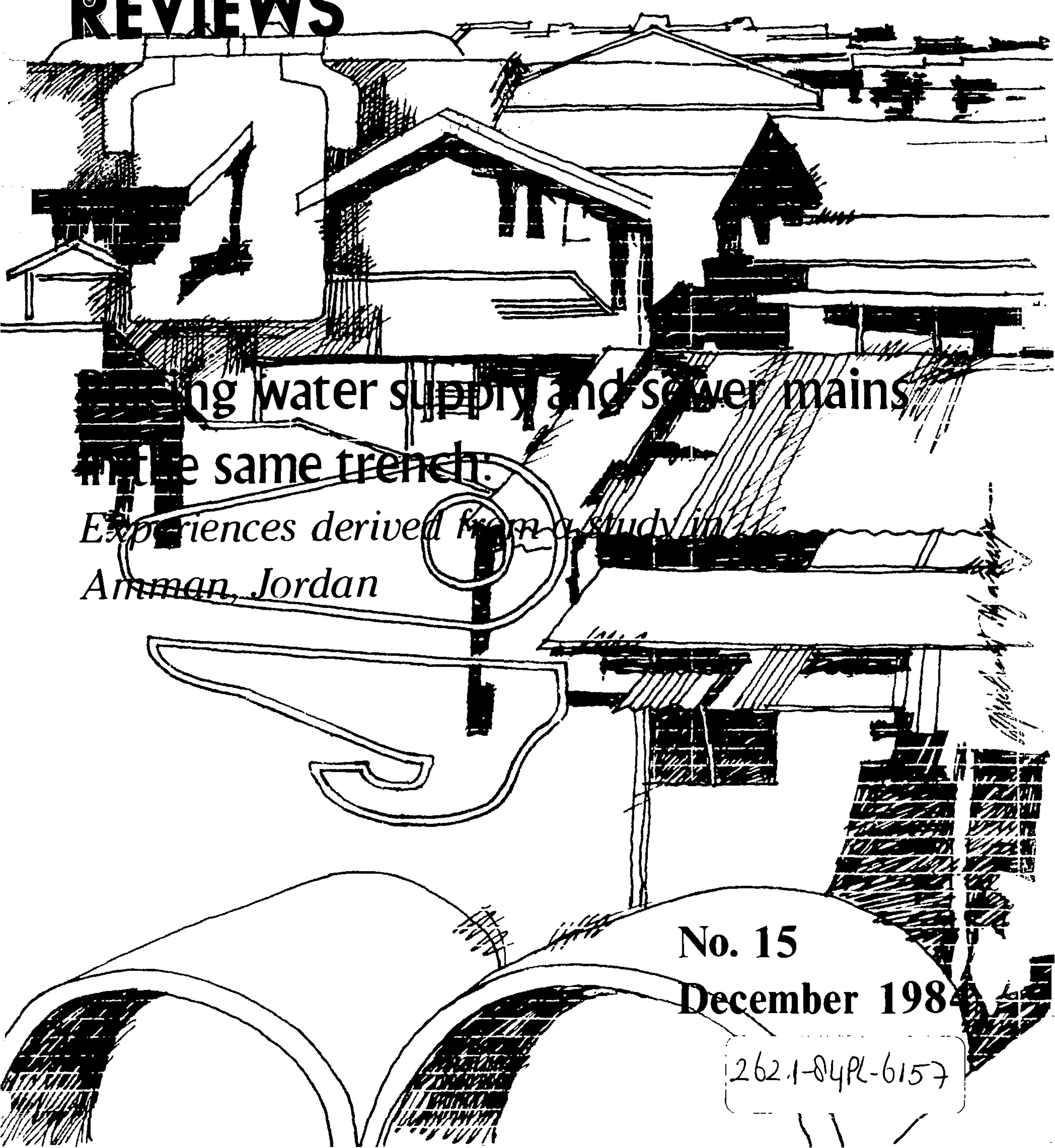
ISSN 0125-5088



# ENVIRONMENTAL SANITATION REVIEWS



## Placing water supply and sewer mains in the same trench:

*Experiences derived from a study in Amman, Jordan*

No. 15
December 1984

# Environmental Sanitation Reviews

## No. 15, December 1984



Environmental Sanitation Information Center
Asian Institute of Technology
P.O. Box 2754
Bangkok 10501, Thailand

# ENVIRONMENTAL SANITATION INFORMATION CENTER




## ACKNOWLEDGEMENTS

*ENSIC gratefully acknowledges the financial support it receives from the* **International Development Research Centre (IDRC)** *of Canada; the* **Government of Australia**; *the* **Canadian International Development Agency (CIDA)** *and the* **Asian Institute of Technology (AIT)**.
*It is also indebted to the* **AIT Regional Computer Center (RCC)** *for the use of its computer facilities.*

# PLACING WATER SUPPLY AND SEWER MAINS IN THE SAME TRENCH: EXPERIENCES DERIVED FROM A STUDY IN AMMAN, JORDAN



by

**H.F. Ludwig**

*Editorial Board Member,
ENSIC*

*and*

*Consulting Engineer,
SEATEC International,
Bangkok*



**ENVIRONMENTAL SANITATION INFORMATION CENTER**
**BANGKOK, THAILAND**
**DECEMBER, 1984**

# JOIN ENSIC

**You will receive.**

Environmental Sanitation Abstracts (3 issues per year)
Environmental Sanitation Reviews (3 issues per year)
A Quarterly Newsletter - ENFO
Occasional Holdings Lists

The ENSIC publications will be made available through subscribed membership of the Center without any extra charge for the publications.

| MEMBERSHIP FEES | US$ | US$ |
|---|---|---|
| **Members from** | **Individual** | **Institutional** |
| Developed Countries[1] | 45 | 85 |
| Developing Countries[2] | 25 | 45 |
| AIT Alumni, All Countries | (15% discount) | – |

(include air-mailing of ENFO and surface-mailing of all other ENSIC publications.)

[1] Europe, North America, Australia, Japan, New Zealand, Middle East.

[2] All other countries.

**To get all your copies by air-mailing add:**

| | |
|---|---|
| Asia | 12 |
| Africa, Europe, Oceania | 19 |
| Americas | 27 |

Payment can be made by bank draft, cashier's cheque or UNESCO coupons, payable to:

**"Environmental Sanitation Information Center"**

## REFERENCE SERVICE

ENSIC Members can use the Center's References at the rate of US$ 3.00/hour.

## DOCUMENT SUPPLY

| | | |
|---|---|---|
| **Hard copies** | | |
| *Including surface mailing charge | 0.20/page | (for Developed Countries) |
| | 0.15/page | (for Developing Countries) |
| *Air-mailing extra charge: | | |
| Asia | 0.05/page | |
| Africa, Europe, Oceania | 0.08/page | |
| Americas | 0.10/page | |
| **Microfiches** (60 pages per fiche) | 3.00/fiche | (Air-mailed) |
| **Binding** | | |

**A service fee of US$ 5.00 is charged for each AIT publication (Theses, Reports, etc.)*

# PREFACE

*This document was written by a renowned authority in the field who at the same time is a consultant for the World Bank. Based on a study conducted at the City of Amman and its suburban areas, this report is a comprehensive evaluation of the feasibility of using water supply and sewer mains in the same trench (WSST) from a technical-cum-public health point of view. The author has formulated his conclusions so that readers will find a general application of WSST.*

*The dearth of published articles on the use of WSST was the main impetus in the choice of this topic. It would seem that in the past this technology has only been used for a limited number of applications, and thus has failed to capture the interest of academicians and consulting engineers sufficiently to warrant further research and discussion of the subject. It is believed, however, that with burgeoning populations and rapid urbanization which is currently taking place, the use of WSST will find high relevance in heavily built-up cities, where space is limited and streets are often the only places available for trenching.*

*In situations where WSST was deemed appropriate, the central issue of the controversy, and one which often barred project approval, has always revolved around the health hazard issue posed by this technology. Considering this issue and the concomitant saving that this technology makes possible, the economic cost/benefit ratio is one of the salient parameters in this study, and is thoroughly addressed in this evaluation report.*

*We hope that this publication will stimulate further research and produce new discoveries as it enjoys wider application in developed as well as developing cities faced with the same circumstances.*

*The Editors*

# LIST OF ABBREVIATIONS

## Agencies

| | | |
|---|---|---|
| AML | : | Amman Municipal Laboratories |
| AWSA | : | Amman Water and Sewerage Authority (now part of WA) |
| AWWA | : | American Water Works Association |
| DMJM | : | Daniel, Mann, Johnson, and Mendenhall |
| Fauzi | : | Fauzi & Associates Consulting Engineers (Amman) |
| JMM | : | James M. Montgomery Consulting Engineers |
| Jouzy | : | Jouzy & Partners Consulting Engineers |
| MOH | : | Ministry of Health |
| NPC | : | National Planning Council |
| NRA | : | National Resources Authority |
| Pirnie | : | Malcolm Pirnie Engineer |
| UNEP | : | United Nations Environment Program |
| UNOTC | : | United Nations Office of Technical Cooperation |
| USPHS | : | United States Public Health Service |
| VBB | : | Vattenbygganadsbyran |
| WAJ | : | Water Authority of Jordan |
| WSC | : | Water Supply Corporation (now part of WAJ) |

## Terms

| | | |
|---|---|---|
| DC | : | Developing Country |
| DWQ | : | Proposed Division of Water Quality in AWSA |
| IAA | : | International Assistance Agency |
| MPN | : | Most Probable Number (Number of Coliform Bacteria per 100 ml Water) |
| MWSS | : | Municipal Water Supply and Sewerage |
| WSDS | : | Water Supply Distribution System |
| WSHC | : | Water Supply House Connection |
| WSST | : | Water and Sewer Lines in the Same Trench |
| WSST/AT | : | WSST/Appropriate Technology |
| WSST/RT | : | WSST/Rigid Technology |

TABLE OF CONTENTS

# Placing water supply and sewer mains in the same trench: Experiences derived from a study in Amman, Jordan

by

H.F. Ludwig

## I. INTRODUCTION

### 1.1 Purpose

This document is based on the author's main report, conducted over the period 1983-1984, to evaluate the use of combining the water supply and the sewer mains in the same trench (referred to here as the WSST method). The report was prepared for the Water Authority of Jordan (WAJ) at Amman, and contain conclusions and recommendations on:

(i) the extent to which special measures should be utilized in Jordan in the future; and

(ii) the extent to which special measures should be implemented by the WAJ to prevent any anticipated health hazards stemming from the WSST already installed.

It is hoped that the kind of issues raised here for Amman could have wide application and usage for people who are facing a similar situation.

