimum. Where connections are required, they are made by fusion welding using special equipment. MDP pipes are already commonly used in rural water supply schemes in several countries, including Nepal. They provide an attractive option technically but at present are rather more expensive than GI pipes. However, they have a much longer working life than GI and may therefore be a cost effective solution in the long term.

The key factors when selecting the most appropriate pipe material are: performance; cost; and availability. Factors to consider when selecting the type of pipe are shown in Table W1.

Table W1. Suggested checklist for pipe selection

1	Diameter of pipe	Range of pipe sizes manufactured
2	Joints	Flexible or rigid. Ease of assembly
3	Class of pipe	Rating for internal pressures
4	Installation	Below ground or exposed
5	Location	Area: urban, rural, seismic risk, soil conditions. Possiblity of disturbance
6	External loading	Earth and vehicle loads. Depth of cover needed. Quality of bedding needed. Effects on pressure rating
7	Flow characteristics	True internal pipe diameter. Internal roughness
8	Operating costs	Pumping and maintenance costs
9	Supply of materials	Delays in delivery. Availability of stocks
10	Surge pressure	Effect on maximum working head
11	Boosting	Possible future increases in flow and/or pressure
12	Handling	Ease of handling. Weight. Ability of pipe materials to resist physical damage during handling and laying
13	Fittings	Availability of suitable fittings. Possible use of standard fittings
14	Strength	Possibility of pipes being unsupported along part of their length, or suffering impact damage
15	Durability	Estimated useful life. Economic benefits or advantages
16	External protection	Soil or environmental conditions may be aggressive for exposed or buried pipes
17	Laying costs	Number, type, cost and reliability of joints. Depth of excavation. Costs of bedding material
18	Factor of safety	Comparison of the ultimate pipe characteristics with the expected operating conditions

Operational features

Sluice valves

Sluice valves are used to subdivide the distribution system, allowing operators to allocate water between areas and to shut down sections of the system to facilitate maintenance or effect repairs. Valves on mains which connect supply zones are normally kept shut. The purpose of these valves is to allow water to be transferred into a zone in the event of a supply failure in that zone. Such valves are referred to as shut valves. Engineers involved in upgrading projects should not normally be required to install shut valves but should be aware of the limits of supply zones and the location of shut valves.

A variation on the shut valve principle is used in areas, such as some parts of Karachi, which have a poor bulk water supply. Because of the shortage of water, supply is provided to various zones or sub-zones in rotation. In such cases, valves must be provided on the supply mains to isolate the various zones and allow the required rotation of supply.

All other valves will normally be kept open. Their purpose is to enable parts of the system to be isolated for repair and maintenance purposes while supply is continued to the rest of the system. As a general rule, valves should be provided so that areas of between 10 and 25 hectares can be isolated. The number of valves required can be reduced if the number of through tertiary mains is kept to a minimum. Figure W10 illustrates what this might mean in practice.

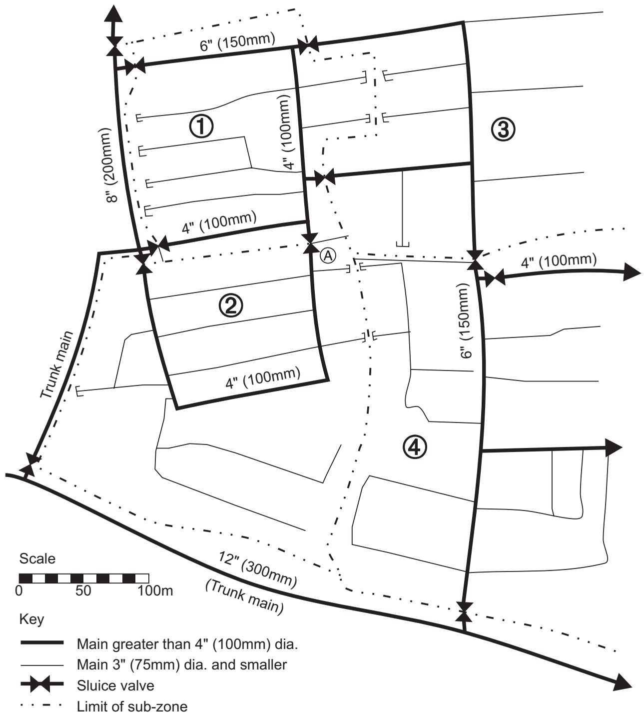


Figure W10. Typical positioning of valves to allow isolation of sub-zones

Fire hydrants

Conventional practice is to provide fire hydrants at intervals determined by the longest hose that is available on the fire appliances used in the area. Typically, this will mean that hydrants are spaced at about 200m intervals along primary and secondary mains.

An initial investigation is advisable, however, to determine whether existing hydrants are adequately maintained. Where either adequate maintenance cannot be guaranteed or the water supply is intermittent, there is a case for providing 75mm dia. standpipes at intervals of perhaps 1-2 km throughout the area. These should be high enough to discharge into fire tenders and water bowsers. Where the water supply is intermittent, a tank should be provided adjacent to the standpipe and this should be kept full at all times. The capacity of the tank should normally be about $10m^3$.

Washouts

Washouts should be provided at low points in the distribution system to enable mains to be drained for maintenance and repair. Typical washout arrangements are shown in Figure W11.

