Water Safety Plan

A Manual for Pilot Study Areas of Hyderabad

Organize Team

WSP

- System Assessment
- Monitoring
- Management Plans

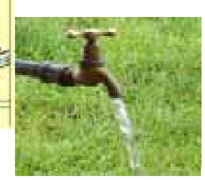
- Source Evaluation
- Treatment Efficiency
- Hazard & Risk in Distribution
- Control Measures
- Validation
- WSP Verification

((Supporting Programmes))

((Continual Improvements))

((Documentation & Records))

((Review and Audits))



United States Environmental Protection Agency

World Health Organization

Hyderabad Metropolitan Water Supply & Sewerage Board

नीरी NEERI National Environmental Engineering Research Institute

November, 2009

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Prepared in Collaboration with :

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Preface

The quality of drinking water is a vital element of public health and well beings. Contaminated water is one of the causes of diarrhea diseases, which kill about 2.4 million persons globally; each year (WHO, 2005). Access to safe drinking water is essential to maintain a good health, and is a basic human right. It is an important component of effective policy for health protection. The most effective means of consistently ensuring the safety of a drinking-water supply is through the use of a comprehensive risk assessment and risk management approach that encompasses all steps in water supply from catchment to consumer. In this manual, such approaches are called Water Safety Plans (WSPs).

The WHO Guidelines for Drinking water Quality, 3rd Edition, (2004) describe the principles of the WSP approach. The aim of this manual is to facilitate WSP development focusing particularly on organized water supplies managed by a water utility. The three key components, of WSP are guided by health-based targets and overseen through drinking water supply surveillance. These are a) System assessment, b) Identification of control measures and c) Management plans.

USEPA, in collaboration with WHO, entrusted the responsibility to National Environmental Engineering Research Institute (NEERI) for development of this Manual for three identified areas of Hyderabad in co-ordination with Hyderabad Metropolitan Water Supply and Sewerage Board (HMWS&SB).

Under this exercise of manual preparation, an attempt has been made to delineate different aspects of WSP using diverse set up and variable situation in a city. The co-operation and assistance extended by the officials of HMWS&SB and other state organizations in completion of this study are gratefully acknowledged. We are grateful to WHO, New Delhi for their active participation and significant contribution towards development of this manual. We also acknowledge with thanks the sponsorship and participation of USEPA in the development of this Manual. I am sure that this manual will be very useful to all other cities in India for real implementation and learning.

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Glossary of Terms

The following terms used in Guidelines for Drinking Water Quality (GDWQ), other documents and guiding materials used throughout this manual.

Term	**Definition**
Control (noun) (for instance control of water safety)	The state wherein correct procedures are being followed and criteria are being met
Control (verb) (for instance control of a hazard)	To take all necessary actions to ensure and maintain compliance with criteria established in the WSP
Control Measure	Any action and activity that can be used to prevent or eliminate a water safety hazard or reduce it to an acceptable level
Corrective Action	Any action to be taken when the results of monitoring at the control point indicate a loss of control
Control Point	A step at which control can be applied to prevent or eliminate a water safety hazard or reduce it to an acceptable level. Some plans contain *key* control points at which control might be essential to prevent or eliminate a water safety hazard
Critical Limit	A criterion which separates acceptability from unacceptability
Deviation	Failure to meet a critical limit
Flow Diagram	A systematic representation of the sequence of steps or operations used in the production or manufacture of a particular water item
HACCP	Hazard Analysis and Critical Control Point
Hazard Analysis	The process of collecting and evaluating information on hazards and conditions leading to their presence to decide which are significant for water safety and therefore should be addressed in the WSP
Hazard	A biological, chemical or physical agent in, or condition of, water with the potential to cause an adverse health effect. Another word for hazard includes,“ contaminant”