### 1.2 Problem

Over the period 1978 to 1981, as part of its continuing program for expanding water supply and sewerage services at Amman, the WAJ utilized WSST for some 200 km of water and sewer mains installed on streets, regardless of the width of the street. The WSST technology used by the WAJ was similar to that currently used by most states in the USA where physical constraints require the use of the same trench for both mains. In addition to suitable pressure pipe for the water mains, this requires:

(i) the use of good quality sewer pipes which are capable of withstanding low-head pressures, with a rubber ring or equivalent joints;

(ii) at least 18 inches vertical separation between the two mains (with the sewer main being below the water main);

(iii) placing the water main in a "side-bench" so it will be supported by undisturbed earth and so the sewer main may be repaired without disturbing the water main.

In this document, this combination of requirements is termed - appropriate technology for WSST in developing countries, or "WSST/AT".

In earlier decades in the USA, before the advent of modern sewer pipe, sewer mains commonly utilized bell-and-spigot joints with cement mortar joints, which were usually subject to considerable leakage. In that period most states of the USA, including the "Ten States" of the Upper Mississippi river basin (now the Great Lakes-Upper Mississippi River Board of State Sanitary Engineers), prohibited the use of WSST as appropriate technology in the sense in which AT was defined above. The original regulation was that separate trenches, at least 10 feet apart should be used whenever physically possible, and WSST should only be used when required by physical or other constraints (such as narrow streets). For such WSST a rigid technology was specified requiring the use of pressure pipe for the sewer and/or encasement of the sewer pipe in concrete. The present-day policy of most states, following the introduction of modern sewer pipe with rubber ring joints, requires the use of separate trenches 10 feet or more apart on wide streets, but allows WSST/AT when a single trench must be used (as in narrow streets or right-of-ways). In Western Europe, however, in towns and cities many hundreds of years old, where many streets are narrow, WSST/AT is commonly utilized on all streets. The District of Columbia in the USA (Washington, D.C.) also commonly utilizes WSST/AT on all streets.

Over the period 1980-1982 the Ministry of Health (MOH) of Jordan questioned the Water Authority of Jordan's use of WSST/AT on any and all streets, stating that such a practice might represent a serious health menace, especially where the quality of construction used for installing WSST might be below standard. The Ministry of Health asked that for the use of WSST in Jordan, the requirements should be similar to the early USA/Ten States standard - that is the use of separate trenches 10 feet or more apart where space permitted, but where a single trench had to be used, a rigid technology for WSST should be applied. It was the Ministry of Health who maintained that this represented minimum international acceptable standards. As a result, in 1981 the Water Authority of Jordan discontinued the use of WSST (except in narrow streets), pending clarification of the issues.

To obtain the needed clarification, the National Planning Council (NPC) asked the U.S. Agency for International Development (USAID) to furnish an Expert Consultant to review the situation and to prepare appropriate recommendations. This work was carried out from 1983 to 1984, and the present document briefly outlines the findings and conclusions of that study.

## 1.3 Study Requirement

### 1.3.1 Salient Parameters

The study included a review and investigation of all the facets of water supply and sewerage practices at Amman relating to the hazard of waterborne disease outbreaks stemming from fecal contamination, including contamination of the water supply in the distribution system. It was recognized at the outset that the use of WSST/AT in Amman involved a risk assessment - that is a recognition of the fact that the hazard of contamination from WSST/AT represents only one of several hazards of fecal contamination in the distribution system. Hence the investigation took into account all such hazards, and notably the following:

(i) hazards stemming from overflows of subsurface septic tank/leaching systems commonly depended upon at Amman and elsewhere in Jordan for the disposal of excreta,

(ii) hazards from cross-connections between the water supply distribution system and the buildings served, especially high-rise buildings, and

(iii) hazards from locating water supply distribution service piping in the same areas utilized for subsurface excreta disposal pits.

Thus the study looked into these various hazards as well as examining WAJ practices in planning, designing, constructing, and operating water supply and sewerage mains, including WSST.

### 1.3.2 Work Program

The initial work done for the study included:

(i) collecting and reviewing background technical reports relating to WSST, obtained from the USA and from international agencies such as the World Bank, the U.S. Environmental Protection Agency and the American Water Works Association;

(ii) reviewing feasibility studies on water supply/sewerage in Amman and Greater Amman, including those done by VBB/Fauzi in 1977 and by JMM/DMJM in 1982;

(iii) meetings and discussions with the President, staff, and Technical Advisor of the WAJ and of the Amman Water Supply System (WAJ/AWSS) and carrying out a review of various WAJ documents and maps;

(iv) field visits to inspect on-going WAJ construction projects and to review field conditions throughout Amman relating to the supply of water and disposal of sewage (including areas with WSST and areas with disposal by subsurface leaching with cesspools);

(v) meetings and discussions with other relevant Jordanian agencies, including the Ministry of Health's Environmental Health Division, the Municipality of Amman, and the National Planning Council (NPC); and

(vi) reviewing AWSS correspondence on WSST from 1980 to 1983 with the Minister of Health, the Prime Minister, the National Planning Council and other officials concerned with WSST practices at Amman.

The second phase of the study included:

(i) international visits to the U.S. Environmental Protection Agency, the U.S. Center for Disease Control (CDC) at Atlanta, Georgia, the WHO/Geneva, and other agencies concerned with WSST;

(ii) a mail survey of current WSST practices in the 50 states of the USA; and

(iii) economic analyses of benefits versus costs for WSST practices at Amman.

### 1.4 Study Area

The study focused essentially on the Amman Water and Sewerage Authority (AWSA) service area or "Metropolitan Amman" - that is, the City of Amman plus its immediate adjacent suburban areas. The conclusions of the study were formulated so as to make them applicable throughout Jordan.

## II. BACKGROUND INFORMATION

### 2.1 Development of Water Supply and Sewerage at Amman

At present the population of Amman municipality is about 750,000, distributed among the "new city" areas, "old city" areas, and refugee camp areas, each representing decreasing levels of affluence. By 1978 the Water Supply Distribution System (WSDS) furnished service throughout the city, but on an intermittent pressure basis. However, many of the supply mains were placed with very little cover (near the surface), and hence have been vulnerable to damage by traffic. In addition, there have been problems of corrosion (amongst others), and consequently much of the WSDS is prone to leakage and requires continuing repairs. In fact, it is expected that sooner or later many of the existing lines will need to be replaced.

Construction of sewers started at Amman about two decades ago and, fortunately, reinforced concrete pipe with rubber rings (capable of withstanding about two meters of pressure) were utilized as the regular sewer pipe from the outset, and have proven to be relatively easy to maintain. The sewerage collection system has been rapidly expanded in recent years so that about 77 percent of the city is expected to be sewered by 1985, with about 90 percent of the houses connected. By 1990 it is planned that coverage will include most of Greater Amman (a zone extending some 30 km from the center of Amman and including about half the population of the Kingdom).

### 2.2 Priorities and Costs

It is expected that the volume of water to be supplied in the Greater Amman region will increase from its present total of about 60 million $m^3$/year (including 32 million $m^3$/year for the Amman municipality) to approximately 70/100/160 million $m^3$/year by 1985/1990/2000. The sewerage facilities are to be similarly expanded, as already noted above. The Government has assigned top priority in the provision of these services in the Greater Amman region, and the proper use of appropriate technology is certainly needed to get the best results from the money invested. It should be noted that, because Jordan is essentially a desert country with very limited surface water supplies, and depends primarily on groundwater for furnishing public water supplies, it is relatively expensive to provide water for municipal water supply systems, and indeed probably involves the highest costs in the Middle East. The total cost of water produced and delivered is roughly estimated at about US\$2.00/$m^3$, with the revenues paying for approximately half of this. Under these circumstances prudent use of appropriate technology certainly seems to be in order.

### 2.3 Use of WSST at Amman

In this document, the term "WSST/AT" or "WSST/Appropriate Technology" is used to mean WSST which (in addition to first class pressure pipe for the water main) utilizes first class sewer pipe (capable of withstanding low head pressures and using rubber ring joints or the equivalent), with the vertical distance between the two pipes not less than 18 inches (with the water main being above the sewer), and with the water main placed on a side-bench (above undisturbed earth) so that the sewer can be repaired without disturbing the water main. The term "WSST/RT" or "WSST/Rigid Technology" means, in addition, the use of pressure pipe (similar to the water main) for the sewer and/or encasement of the sewer in concrete. The specification for WSST installed at Amman are essentially the same as WSST/AT, whereas the procedures recommended by the Ministry of Health are essentially WSST/RT.

### 2.4 Distribution System Pressures

In earlier years, the Amman water supply distribution system (WSDS) was not able to give continuous service, resulting in frequent occurrences of zero or negative pressures within the water supply distribution system. The improvement program underway has furnished:

(i) additional quantities of supply, together with

(ii) an increased number and increased volume of storage reservoirs at elevated locations corresponding to the various different pressure zones, including increased pumping capacity.

As a result the water supply distribution system within Amman proper achieved a situation of continuous positive pressure (with a minimum head of about 10 meters throughout the system) early in 1982. Hence the summer of 1982 was the first summer when water was not rationed.

Achievement of continuous positive pressure of course represents a "great leap forward" in the development of the Amman water supply distribution system, and this will be very important in preventing contamination of the water supply from cesspool contamination or from sewer leakages. However, while it will alleviate somewhat the problem of contamination from cross-connections in high-rise buildings, it will not eliminate such cross-connections, and hence the solution to this problem must be approached by other means.

Although continuous pressure is essential for minimizing contamination hazards, it also serves to increase loss of water in the distribution system through leaks in older/corroded/damaged mains. The number of breaks has progressively increased with pressure increases, and in 1983 reached a level of some 2,000/month. Some of these are in smaller mains due to damage from traffic because they were placed too close to the surface. Most of the breaks in the larger mains have been caused by the construction of other utilities.

## 2.5 Leakage Correction Program

The problem of leakage within the water supply distribution system was reviewed in the VBB/Fauzi's study (1977). This indeed represents a major problem, mainly because of the age of much of the piping and the corrosion that has occurred, and even more so because of physical damage to the mains, many of which were placed too close to the surface (some actually at the surface).

The leakage problem in Amman has been assessed in detail in a March 1983 report prepared by the WAJ/AWSS (Stearn, 1983). This report notes that the WAJ/AWSS have made good progress over the past several years, and recommends strengthening this activity. It also presents a preliminary proposal for consideration by the WAJ/AWSS for the next appropriate step in the strengthening program. It appears that the proposed program would have a very high benefit/cost ratio.