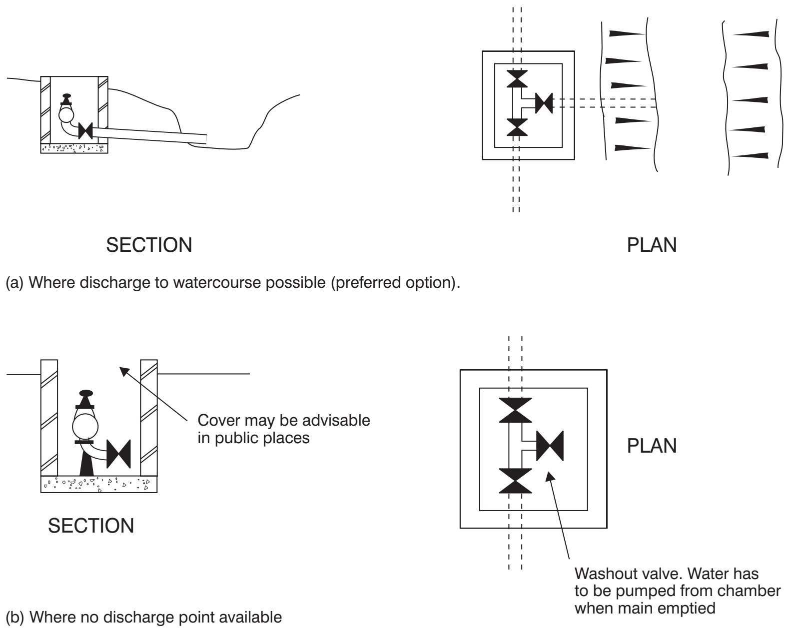


Figure W11. Typical wash-out arrangements

Air-valves

Air valves should not normally be required in upgrading schemes because any air that collects in mains will be vented through house connections.

Tool W4 Water supply: Handy Tips

Piped supplies and standposts: where to use them

- See Tool W1

Piped supplies and standposts: construction tips

- Public taps need to be strong and of good quality; if the pressure is too low, users often remove the tap in order to collect more water.
- Intermittent water supply systems are prone to pollution from back-syphoning of polluted water; care should be taken to lay pipes away from drains.
- Galvanised Steel (GI) pipes have threaded joints and can be used in community managed schemes.
- Protect the outer face of GI pipes from corrosion by painting it with bitumen, then wrap it in bitumen-soaked jute sacking.
- In streets subject to traffic loads, the cover over water mains should be at least 900mm.
- Minimum cover in lanes less than 3m wide should be 600mm.
- GI mains may be laid above ground in pedestrian lanes; take care not to obstruct doorways and rights of way.
- Minimise the length of GI main laid below ground.
- Where ground conditions are poor, bed all pipes in sand or gravel.
- uPVC pipes need careful bedding on sand or gravel. Under no circumstances should pipes be supported by bricks.
- Provide concrete thrust blocks at all bends and tees to resist the force produced by the pressure in the mains.
- Pressure test water mains after they are laid to ensure that there are no defective pipes and that the joints are sound.

Piped supplies and standposts: operation and maintenance tips

- Users to check tap/bib-cock and replace as necessary.
- Regular cleaning of nearby drainage channels to ensure free drainage from the standpost.
- Check the condition of the standpost supporting structure periodically.
- Make sure that 'as-built' drawings and records are kept including all pipe sizes, locations of sluice valve and other fittings.
- Unaccounted for water is a serious problem; skilled leak detection teams need to be trained and resourced to cope both with emergency repairs and persistent leakages.
- Minor local repairs can be community managed.
- It is sometimes necessary to disinfect water using chlorine at strategic locations in the distribution system.
- Regular monitoring of water quality and water pressure needs to be developed as part of the operational support programme.
- Periodic maintenance and changing of valve spindle rods helps to reduce leakage and ensure smooth operation.

Handpump supplies: where to use them

- Usually for tapping deep aquifers.

Handpump supplies: construction tips

- Construction can be done by motorised drilling rigs, or manually using a tripod and winch in soft ground.
- Not suitable for community based works, although participation of user groups is essential in agreeing the location and type of handpump.
- Location should take into consideration potential sources of pollution, for example leach pits.

Handpump supplies: operation and maintenance tips

- The useful lifespan of a borehole depends on the quality of the casing pipe, proper screening/ filtering media and water quality.
- Government involvement in O&M has generally been low; involvement of user groups in handpump maintenance is therefore very important; it is possible to train users to carry out basic routine maintenance.
- There is a strategic need for trained technician support with adequate spares and tools; this could be organised on a Ward/zone basis.
- In areas of very high handpump usage it is difficult to take a pump out of commission without providing an alternative temporary supply.

Shallow well supplies: where to use them

- Commonly used where groundwater is shallow, despite potential pollution problems.

Shallow well supplies: construction tips

- Construction is simple but often risky.
- The wall thickness needs to be sufficient to cope with earth pressure; linings are not required for soft rock conditions.
- Linings need to be open jointed to allow water to infiltrate in; brick is not a particularly good material for wall construction.
- Location should take into consideration potential sources of pollution, for example leach pits.
- Wells need to be properly fenced and protected.

Shallow well: operation and maintenance tips

- Suitable for community management.
- Desilting may be required on an annual basis.
- Periodic disinfection may be required depending upon the use to which the water is put.
- Algal growth can be a problem; plants growing out of wall joints need to be removed.
- Water from washing, bathing and cleaning tends to find its way back into the well, leading to deterioration in water quality.