Term	Definition
Hazardous Event	A process whereby a hazard / contaminant is introduced into a water supply
Monitor	The act of conducting a planned sequence of observations or measurements of control parameters to assess whether a control point is under control or whether the water meets quality criteria
Risk Assessment	For the purposes of this manual, risk assessment has the same meaning as hazard analysis.
Risk Score	The score assigned to a hazard based on the risk analysis process
Step	A point, procedure, operation or stage in the water supply chain including raw materials, from primary production to final exposure
Supporting Programs/ Supporting Requirements	The foundation activities required to ensure safe water including training, raw material specifications and general good water management practices. These programs can be just as important as control points in controlling water quality risks but are used where application tends to cover long timeframes and/or broader organizational or geographic areas. Includes general organizational supporting programs as well as specific programs targeted to particular risks
Validation	Obtaining evidence that the elements of the WSP can effectively meet the water quality targets
Verification	The application of methods, procedures, tests and other evaluations, to determine compliance with the WSP i.e. checking whether the system is delivering water of the desired quality and whether the WSP is being implemented in practice
WHO	World Health Organization
WSP	Water Safety Plan

List of Abbreviations

- AC - Asbestos Cement
- AMRP - Akkampally Madhava Reddy Project
- ASCI - Administrative Staff College of India
- BDL – Below Detectable Level
- BOD - Biochemical Oxygen Demand
- CFU - Colony Forming Units
- CI - Cast Iron
- CIM- Contaminant Intrusion Model
- CPCB – Central Pollution Control Board
- CPHEEO - Central Public Health & Environmental Engineering Organization
- CWR - Clear Water Reservoir
- DD – Durgabhai Deshmukh
- DI - Ductile Iron
- DMA - District Metering Area
- DOH - Department of Health
- EB - Enumeration Blocks
- ES - Effective Size
- FRL - Full Reservoir Level
- GDWQ - Guidelines for Drinking Water Quality
- GHMC - Greater Hyderabad Municipal corporation
- GIS – Geographic Information System
- GLSR – Ground Level Service Reservoir
- GOI - Government of India
- HACCP - Hazard Analysis and Critical Control Point
- HDPE - High density Polyethylene
- HMWS&SB - Hyderabad Metropolitan Water Supply & Sewerage Board
- HUDA - Hyderabad Urban Development Authority
- IDSP - Integrated Disease Surveillance Programme
- HIS - Institute of Health Systems
- IPM - Institute of Preventive Medicine
- IRA - WDS-Integrated Risk Assessment of Water Distribution System
- ISO - Indian Standard organization

- LLR - Low Lying Reservoir
- LPS - Liters Per Second
- MBR – Master Balancing Reservoir
- MCA - Master Census Abstracts
- MCM - Million Cubic Meters
- MG - Million Gallon
- MGD – Million Gallons Per Day
- ML - Million Liters
- MLD - Million Liters Per Day
- MM - Millimeter
- MS - Mild Steel
- MSL - Mean Sea Level
- NEER I- National Environmental Engineering Research Institute
- NGO – Non Governmental Organization
- NRW - Non-Revenue Water
- NSSO - National Sample Survey Organization
- NTU – Nephelometric Turbidity Unit
- O&M – Operation & maintenance
- OHT – Over Head Tank
- PCA - Pipe Condition Assessment
- PPM - Parts Per Million
- PPS - Probability Proportionate to Size
- PSP – Public Stand Post
- PVC - Poly Vinyl Chloride
- QAT - Quality Assurance &Testing
- RAM - Risk Assessment Model
- RCC - Reinforced Cement Concrete
- RGI - Registrar General of India
- SDSS - Spatial Decision Support System
- SOP - Standard Operating procedure
- STP -Sewage Treatment Plant
- SWD-Side Water Depth
- SWP- Stoneware Pipes
- TDS- Total Dissolved Solids

- TMC – Thousand Million Cubic Feet
- TSS- Total Suspended Solids
- UASB – Up flow Anaerobic Sludge Blanket
- UC - Uniformity coefficient
- UFW - Unaccounted Flow of Water
- USEPA - United States Environmental Protection Agency
- WHO – World Health Organization
- WS – Water Supply
- WSP - Water Safety Plan
- WTP - Water Treatment plant

1.0 Introduction

1.1 Preamble

Water, an essential commodity, is getting contaminated due to inadequate control and safe system in view of urbanization and overexploitation. About 1.1 billion people globally lack access to improved water supply and about 2.0 million people, mostly children below five years die every year due to water-borne diseases (WHO). The poor quality of raw water sources warrants application of stringent treatment technologies and proper monitoring to ensure supply of safe drinking water.

Morbidity and mortality due to consumption of unsafe drinking water and spread of water borne diseases continues to impact communities in developing countries. Access to safe drinking water is a basic need and is one of the most important contributors to public health. The most effective means of consistently ensuring the safety of a drinking water supply is through the use of a comprehensive risk assessment and management approach that encompasses all steps in water supply from catchment to consumer. Such approaches are called Water Safety Plans (WSPs).