## 2.6 Pipeline Construction Practices

### 2.6.1 Pipeline Materials

At present the WAJ/AWSS utilize mostly ductile or cast iron pipe, or steel pipe with bituminous linings, for water supply distribution system mains, and use GI steel pipe for water supply house connections. These have proven to give good service (30 and 20 years life expectancy respectively). In earlier years, other pipe materials were utilized - including PVC for mains, which were only partially satisfactory, and ABS plastic for laterals, which were generally unsatisfactory. The PVC is believed to have been improperly stored and sometimes not properly placed, and hence some of it had insufficient cover and was vulnerable to being readily damaged by traffic. Under the present practice a minimum of one meter of cover is utilized (the usual cover is one meter).

For sewer lines the practice continues of using reinforced concrete pipe with rubber rings, which represents an excellent sewer pipe with relatively little hazard of leakage and which is virtually free from problems of root penetration which have plagued sewerage agencies in the USA, where the pipe joints were formerly ball-and-spigot with cement mortar (the problem was especially severe in arid/desert regions like Southern California). In addition, because of the topography at Amman, flow velocities sufficient to prevent sulfide corrosion of concrete are usually easy to obtain (an average flow velocity of not less than 1 m/s is needed for self-cleansing and prevention of sulfide corrosion).

#### 2.6.2 Backfilling

The backfilling practice now used by the WAJ/AWSS involves the use of imported sandy backfill material for bedding and for covering the pipe to 2wspecified depths, in conjunction with mechanical tamping. Field visits indicated a good quality of construction and backfilling following this practice. In earlier years backfilling usually involved more use of the excavated materials, which were screened to furnish materials suitable for bedding and pipe covering. The present method is easier to control but appears to be relatively expensive.

A recent WAJ/AWSS specification differs from the above by including the option of backfilling by pudding (Engineering Science, 1983). With respect to WSST, in those areas where the subsoils are rocky limestone, the use of modified backfilling procedures may possibly present considerable advantages by creating a relatively impermeable limestone layer between the water and sewer lines. A suggested testing program for exploring this potential is included in the overall study report.

### 2.7 Chlorination of Water Supply

Information furnished by WAJ/AWSS indicated that chlorination has been recognized as an important means for combatting water supply distribution system contamination hazards. Under the present practice all water pumped into the elevated service reservoirs is chlorinated. The WAJ/AWSS policy requires a chlorine residual of 2 ppm for the water introduced into the reservoirs. Records of the amount of chlorine used and of the residual chlorine are kept at each of the pumping plants where chlorination is needed. It appears that this system manages to achieve chlorination of the supplies delivered to all reservoirs which serve the public for all of the five pressure zones.

### 2.8 Water Quality Monitoring

#### 2.8.1 WAJ/AWSS Laboratory

The WAJ/AWSS Laboratory furnished information on this laboratory (located at the Sewage Treatment Plant) which was built and implemented in

1981. About twenty water samples were taken from wells once a week except for the remote wells at Asrag where samples are taken once a month, and from four pumping-cum-chlorination stations twice a week, including field chlorine residual tests and laboratory bacteriological determinations (using tubes procedure from "Standard Methods"). In addition the samples were tested in the laboratory for eight chemical parameters including pH, alkalinity, conductivity, chlorides, and nitrates. Chlorine is added into the well and well samples are taken from the well discharge pipe. So far practically all of the samples have shown the presence of significant free chlorine and coliform levels, below the Jordanian standards.

#### 2.8.2 Municipal Laboratory

The municipality's laboratory carries out water sampling and testing on behalf of the WAJ/AWSS as well as the Municipal Health Department. It is also responsible for food sampling and testing, but water sampling and testing represents about 30 percent of the overall work and budget.

Information on the water quality standards utilized in Jordan (developed by an inter-agency committee) and an example of a typical laboratory report for bacteriological testing of a water sample are given in the overall report.

The Jordanian standards noted above provide that, for acceptability, the sample must have a total bacterial count of less than 100, and a total coliform MPN (confirmed) of less than 10/100 ml. (This coliform standard is considerably less rigorous than the USA standard.)

### 2.9 Use of Septic Tank/Cesspool Systems

#### 2.9.1 Contamination Hazards from Overflows and Infiltration

Prior to implementation of the public sewerage system at Amman (beginning 15 to 20 years ago), septic tank and/or cesspool systems were used by all buildings in the city as the means of disposing of sanitary wastes, including excreta. While some of these gave excellent service, many others did not, due to adverse soil conditions (low infiltration rates), an inadequate leaching area, and inadequate servicing (lack of desludging when needed), especially in the more densely built-up zones. This resulted in frequent cesspool overflows, and created serious contamination hazards, including hazards of contaminating food, hazards to children at play, and hazards to the water supply distribution system piping which might have leaks and be under negative pressure.

Some of the effluent tended to flow underground, presumably at the interface between the top soil and the underlying impermeable soils (about half of Amman municipality has rocky, limestone basic soil, and about half clayey soils) and outcrop onto properties farther downhill. Even that portion of the cesspool liquid which infiltrated into the ground created a public health problem by increasing the concentration of nitrogen and other dissolved salts and substances in the region's groundwater basin, which is a primary source of the Amman water supply. These problems were reviewed in some detail by the Greater Amman Wastewater Feasibility Study (JMM/DMJM, 1982), with the conclusion that, if for no other reason than for protecting groundwater quality, a comprehensive sewerage system is needed at Amman and at all other Jordanian cities where the primary dependence on cesspools for the disposal of sanitary wastes would seriously impair the quality of the groundwater - which is the basic source of raw water for the municipality.

As previously noted it is estimated that about 77 percent of Amman municipality's population is now connected to the public sewerage system, and that the percentage will reach about 95 percent in the near future, with continuing expansion of the system as now planned. However, the bulk of the surface contamination problems noted above, including hazards to water supply distribution system mains (including those at or near the surface and WSST mains) have been eliminated. First, the sewerage implementation program focused on those portions of the city zones where the water supply distribution system piping had been located close to the surface. Second, in the newer city zones occupied mostly by affluent families, the cesspools are large enough to have sufficient infiltration capacity. Third, the municipality has cooperated with the WAJ/AWSS in requiring that cesspools with inadequate infiltration capacity, should be pumped out as frequently as needed. The WAJ/AWSS has to notify the municipality whenever, in the course of implementing sewers and house connections, any overflow problem is identified.

Outside the Municipality boundaries the problem is still serious, depending on the extent of coverage of the public sewerage system and the ability of the communities to exercise surveillance and to enforce pumping as needed.

In the full report a drawing showing typical residential subsurface disposal systems used at Amman and probably elsewhere in Jordan is included. There is essentially no septic tank, only a small trap discharging to the cesspool(s), with the cesspool(s) providing both the functions of a septic tank and of a leaching system. Three standard sizes are shown, and it seems the design procedure is limited to selecting one of these. Leaching tests are not made.

### 2.9.2 Contamination Hazard from the Water Supply House Connections

A much more serious hazard to the household water consumed in Amman has occurred in the densely built-up zones with small lot sizes, because the water supply house connection has in many cases passed through the cesspool itself. The situation is difficult to avoid on account of physical restrictions. Over the past several years, the WAJ/AWSS, in implementing its expanding water supply distribution system program, has found this to be a fairly common occurrence. As many as 10 cases per week were reported and detection was based on visible contamination of the water served. The contamination was caused by placing the water supply house connection in the cesspool area, with the result that, at times of discontinuation of pumping/pressure, the cesspool contents were backflowing into the water supply distribution system. The WAJ/AWSS has focused its water supply distribution system improvement program on these areas to eliminate this type of water supply house connection, as well as to maintain continuous pressure. Consequently, while such problems still occur, they are now relatively rare.

This contamination hazard is another powerful argument for expanding the sewerage system to cover, as far as possible, the entire urbanizing areas, to the extent feasible, so that the cesspools can be closed and no longer used. One problem in this respect is that, in order to save on sewer connection costs, some householders are still using cesspools which were assumed to be no longer in use.

A review of the correspondence on WSST between the WAJ/AWSS and the Ministry of Health appears to indicate that the Ministry of Health disapproves the use of WSST in Jordan except where such use cannot be avoided because of physical constraints and that, if used in such instances, the installations should follow the "international standards" requiring costly encasement of the power pipe in concrete. The Ministry of Health also indicated serious reservations about the quality of WAJ/AWSS construction practices, which sometimes led to the WSST actually installed not following the WSST/AT specifications. The position of the WAJ/AWSS appears to have been:

(i) agreement that protection of the public health is essential;

(ii) standards for appropriate use of WSST in Jordan should be developed, not by copying standards used in the industrialized countries, but by careful consideration of the situation/needs of Jordan so that the standards will be appropriate for Jordan at this stage of Jordan's development; and

(iii) pending resolution of (ii), the WAJ/AWSS has discontinued any further use of WSST.

The recommended appropriate standards or criteria prepared by Water Authority of Jordan and Amman Water Supply System are included in the full report.

## III. ASSESSMENT OF WATER SUPPLY CONTAMINATION HAZARDS AT AMMAN

While WSST is one type of hazard to the water supply distribution system at Amman, it is only one of several hazards, and its significance can hardly be evaluated in isolation. It should therefore be evaluated along with other significant hazards to the public water supply.

There appear to be three significant sources for possible contamination of the water supply distribution system, namely:

(i) WSST;

(ii) cesspool overflows and cross-connections; and

(iii) cross-connection hazards from buildings with roof tanks, especially high-rise buildings.

While there are no known studies which have compared the relative degrees of hazard from these sources in developing countries, it is estimated that the cross-connection and cesspool hazards are by far the most serious, perhaps of the order of 100 times more serious than the hazard from WSST. This estimate is based on the following considerations:

(a) In any metropolitan center with high-rise buildings using roof storage reservoirs which are served from water supply distribution systems with relatively lower pressures most of the time, and where there is no effective building/plumbing cross-connection control program, it is virtually certain that many cross-connections will be made in the building plumbing system which can permit relatively easy backflow into the water supply distribution system. That is, without an effective building/plumbing cross-connection control program, such connections commonly take place, and at times of pressure variations within the building plumbing system sanitary wastes may readily gain access to the water supply distribution system through reversals in the flow patterns. In cities in the USA, Los Angeles and Washington, D.C., for example, the control of cross-connections is a major activity of the municipal water department, involving regular periodic inspections and installation and repair of positive cross-connection prevention devices. There is no such program at Amman (nor in most metropolitan centers in developing countries).

(b) While there is always the possibility of some leakage from sewers under WSST conditions, in order for contamination to occur there must also be a negative pressure, or at least an aspirating effect in the water supply main, and removal of pathogens by the intervening soil must be ineffective (which may not be the case for many soils including those found at Amman). For such cross-contamination to occur, this would require enough leakage to cause flooding of the trench together with a negative pressure in, or aspiration action by, the water mains, a situation which could be expected to occur very rarely. The hazard certainly exists, but appears to be a remote one compared to that of other sources, including high-rise cross- connections. It will of course be greatest where the water lines are very leaky, say from corrosion, and where in the same vicinity the sewer lines are also leaking. With the reinforced concrete pipe and rubber rings used for sewers, which can stand about two meters pressure, the possibility of such leakage seems remote.

(c) The contamination hazard from cesspool overflows at Amman, and from the water supply connection to houses, which passes through cesspools, seems to be under fairly effective control. Nevertheless, WSST does present a hazard, especially in the urbanizing areas outside the Amman Municipality and in other urban centers in Jordan where the water supply distribution system mains are at or close to the surface and easily subject to physical damage. In other cities in Jordan, which are hilly, and on limestone formations like Amman, where there are no strict controls on the quality of construction, and where the mains are layed at or close to the surface, this hazard will be serious. Similarly, the problem of the water supply connections which pass through cesspools to houses may be serious in developing urban zones where the land is divided into small lots.

As regards the evidence of high coliform counts in Amman (as reported in the JMM/DMJM report, 1982), it is suspected that these may be due primarily to the cross-connections between the water supply to houses and the cesspool (and to the cross-connections with WSDS mains serving refugee camp zones), and secondarily to the cross-connections to high-rise buildings. With the improvements which have been made, these hazards at Amman are being brought under control; however, they no doubt exist in other cities in the country.

None of the reference reports that were reviewed, including the VBB/Fauzi/Amman and the JMM/DMJM/Greater Amman feasibility studies, seem to mention either the high-rise cross-connection hazard, or the WSDS/cesspool cross-connection hazard, or the WSST hazard, - or in their discussions of public health aspects or of environmental impacts. Nor, it seems, was the high-rise cross-connection hazard mentioned in the WAJ/AWSS file of correspondence on WSST.

## IV. APPROPRIATE TECHNOLOGY CRITERIA FOR AMMAN

In the past decade, the international assistance agencies have placed considerable emphasis on the need to develop and use appropriate technology including criteria/standards for use in developing countries. Although the World Bank's series of manuals on "Appropriate Technology for Water Supply and Sanitation" represent a significant advance in this direction, in general not much progress has been made - primarily because to develop appropriate criteria/standards for a developing country is difficult and requires a great deal of expertise in environmental technology (which is not a very available commodity, especially in most developing countries). Instead the tendency has often been in many instances for the developing country official to try to utilize criteria/standards developed in the industrialized countries (especially the USA) simply because this is easy to do and avoids the painful examination of the relationship of appropriate standards to the current status of economic development of the country concerned. In the writer's experience in working in some 30 developing countries over the past 30 years, it can generally be said that whatever is appropriate for use in the USA will in all probability not be very appropriate for use in most developing countries.

It must be recognized that there are few "absolute" standards of environmental quality, and that in most instances in the industrialized countries the standards relate closely to the status of economic development in those countries. Thus in the USA over the last four decades (the period corresponding to the writer's experience) most environmental quality standards have been progressively increased over the decades. In Los Angeles and San Francisco, for example, unfiltered water was quite acceptable for the public water supply in 1944, but only filtered water is acceptable now. In the writer's view, the standards used in California in 1944 would often be much more appropriate for use in many developing countries than the 1984 standards.

Jordan of course is not the USA - it has its own uniqueness. Hence any environmental standards or criteria development for Jordan should be tailored to suit Jordan's unique situation. They should be objective - that is, realistic in terms of matching desires versus affordabilities at the time, so that the greatest overall public benefit will result.

# V. WSST PRACTICES AND REGULATIONS IN USA

## 5.1 Survey Procedure

Current practices in the USA on the use of WSST on regulations governing these practices are summarized, state by state, in Table 1. This also includes information on practices as recommended by the agency known formerly as the "Ten States", now the "Great Lakes/Upper Mississippi River Board of State Sanitary Engineers," and by the American Water Works Association (AWWA).

## 5.2 Survey Results

The WSST practices and regulations in the USA may be summarized as follows:

(a) While there is considerable variation in practices between states, nevertheless there is a general concurrence which may be expressed as follows: Water mains and sewer mains should be placed in separate trenches 10 feet or more apart, but if required by physical constraints (such as narrow streets), they may be placed in the same trench provided:

- the water main is at least 18 inches above the sewer main;
- the water main is located in a "side-bench" so the sewer may be repaired without disturbing the water main;
- the water main is a pressure main (such as a ductile pipe or cement-asbestos pipe with mechanical or other pressure-resistant joints) meeting the same AWWA specifications as are stipulated for water mains placed in a trench by itself; and

  the sewer main is of a modern type which can withstand low-head pressures and which has rubber ring joints or other joints which are essentially leak-proof and root-penetration-proof (i.e., modern pipe materials and joints are used).

Thus, the states in effect approve of WSST, without any special encasements, when required by physical constraints (such as narrow streets) or by other constraints (such as limited rights-of-way), but "frown" on such use in wider streets where there is room for meeting the 10-foot separation requirement.

**Table 1**
**Summary of WSST Regulations Utilized in USA**
**(1 March 1984)**

| USA State or Other Agency | Normal requirement = separate trenches with undisturbed earth between (ft) | Requirements for WSST when required by physical constraints | | | | | Other alternative | | |
|---|---|---|---|---|---|---|---|---|---|
| | | No exceptions permitted (X) | Water main on undisturbed bench (Y) | Vertical separation (in)[1] | Horizontal separation (ft) | Special jointing and/or pressure sewer main (X) | Vertical separation (in) | Horizontal separation (ft) | Presume pipe (PP) alternative (if mentioned) |
| Alabama | 5 | – | x | 18 | – | – | – | – | PP |
| Arizona | 6 | – | – | – | – | x | – | – | PP |
| Arkansas | 10 | – | x | 18 | – | – | – | – | PP |
| California | 10 | – | – | above | 4 | x | – | – | – |
| Dist. of Columbia | 10 | – | | | | | – | – | – |
| Georgia | 10 | – | x | 18 | – | – | | | PP |
| Hawaii/Honolulu | 6 | – | x | 6 | – | – | – | – | – |
| /Kauai | 6 | – | – | – | – | – | 12 | 3 | – |
| Idaho | 10 | – | – | 18 | 6 | – | – | – | PP |
| Illinois | 10 | – | x | 18 | – | x | – | – | PP |
| Iowa | 10 | – | x | 18 | 3 | – | – | 2 | PP |
| Kansas | 10 | x | – | – | – | – | – | – | – |
| Massachusetts | 10 | – | x | 18 | – | – | – | – | PP |
| Michigan | 10 | – | x | 18 | – | – | – | – | PP |
| Minnesota | 10 | – | x | 18 | – | – | – | – | PP |
| Mississippi | 10 | – | x | 18[1] | – | – | – | – | PP |
| Missouri | 10 | – | x | 18 | – | – | | | PP |
| Montana | 10 | – | x | 18 | – | – | – | – | PP |
| New Hampshire | 10 | – | x | 18 | 3 | – | – | – | PP |
| New York | 10 | – | x | 18 | – | – | – | – | PP |
| North Dakota | 10 | – | – | above | – | x | – | – | – |
| Ohio | 10 | – | x | 18 | – | – | – | – | PP |
| Oragon | 10 | – | x | 18 | 1 | – | – | – | PP |
| Pensylvania | 10 | – | x | 18 | – | – | – | – | PP |
| South Carolina | 10 | – | – | – | – | – | – | – | PP |
| Texas | 9 | – | – | – | – | – | 24 | 4 | PP |
| Utah | 10 | – | x | 18 | – | – | – | – | PP |
| Vermont | 10 | – | x | 18 | – | – | – | – | PP |
| Virginia | 10 | – | – | 18 | | | – | – | PP |
| Washington (State) | 10 | – | – | above | 4 | x | – | – | – |
| West Virginia | 10 | – | – | 18 | 3 | x | – | – | – |
| Wyoming | 10 | – | x | 18 | – | – | – | – | – |
| AWWA (1979)[2] | 10 | – | – | – | – | – | 18 | x | PP |
| GL/UM States (1982)[3] | 10 | – | x | 18 | – | – | – | – | PP |

*Notes:*
[1] *Distance by which bottom of water main (WM) is above top of sewer main (SM)*
[2] *American Water Works Association (1979).*
[3] *Great Lakes/Upper Mississippi River Board of State Sanitary Engineers (1982). Includes Illinois, Indiana, Iowa, Michigan, Minnesota, Missouri, New York, Ohio, Ontario, Pennsylvania, and Wisconsin.*

(b) The consensus regulation noted in Item (a) differs from regulatory practice in the USA in earlier decades when it was common to use bell-and-spigot joints with cement mortar in sewer mains, and, unlike the modern pipes, these mains were characterized by significant leakage/infiltration rates. Hence, some of the earlier codes for WSST, including that of the Ten States, specified use of concrete encasement around the sewer, or use of water-main type piping for the sewer.

(c) It appears that in Western Europe it has been fairly common practice to use WSST (following the requirements of (a) above), because narrow streets are common in many of the cities. In the USA, however, the city streets are generally wide, hence it has been easy to use separate trenches 10 feet or more apart. It follows that the practices and regulatory codes which have developed in the USA differ from those which have emerged in Western Europe.

(d) When comparing USA practices in water supply and sanitation with the circumstances in developing countries, it is necessary to take into account the differences in excreta disposal practices. In most USA communities, fairly satisfactory excreta disposal has been achieved since the turn of the century through the use of public sewer systems or through the use of properly functioning subsurface excreta disposal systems (usually septic tank/leaching systems serving individual buildings). Such systems are generally lacking in many developing countries. There are few public sewers and few septic tank/leaching systems, and dependence is generally placed on the use of subsurface leaching pits or cesspools (without septic tanks). While these may function with reasonable success when soil permeability and groundwater conditions are favorable, they often do not, because of unfavorable soil/groundwater conditions, with the result that pit overflows are common and excreta materials are often distributed around the urban neighborhood.

(e) The information in Table 1 on AWWA criteria for WSST is taken from a 1979 report of an AWWA committee which reviewed disease outbreaks associated with municipal water supply systems in the USA (AWWA committee, 1979). This report notes that, of the total of 454 outbreaks known to have occurred over the period 1946 to 1974, involving some 84,261 cases of illness, some 68 outbreaks (and 5,237 cases of illness) were associated with distribution systems. Most of these stemmed from cross-connections with sewage lines. None were known to be due to WSST per se (two apparently involved water mains passing through sewer manholes). The number of cases of illness due to distribution system contamination was small compared to the cases caused by source contamination or treatment system deficiencies.

# VI. MEETINGS AND CORRESPONDENCE WITH USA AND INTERNATIONAL OFFICIALS

Detailed notes on the meetings held in 1984 with agencies of the U.S. Government and International Agencies concerned with water supply contamination hazards are included in Annex XVI of the final report.

## 6.1 Discussion Procedure

The meetings were initiated by reviewing the problem of WSST at Amman and the results of the mail survey of practices/regulations on WSST in states of the USA. The agency was then asked whether it could offer comments on any studies done by themselves or others which had produced findings relating to WSST or which could help assess WSST practices. In addition, at EPA/Cincinnati and Center for Disease Control/Atlanta, a letter of inquiry was submitted asking the question, if WSST is considered acceptable, from the public health point of view, for use in narrow streets (following the specifications for WSST/AT described in Section 5.2 (a) above), why should this same practice not be considered acceptable on wider streets, especially where people depend on subsurface leaching systems for excreta disposal - systems which function poorly and commonly overflow?

## 6.2 U.S. Environmental Protection Agency

The primary agency of the U.S. Government concerned with water supply contamination hazards, including research studies, is the U.S. Environmental Protection Agency (EPA). With respect to WSST, the EPA components concerned are located at Cincinnati (Ohio) and at Washington D.C.

The results of the meetings with EPA officials may be summarized as follows:

(a) It was generally agreed that the criteria for WSST for developing countries should be established by each country to meet its own local conditions, and not "copied" from the USA or from some other industrialized country where the criteria might well be different in some respects.

(b) While the EPA/Cincinnati offices have been continually investigating and assessing waterborne disease outbreaks known to have occurred in the USA (in collaboration with the Center for

Disease Control/Atlanta), they do not know of any outbreaks attributed to WSST. Most of the outbreaks relating to water supply distribution systems appear to have been caused by cross-connections between water and sewer lines.

(c) Maintenance of a free chlorine residual line in the distribution system is the best method for protecting the distribution system from contamination from any and all sources.

(d) Sewage which is in the vicinity of a leak in a water main may be sucked into the water main by "aspiration," even if there are no negative pressures in the water main.

(e) A primary objective of sanitation programs should be to get excreta materials collected into a sewer pipe, rather than to have excreta distributed on the surface of the ground. If this objective is pursued, the benefits of sewers could be quite large, and outweigh the relatively remote hazard of using WSST built with good-quality pipes and in accordance with the correct construction procedures. This relationship could be quantified by a "risk assessment" analysis.

(f) The cost of installing water/sewer mains in urban zones increases with population density, and hence the use of WSST could offer increasing levels of savings at higher urban densities.

### 6.3 U.S. Public Health Service/Center for Disease Control

The U.S. Public Health Service/Center for Disease Control at Atlanta (Georgia), which is the national center with responsibility for investigating disease outbreaks, includes an Investigations Section with responsibility for investigating waterborne outbreaks in the USA (Lippy, 1981). The Investigations Section cooperates closely with their counterparts at EPA/Cincinnati in carrying out studies on waterborne diseases.

Discussions with officials from the Investigations Section led to confirmation of findings similar to those produced at EPA/Cincinnati. The officials were not aware of any waterborne outbreaks which could be attributed to WSST, but they pointed out that there has only been limited use of WSST in the USA.

## 6.4 World Health Organization (WHO)

The WHO component primarily concerned with water supply contamination hazards is the Division of Environmental Health, and within this division two sections are concerned, namely the Environmental Health Technology and Support section and the Environmental Hazards and Food Protection section.

The results of meetings with officials from these two sections are summarized below:

(a) WHO has not established any specific criteria or standards for WSST in developing countries, but believes the best approach is for each developing country to establish its own criteria based on the prevailing local conditions as well as on international experience.

(b) Most of the WHO officials interviewed felt that the appropriateness of using WSST in a developing country can be properly evaluated on the basis of obtaining maximum health protection with a limited amount of funds, taking into account all the hazards of contamination from sewage in the community environment. Some experts concurred that the hazard of excreta contamination from overflows of poorly functioning subsurface disposal units represents a much greater hazard than the use of WSST where good-quality sewers (rubber ring joints or equivalent) with competent supervision are installed.

## 6.5 World Bank

Discussions were held with the Bank's Project Engineer for the AWSS water supply/sewerage projects when WSST was being utilized on wide as well as narrow streets, making a total of 200 km of WSST total. The head of the Bank mission to the AWSS noted that WSST was common practice in Sweden and elsewhere in Western Europe on streets of all widths. This was confirmed by the Chief Staff Sanitary Engineer for the Bank, who has been responsible for establishing design criteria and guidelines for Bank projects in water supply and sewerage.

These officials agreed that apparently it is appropriate to utilize WSST on streets of any width when this would result in a significant increase in overall public health protection, and that this was the basis for the Bank's concurrence with the installation of some 200 km of WSST in Amman. They agreed that special care should be exercised when using WSST to ensure the use of good quality pipe materials, good quality jointing, proper bedding, adequate backfilling, and the provision of sufficient cover for protection against surface traffic.

Letters were received from both EPA/Cincinnati and the Center for Disease Control/Atlanta, responding to the written letters of inquiry submitted during the visits to these agencies, asking for their comments on the appropriateness of using WSST/AT at Amman. These responses indicate that these agencies do not recommend against use of WSST on wide streets in developing countries where such use would result in significant savings, hence in greater service for limited funds.

# VII. ECONOMIC ANALYSES ON USE OF WSST AT AMMAN

## 7.1 Initial Analysis

Based on the estimate given earlier on the relative degrees of health hazards for contaminating the water supply distribution system at Amman, a preliminary analysis was made of the relative costs-cum-health benefits for a 10 km stretch of street in Amman or other urban centers in Jordan, assuming the use of WSST/AT versus the more rigid WSST/RT requirements requested by the Ministry of Health. The analysis assumed that the use of WSST/AT represents a hazard which is one percent of the total hazards for contamination of the water supply distribution system at Amman, and that the hazards of disease outbreak from contamination of the water supply distribution system represents 10 percent of the total health hazard attributed to fecal pollution. The analysis also assumed that

(a) for 10 percent of the distance there would be narrow streets where WSST would have to be used; and

(b) for the other 90 percent:

- separate lines would be used for the water and sewer mains;
- WSST/AT would use appropriate technology criteria, i.e. reinforced-concrete pipe for gravity sewers, cast or ductile iron for water mains, with one meter or more vertical separation; and
- for WSST with vertical separation less than 1 meter but more than 30 cm, iron or ductile pipe would be used for the sewer, and for vertical separation of less than 30 cm the iron sewer pipe would be encased in concrete.

Details of the analysis are shown in the full report. The assumed manhole spacing for the sewers was 70 m.

The results of the analysis shows that, for equivalent health protection, the alternative of using the recommended WSST/AT would reduce the total construction costs by approximately 15 percent. The estimated total construction costs for the two alternatives for the 10 km stretch are approximately JD 520,000 using the Ministry of Health criteria, and JD 438,000 using the appropriate technology criteria. (One JD equals approximately US$2.71).

## 7.2 Additional Analysis

The analysis noted above was extended to cover a range of values for the relative degree of hazard (RH) stemming from the use of WSST, which was taken to be one percent in the original analysis. The subsequent analysis assumed this hazard to range from one to as much as 50 percent of the total hazard of contaminating the water supply distribution system.

For an assumed budget limit for investment of JD 438,000, if the rigid Ministry of Health criteria are utilized the resulting total health benefit may be expressed as 8,400 HBU (health benefit units). The total HBU using WSST with appropriate technology criteria ranges from 9,500 HBU where RH is 50 percent to 9,990 HBU where the RH is one percent. Thus from the point of view of obtaining maximum protection from contamination from excreta, for a fixed investment in water and sewer mains under the conditions pertaining at Amman, the use of WSST/AT criteria on all streets results in more protection than is provided for by the Ministry of Health criteria, ranging from about 13 percent for an RH of 50% up to about 19 percent for an RH of 1 percent. In general it can be concluded that the extra health protection will be in the order of 15 percent.

## 7.3 Estimated Annual Savings

Assuming the construction of some 200 km/year of water and sewer mains, and an average unit cost of about JD 25 per foot, the annual savings would be of the order of US$2.3 million/year, or some US$28 million over a period of 10 years.

# VIII. CORRECTIVE MEASURES FOR EXISTING WSST

## 8.1 Strengthening of the Chlorination Program

In view of the assessment of hazards as expressed above, the most appropriate primary method for controlling the existing WSST hazard at Amman, together with all other water supply contamination, is to strengthen the WAJ/AWSS program for chlorination of the water carried in the water supply distribution system at Amman so that a positive discernible chlorine residual will be maintained throughout the distribution system at all times. This should include regular monitoring at a sufficient number of points in the water supply distribution system to ensure that monitoring is being carried out on a continuing basis. This will require a special study or analysis of the water supply distribution system to determine the needs for equipments, supplies, and personnel for achieving the objective.

At the present time WAJ/AWSS has one engineer assigned to monitoring chlorine residuals at various points in the water supply distribution system, with the objective of achieving a discernible chlorine residual (not over 0.5 ppm nor less than 0.1 ppm) at all times. The proposal here is to expand the monitoring program (see Section 8.3) to ensure that this objective is achieved. Considering the size of Amman and the present total lengths of water supply distribution system mains (now about 500 km), and the relative types/degrees of hazards, it is estimated on the basis of experience gained in the USA that the chlorine residual monitoring program should include about 100 stations selected throughout the city to accommodate the five different pressure zones. Such a monitoring program would do much towards ensuring safe water delivery, up to the water meter connection point, to all AWSS consumers. Based on the results of the program, adjustments could be made in the program of chlorination at the various pumping stations so as to optimize overall chlorination requirements and costs. Booster chlorination stations could be used, if needed, to supplement the stations adding chlorine into the reservoir system.

As noted in Section 2.8, the present water quality monitoring program has partially achieved this objective already. The recommendation here is to strengthen the overall chlorination program to make it as effective and foolproof as possible.

The practice of maintaining a positive chlorine residual throughout the distribution system has been common in cities in the USA for many decades, in order to protect the water supply from recontamination from any and all sources, including cross-connection inflows. A recent report by the U.S. EPA Health Effects Research Laboratory (1983) confirms the validity of this method of control. For Amman it would give very valuable protection against WSST hazards. In addition, the maintenance of chlorine residuals throughout the water supply distribution system should be very valuable for preserving water quality through the control of undesirable biological growths, including slimes.

### 8.2 Repair of Existing WSST Piping

In view of the above discussion, it does not appear warranted to dig up and replace the existing WSST piping except for special situations. This would require a large investment for correcting a minor part of the overall contamination hazard from the water supply distribution system. Nevertheless, the WAJ/AWSS should utilize its mapping and leak detection programs to identify any portions of WSST which may be defective. As mentioned earlier, the municipal water supply leakage detection program at Amman should be strengthened as a matter of high priority. In any case the leakage program efforts should be focused on the WSST locations as the first priority.

### 8.3 Improved Map Records

The WAJ/AWSS is now engaged in improving its system of map records for Amman so that water and sewer lines in all portions of the city will be shown at a scale of 1:1,000. Such maps would greatly facilitate all field work including leakage detection, and will be far more useful than the presently available maps which are at scales of 1:500 (too many maps required) or 1:2,500 (not enough detail shown). It is recommended that the 1:1,000 mapping program also focus first on the WSST locations. Once all the WSST location have been reliably mapped, this information can be used for guiding the efforts of the leak detection, chlorination, and water supply distribution system pipe replacement programs.

Whenever it is found that any existing WSST facility is defective - that is, has leaky piping or vertical separation between piping less than 18 inches the water main should be replaced in a separate trench.

### 8.4 Water Quality Monitoring

Experience in industrialized countries like the USA has shown that when a serious epidemic of enteric diseases occurs: (i) the primary focus of attention is the public water supply (Feachem, R., 1980); (ii) the essential responsibility for guaranteeing the safety of the public water supply is the public water supply agency and the official health authority, and the water agency's basic responsibility cannot be delegated to other agencies; and, (iii) the most important evidence needed by the water agency are records showing that appropriate chlorine residuals and bacteriological (coliform) standards have been maintained in the area in question. For these reasons it is recommended that the WAJ/AWSS should itself assume the basic responsibility for bacteriological sampling/analysis for the distribution system as well as for chlorine residuals and other important water quality criteria. Bacteriological tests and others should be done by the WAJ/AWSS laboratory (expanded and strengthened as needed). The role of Ministry of Health and the Municipality Health Department laboratories would be to monitor the WAJ/AWSS monitoring program, including spot checking. This is the usual practice throughout the USA.

Considering the small cost of such water quality monitoring, as a percentage of overall AWSS program costs, it would seem to make sense for AWSS itself to have direct management of the monitoring function - if for no other reason than to protect itself. The second main reason is to bring the monitoring program results into close if not "intimate" association with AWSS the construction and operating divisions of AWSS, in order to ensure the type of communications which could be expected to lead to the optimization of quantity-cum-quality management of the overall AWSS program. With respect to costs, a USA "rule of thumb" which may be useful is that an appropriate annual budget for the overall water quality monitoring program for an agency like the WAJ/AWSS is about one percent of the total capital investment (Ludwig, H.F., 1961).

### 8.5 Establishment of a Division of Water Quality

The recommendations discussed above, considered together, lead to another recommendation of an institutional nature, namely that the WAJ/AWSS should establish a separate "Division of Water Quality Control" (or "Office of Water Quality Control") which would work in parallel with the construction and operating divisions. The responsibilities and functions of the proposed Division would be limited to the surveillance and monitoring needed for the maintenance of water quality, including the protection of public health. The Division's duties would include the surveillance of planning/construction/operational activities of the WAJ/AWSS in order to achieve an optimally balanced overall program of quantity-cum-quality. It would be essentially a service division, advising and assisting the planning/construction/operating divisions, and would be headed by a sanitary engineer skilled both in water supply "quantity operations" and environmental technology.

The above recommendation is the practice in most major cities in the USA. Experience has shown that it is not realistic to expect the water supply agency's "quantity operators" (who are bearing the main brunt of public expectations in making reasonable quantities of water available where needed) be responsible for water quality control as well, - and especially as additional types of expertise are involved in quality control.

Another important advantage of having a separate Division of Water Quality (DWQ) is that it could act as a "counterpart" for the WAJ/AWSS in facilitating relationships with the Ministry of Health, the Municipality, and other agencies concerned with water quality and public health. In this way appropriate attention to water quality and public health could be built into the planning/construction/operations activities of the WAJ/AWSS from the outset.

The new Division would be expected to make continuing efforts for devising appropriate criteria and standards for WSST and all other aspects of the WAJ/AWSS operations. Its program of surveillance would include routine periodic checking of all hazards to water supply contamination (including, for example, checking "closed" cesspools to be sure they are closed), plus surveillance and evaluation of the WAJ/AWSS waste treatment/disposal facilities to ensure these are properly planned, built, and operated to furnish the needed environmental protection. Again, it is important to appreciate that the necessary management systems should be tailored to Jordanian conditions (and the common practice of "copying" industrialized country technology should be avoided). The new Division's duties would include the formulation and implementation of a minimum desirable building cross-connection control program over an appropriate period of years. It would also be responsible for the formulation and implementation of an appropriate methodology/technology for regulating industrial waste discharges (Ludwig, H.F., 1978).

### 8.6 Summary and Conclusions on Existing WSST

A preliminary assessment has been made of the nature and significance of the contamination hazards from the water supply distribution system at Amman due both to WSST and to other sources (namely cesspools and building cross-connections). It is clear that the WSST hazards represent only a small part of the overall hazards involved in the water supply distribution system, and that the primary defense against all of these hazards should be to implement a strengthened chlorination-cum-monitoring program to ensure safe water throughout the distribution system at all times. This is the approach almost universally used in the USA to furnish continuing protection against the hazards of water supply distribution system contamination of all types.

The use of chlorination in the context described above is analogous to the use of pasteurization in milk sanitation. Milk sanitation programs strive to achieve as much cleanliness in dairies as possible, and they give special certification for milk from dairies passing rigid cleanliness tests. However, pasteurization is required for all of them, and it is recognized that pasteurized milk, even if it is less clean, it is safer than the cleanest milk which has not been pasteurized.

With specific reference to existing WSST, it would hardly be feasible to dig up and replace the approximately 200 km of water mains in WSST trenches (a large investment would be needed for a relatively small benefit, and most of the contamination hazards would remain). The appropriate approach is to implement the strengthened chlorination-cum-monitoring program noted above and to carry out corrective measures so that this hazard, together with the cesspool and building cross-connection hazards, will be progressively minimized. (It must be expected that in all probability such hazards will never be totally eliminated -- they exist in water supply distribution systems throughout the world.) For WSST, the recommended correction program is *through strengthened mapping/leak detection and water mains replacement* programs, to identify points in the WSST system which are hazardous (leaky pipes and/or less than one meter of vertical separation), and to relocate the water main (or sewer pipe) at the hazardous points.

With respect to the contamination hazard from cesspools, the correction program should include (i) correction of the problem through the provision of sewerage, the use of more cesspool capacity, or the provision of more frequent pumping, and also (ii) an improvement in the design of new cesspool systems, using leaching tests, so that percentage of failures will be reduced. (Background information on appropriate technology is given in the full reports.)

With respect to building cross-connections, an appropriate control program should be planned, to be implemented over a period of years, through adaptation of the technology developed in industrialized countries.

A new Division of Water Quality should be established within the WAJ/AWSS to have primary responsibility for planning, implementing, and managing the contamination protection measures noted above, and also for carrying out the other health and environmental activities relevant to WAJ/AWSS activities. This new division should be assisted by AWSS construction and operation division. It would be an opportune time for the WAJ/AWSS to take this step, as part of its program of continuing development.

## IX. APPROPRIATE USE OF WSST IN JORDAN IN THE FUTURE

A review of WSST experience in the USA and elsewhere, which has included consultation with the USA and international agencies carrying out evaluations and research on water supply contamination hazards, has clearly indicated that WSST is regarded as an acceptable practice in many localities, without the use of special encasement of the sewer pipe and/or the use of pressure pipe for the sewer, provided (i) the sewer pipe is of first-class quality (can withstand low head pressures with rubber ring joints or the equivalent); (ii) the vertical separation between the two pipes is at least 18 inches; and, (iii) the water main is located on a side-bench so that the sewer main may be repaired without disturbing the water main. This practice is commonly used in Western Europe - and in the USA it is generally allowed whenever the physical or right-of-way constraints make it necessary to utilize a single trench for both mains. It is commonly used in Washington, D.C.

In Amman, the use of "Appropriate Technology WSST" (or WSST/AT) has resulted in a reduction in the cost of the water supply system of about 15 percent. Where excreta disposal depends on the use of subsurface leaching areas, as is the case in the urban areas of many developing countries, WSST/AT, used on wide as well as narrow streets, would be a relatively cheap way of providing health protection. The alternative, i.e. the use of separate trenches or of WSST with rigid sewer requirements (i.e. the use of pressure pipe and/or encasement), might be too expensive for developing countries to afford. However, this assumes that the quality of construction of WSST will meet minimum international standards, and the construction records of municipal water supply agencies in many developing countries may show that they do not meet this requirement.

This is one of the main reasons for recommending that the WAJ/AWSS should establish a Division of Water Quality (DWQ), one of whose functions would be to monitor and exercise surveillance over the planning, design, and construction of future water supply and sewer mains, especially WSST, to ensure that construction practices do in fact meet the minimum international standards. The DWQ would of course work closely with the Ministry of Health to keep the Ministry of Health appraised of its activities and progress. Assuming that this is done, it would be good practice to use WSST/AT Amman and elsewhere in Jordan (i) where separate trenches are not feasible (due to physical constraints or right-of-way constraints), and (ii) in wider streets where the savings would result in enhancing the overall health protection obtainable with limited funds.

## REFERENCES

Acra, Aftim (1980). "Environmental Conditions Related to Waterborne Disease in Zarqa-Ruseifa". In: Feasibility Study Zarqa - Ruseifa Water Distribution, Sewerage and Stormwater System. Malcolm Pirnie Engineer and Jouzy & Partners Consulting Engineers, Amman.

Amman Water Supply System Correspondence File with Ministry of Health.

Anon (1977). "Amman Water & Sewerage Authority Law, Law No. (48)." December 1977.

Anon (1980). "Cross Connection Control Means Potable Water Safety". American City and County, 61-62.

Anon (1980). "Description of Affected Environment". In: Feasibility Study Zarqa - Ruseifa Water Distribution, Sewerage and Stormwater System. Malcolm Pirnie Engineer/Jouzy & Partners Consulting Engineers, Amman.

Anon (1980). "Guidelines for Water Reuse". EPA-600/8-80-036. U.S. Environmental Protection Agency.

Anon (1981). "Onsite Wastewater Treatment and Disposal Systems". EPA-625/1-90-012. U.S. Environmental Protection Agency.

Anon (1981). "Process Design Manual for Land Treatment of Municipal Wastewater". EPA-625/1-81-013. U.S. Environmental Protection Agency.

Anon (1983). "Health Effects Associated with Wastewater Treatment and Disposal Systems, State-of-the-Art Review", Volume II, Part 1. U.S. EPA Publication, EPA-600/1-79-016b. Health Effects Research Laboratory, Research Triangle Park, North Carolina.

Brown, K. et al. (1979). "The Movement of Fecal Coliform and Coliphages below Septic Lines". J. Environ. Qual., 8(1): 121-125.

Clark, R. et al. (1982). "Determinants and Options for Water Distributions System Management". U.S. EPA/Cincinnati, Municipal Environmental Research Laboratory.

Engineering-Science (1983). "Contract Documents for the Design, Construction and Commissioning of Facilities for the Immediate Relief of Overloaded Conditions at the Ain Ghazal Sewerage Treatment Plant". Amman Water Supply System, Amman.

Feachem, R. et al. (1980). "Appropriate Technology for Water Supply and Sanitation, Volume 3 - Health Aspects and Excreta and Sullage Management, A State-of-the-Art Review". World Bank.

JMM/DMJM - James M. Montgomery Consulting Engineers/Daniel, Mann, Johnson, & Mendenhall (1982). "Final Master Plan Report and Engineering Design and Economic Analysis, Report for Wastewater Disposal for Greater Amman Area". Nation Planning Council, Amman. 2 volumes.

Lippy, E.C. (1981). "Waterborne Disease: Occurrence is on the Upswing". J. AWWA, 57-62.

Ludwig, H.F. (1961). "Report on Collection, Collation, and Evaluation of Marine Water Quality Monitoring Program of California State Water Resources Control Board". California State Water Resources Control Board.

Ludwig, H. F. (1978). "Guidelines for Preparation of Ordinances for Regulating Sanitary and Industrial Wastes Discharges for Municipalities in Indonesia". UN Office of Technical Cooperation/Government of Indonesia.

Ludwig, H. F. (1983). "Interim Report on WSST at Amman". USAID and Water Authority of Jordan/American Water Works Association.

McGinnis, J. & Dewalle, F. (1983). "The Movement of Typhoid Organisms in Saturated Permeable Soil". J. AWWA, 266-271.

Municipalities of Metropolitan Seattle (1983). "Health Effects of Sludge Land Application, A Risk Assessment - Appendix B". Sludge Management Plan.

Pirnie/Jouzy - Malcolm Pirnie Engineer/Jouzy & Partners Consulting Engineers (1980). "Feasibility Study, Zarqa-Ruseifa Water Distribution, Sewerage and Stormwater Systems". National Planning Council.

Prevost, R. (1981). "Pipelines for Water Supply and Sewerage". World Bank Publication TWT/N-5. World Bank, Washington D.C.

Stearn, H. (1983). "Leak Detection" (Draft). Amman Water Supply System, Amman.

USAID/Jordan (1979). "Project Paper Jordan, Amman Water and Sewerage, Loan No. 273-K-023".

U.S. Public Health Service/Center for Disease Control (1983). "Water Related Disease Outbreaks Surveillance, Annual Summary 1982". Atlanta.

University of Jordan and Royal Scientific Society (1979). "Prevention of Groundwater Backflow into Distribution Systems". J. AWWA, 76-79.

VBB - Vattenbygganadsbyran (Amman) (1972). "Feasibility Study and Master Plan for Amman Water and Sewerage Works, State 3, Summary Draft Final Report". Amman Water Supply System, Amman.

VBB/Fauzi - Vattenbygganadsbyran and Fauzi & Associates Consulting Engineers (Amman) (1977). "Feasibility Study for Amman Water Supply and Sewerage Facilities, Final Report". Amman Water Supply System, Amman. 3 volumes.

## ANNEXES

The overall WSST study report included some 20 annexes containing support and background information. Selected annexes are included here:

# ANNEXES I

## SURVEY OF WSST PRACTICES AND THE WSST SPECIFICATIONS IN THE UNTIED STATES OF AMERICA

### Survey of WSST Practices in USA

1. In November 1983 the consultant initiated a mail survey of state water pollution control agencies in the USA in order to evaluate current practices in the USA on the use of WSST and on regulations governing these practices. The questionnaire was sent to the directors of the appropriate state agencies (usually environmental, water pollution, or public health departments) having jurisdiction over use of WSST.

2. By the end of February 1984, replies had been received from 30 of the 50 states. These results are summarized, state by state, in Table 1. The table also includes information on practices as recommended (i) by the agency known formerly as the "Ten States" (now the "Great Lakes/Upper Mississippi River Board of State Sanitary Engineers"), and (ii) by the AWWA (American Water Works Association).

3. The results of the survey may be summarized as follows:

   (a) While there is considerable variation in the practices adopted by different states, nevertheless there is a general concurrence which may be expressed as follows: water mains and sewer mains should be placed in separate trenches, 10 feet or more apart; but if required by physical constraints (such as narrow streets), they may be placed in the same trench provided (i) the water main is at least 18 inches above the sewer main; (ii) the water main is located in a "side-bench" so that the sewer may be repaired without disturbing the water main; (iii) the water main is a pressure main (such as ductile pipe or cement-asbestos pipe with mechanical or other pressure-resistant joints) meeting AWWA specifications (the same as for water mains placed in a trench by itself); and, (iv) the sewer main is of the modern type which can withstand low-head pressures and which has rubber ring or other joints which are essentially leak-proof and root-penetration-proof (i.e. modern pipe materials and joints are used). Thus, the states in effect approve of WSST, without any special encasements in narrow streets but "frown" on such use in wider streets where there is room for meeting the 10-foot separation requirements.

(b) The consensus regulation noted in Item (a) differs from regulatory practice in the USA in earlier decades when sewer mains commonly used bell-and-spigot joints with cement mortar, and, unlike the modern pipes, were characterized by significant leakage/infiltration rates. Hence, some of the earlier codes for WSST specified use of concrete encasement around the sewer, or use of water-main type piping for the sewer.

(c) It appears that in Western Europe it has been fairly common practice to use WSST (following the (a) specifications) because narrow streets are common in many of the cities. In the USA, however, the city streets have been generally wide, hence it has been easy to use separate trenches 10 feet or more apart, hence the practices and regulatory codes developed along these lines, different from Western Europe.

(d) When comparing USA practices in water supply and sanitation with the developing countries, it is necessary to take into account the differences in excreta disposal practices. In most USA communities, fairly satisfactory excreta disposal has been achieved since the turn of the century through the use of public sewer systems or through the use of properly functioning subsurface excreta disposal systems (usually septic tank/leaching systems serving individual buildings). There is a general lack of such systems in many developing countries. There are few public sewers and few septic tank/leaching systems, and people generally depend on, subsurface leaching pits or cesspools (without septic tanks). While these may function with reasonable success when soil permeability and groundwater conditions are favorable, they often do not function well, with the result that pit overflows are common and excreta materials are often distributed around the urban neighborhood.

Recommended Standards For Water Works by Great Lakes-Upper Mississippi River Board of State Sanitary Engineers for the year 1968 and 1982 are extracted and given in the following pages.

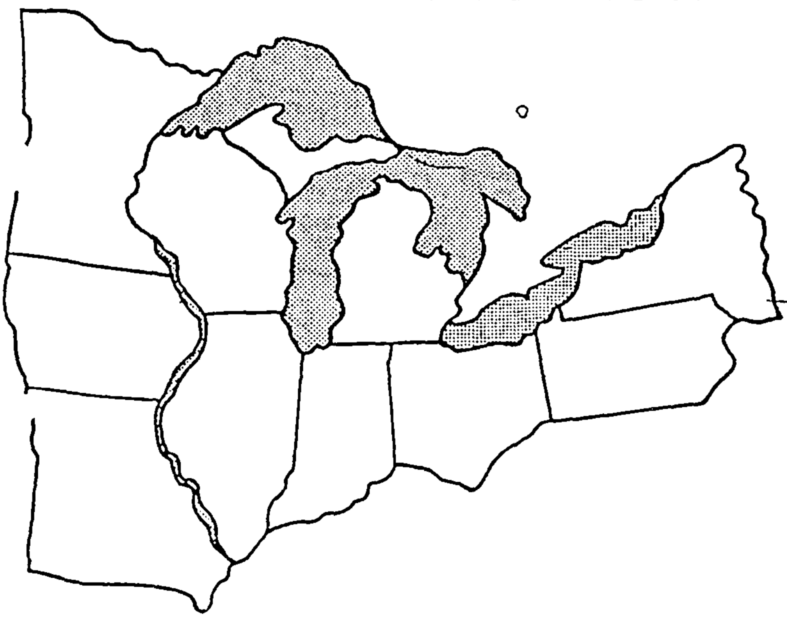
# *Recommended Standards*

for

# WATER WORKS

Great Lakes-Upper Mississippi River

Board Of State Sanitary Engineers



ILLINOIS
INDIANA
IOWA
MICHIGAN
MINNESOTA
MISSOURI
NEW YORK
OHIO
PENNSYLVANIA
WISCONSIN

**1968**
**EDITION**

## 8.3 INSTALLATION OF MAINS

8.3.1 Adequate support shall be provided for all pipes.

8.3.2 A continuous and uniform bedding shall be provided in the trench for all buried pipe.

8.3.3 Stones found in the trench shall be removed for a depth of at least 6 inches below the bottom of the pipe.

8.3.4 The specifications shall include:

a. pressure testing of the installed pipe;

b. allowable leakage of the installed pipe;

c. reference to applicable American Water Works Association standards and/or manufacturer's recommended installation procedures.

## 8.4 SEPARATION OF WATER MAINS AND SEWERS

8.4.1 General - The following factors should be considered in providing adequate separation:

a. materials and type of joints for water and sewer pipes;

b. soil conditions;

c. service and branch connections into the water main and sewer line;

d. compensating variations in the horizontal and vertical separations;

e. space for repair and alterations of water and sewer pipes;

f. off-setting of pipes around manholes.

8.4.2 Parallel Installation -

8.4.2.1 Normal conditions - Water mains shall be laid at least 10 feet horizontally from any sanitary sewer, storm sewer or sewer manhole, whenever possible; the distance shall be measured edge-to-edge.

# Recommended Standards For Water Works

1982

ILLINOIS IOWA MINNESOTA NEW YORK PENNSYLVANIA ONTARIO
INDIANA MICHIGAN MISSOURI OHIO WISCONSIN

e. space for repair and alterations of water and sewer pipes,

f. off-setting of pipes around manholes.

### 8.6.2 Parallel installation

Water mains shall be laid at least 10 feet horizontally from any existing or proposed sewer. The distance shall be measured edge to edge. In cases where it is not practical to maintain a ten foot separation, the reviewing authority may allow deviation on a case-by-case basis, if supported by data from the design engineer. Such deviation may allow installation of the water main closer to a sewer, provided that the water main is laid in a separate trench or on an undisturbed earth shelf located on one side of the sewer at such an elevation that the bottom of the water main is at least 18 inches above the top of the sewer.

### 8.6.3 Crossings

Water mains crossing sewers shall be laid to provide a minimum vertical distance of 18 inches between the outside of the water main and the outside of the sewer. This shall be the case where the water main is either above or below the sewer. At crossings, one full length of water pipe shall be located so both joints will be as far from the sewer as possible. Special structural support for the water and sewer pipes may be required.

### 8.6.4 Exception

The reviewing authority must specifically approve any variance from the requirements of Sections 8.6.2 and 8.6.3 when it is impossible to obtain the specified separation distances.

### 8.6.5 Force mains

There shall be at least a 10 foot horizontal separation between water mains and sanitary sewer force mains. There shall be an 18 inch vertical separation at crossings as required in Section 8.6.3.

### 8.6.6 Sewer manholes

No water pipe shall pass through or come in contact with any part of a sewer manhole.

## 8.7 SURFACE WATER CROSSINGS

Surface water crossings, whether over or under water, present special problems. The reviewing authority should be consulted before final plans are prepared.

### 8.7.1 Above-water crossings

The pipe shall be adequately supported and anchored, protected from damage and freezing, and accessible for repair or replacement.

### 8.7.2 Underwater crossings

A minimum cover of two feet shall be provided over the pipe. When crossing water courses which are greater than 15 feet in width, the following shall be provided:

a. the pipe shall be of special construction, having flexible watertight joints,

# ANNEX II

## ILLUSTRATIVE WSST SPECIFICATIONS

### Specifications Used by Amman Municipal Water System

1. As a general rule, water pipes and sewers should not be laid in the same trench. They should be laid in separate trenches at least 3 m apart in a horizontal direction; the distance being measured edge-to-edge as shown in Fig. 1.

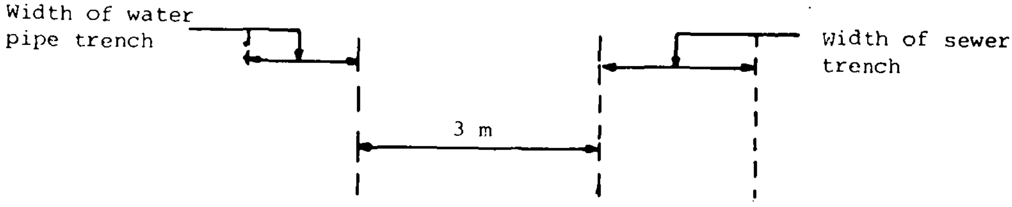



Fig. 1. Plan view

Additional protection may be provided by laying the water pipe not less than 50 cm higher than the sewer line, as shown in Fig. 2.

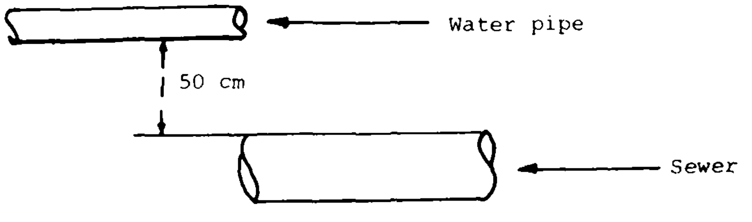



Fig. 2. Sectional View

2. If local conditions do not permit the horizontal minimum separation of 3 m (e.g. very narrow streets), this distance could be decreased - but the bottom of the water pipe must be kept at least 50 cm above the top of the sewer, as shown in Fig. 2.

3. If the vertical separation cannot be obtained, sewer material and joints should be equivalent to water main standards of construction (pressure pipes) and should be pressure tested to ensure watertightness before back-filling.

4. In cases where there is no alternative but to lay both water pipes and sewers in the same trench, the following points should be observed:

   (a) The water main should be offset on an undisturbed earth shelf.

   (b) The bottom of the water main should be at least 30 cm above the top of the sewer line, as shown in Fig. 3.

   (c) Both water and sewer lines should be cast iron with mechanical joints or equal construction.

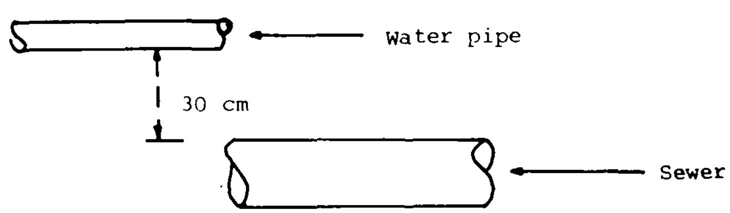



Fig. 3. Sectional View

5. In situations where water pipes are in close proximity to sewers and no adequate horizontal or vertical separations can be provided consideration should perhaps be given to enclosing sewer lines in concrete in addition to using pressure-type pipes for sewers.

6. Where sewers cross water mains, sewers for a distance of at least 3 m on each side of the water line should be constructed of materials and joints that are equivalent to water main standards of construction and should be pressure-tested to assure watertightness before back-filling.

A vertical separation of at least 50 cm between the bottom of the water main and the top of the sewer should be provided, whenever possible, as shown in Fig. 2.

7. If sewers have to pass over water mains, the following points should be considered:

(a) Vertical separation of at least 50 cm between the bottom of the sewer and the top of the water main, as shown in Fig. 4.

(b) Sewers should be constructed of materials described in item 3 above i.e. a pressure-type pipe.

(c) Adequate structural support for the sewers to prevent excessive deflection of joints and settling on the breaking and water mains.

(d) The length of water pipe should be centered at the point of crossing so that the joints will be equidistant and as far as possible from the sewer.

(e) Consideration might also be given to enclosing the sewer line in concrete for a distance of at least 3 m on either side from the point where water pipes cross sewers.

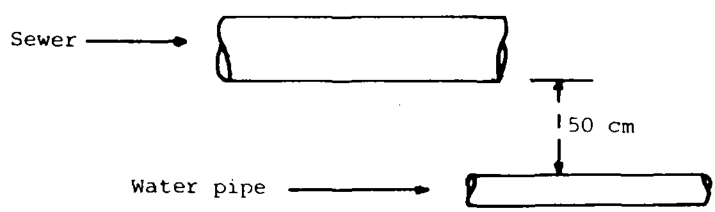
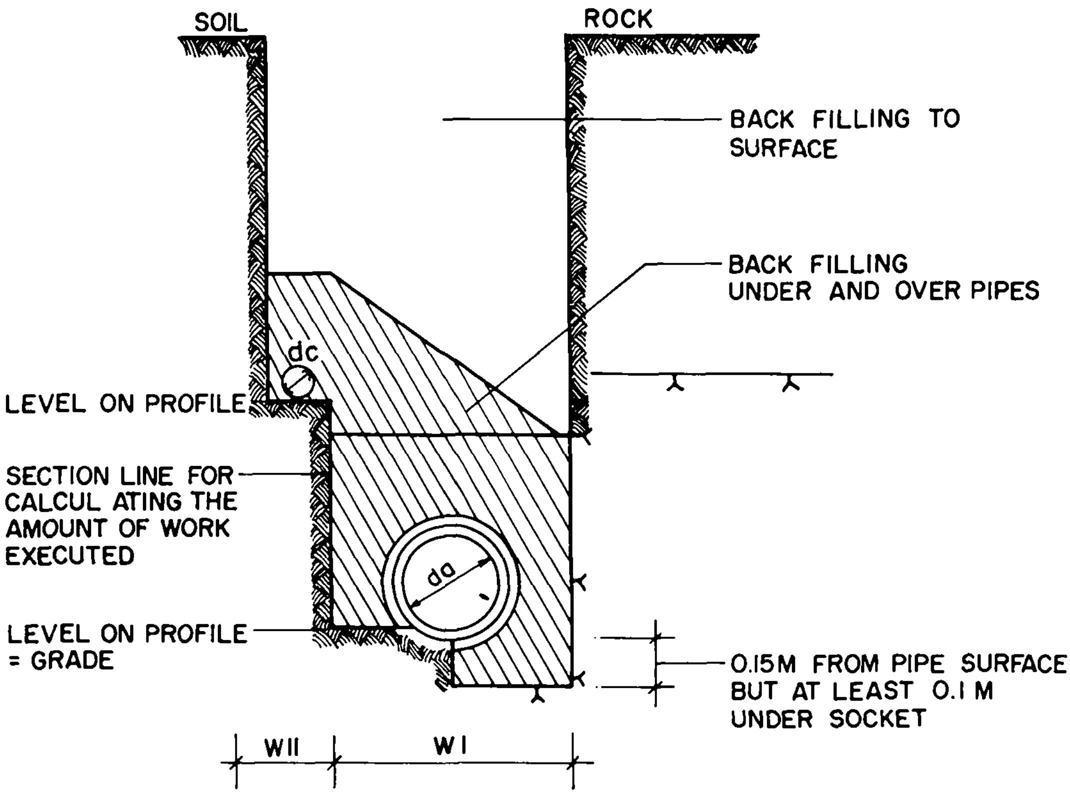



Fig. 4. Sectional View

## TYPICAL TRENCH - SECTION FOR TWO LINES IN SOIL AND ROCK




da = SANITARY SEWER DIAMETER IN MM
dc = WATER LINE DIAMETER IN MM

TABLE OF TRENCH - WIDTH

$W_I$ IN M

| da | 150 | 200 | 300 | 400 | 500 | 600 | 800 | 1000 |
|---|---|---|---|---|---|---|---|---|
| $W_I$ | 0,6 | 0,6 | 0,7 | 0,9 | 1,0 | 1,2 | 1,5 | 1,7 |

$W_{II}$ IN M

| dc | ≥ 100 | 150 | 200 | 250 | 300 | 400 |
|---|---|---|---|---|---|---|
| $W_{II}$ | 0,2 | 0,2 | 0,3 | 0,4 | 0,5 | 0,6 |