The aim of a WSP is to organize and systematize records of management practices applied to drinking water and to ensure workability of such practices to organized drinking water supply. Major objectives of a water safety plan are:

- Prevent contamination of sources
- Treat the water to remove contamination to the extent necessary to meet the water quality targets and
- Prevent re-contamination during storage, distribution and handling.

1.2 Role of Water Safety Plan

Water Safety Plan (WSP) addresses the overall issues of complete programme wherein a source to delivery of water to the consumers is mapped through different means to assess the risk of contamination at various levels. Some elements of WSP will often be implemented as part of a drinking water supplier’s usual practice or as part of benchmarked good practice without consolidation into a comprehensive WSP. This may include quality assurance systems (e.g., ISO 9001:2000). However, existing practices may not include system-tailored hazard identification and risk assessment as a starting point for system management. Existence of such good management practices provides a suitable platform for integrating WSP principles.

Formulation and implementation of WSP helps achieve better quality water in a sustainable manner by eliminating the possibilities of any risk of contamination. It leads to enormous health benefits as ensuring safe water supply provides morbidity reduction. WSPs are based on preventive risk management utilized to effectively monitor and manage potential contamination of water to prevent public health burdens before they occur.

1.3 The Basis for Water Safety Plan

The most protective means of consistently assuring a supply of acceptable drinking water is the application of some form of risk management system with sound science background and supported by appropriate monitoring. This concept is depicted in **Figures 1.1** and **1.2.** The simplified form of framework (Figure 1.1), is an iterative cycle that encompasses assessment of public health concerns, risk assessment, establishment of health based targets and risk management. Feeding into this cycle is the determination of environmental exposure and the estimation of acceptable risk.

The risk management approach that was outlined in Figure 1.2 was based largely upon Hazard Analysis and Critical Control Point (HACCP). It is a preventive risk management system that has been used in the food manufacturing industry for number of decades. The principle of HACCP is based on developing an understanding of the system, prioritizing risks and ensuring that appropriate control measures are in place to reduce risks to an acceptable level. These principles have been refined and tailored to the context of drinking water following the application of HACCP by several water utilities including in the US and Australia. The experience of the application of HACCP by water utilities has led to the development of the water safety plan approach. Many of the principles and concepts from other risk management approaches like multiple barrier approach are also considered. It is important that risk management needs to cover the whole system from catchments to consumer as shown in **Figure 1.3.**

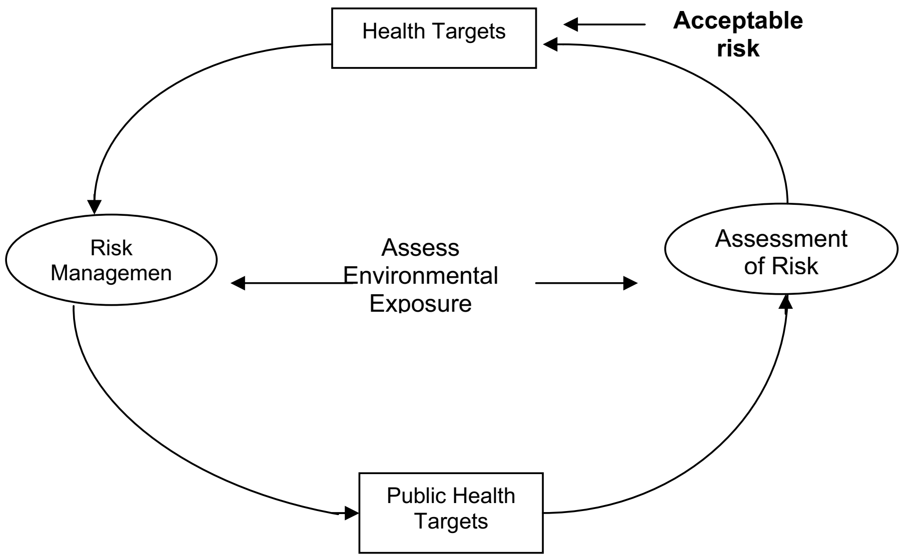


Figure 1.1: Simplified Framework (*Bartram et. al 2001*)

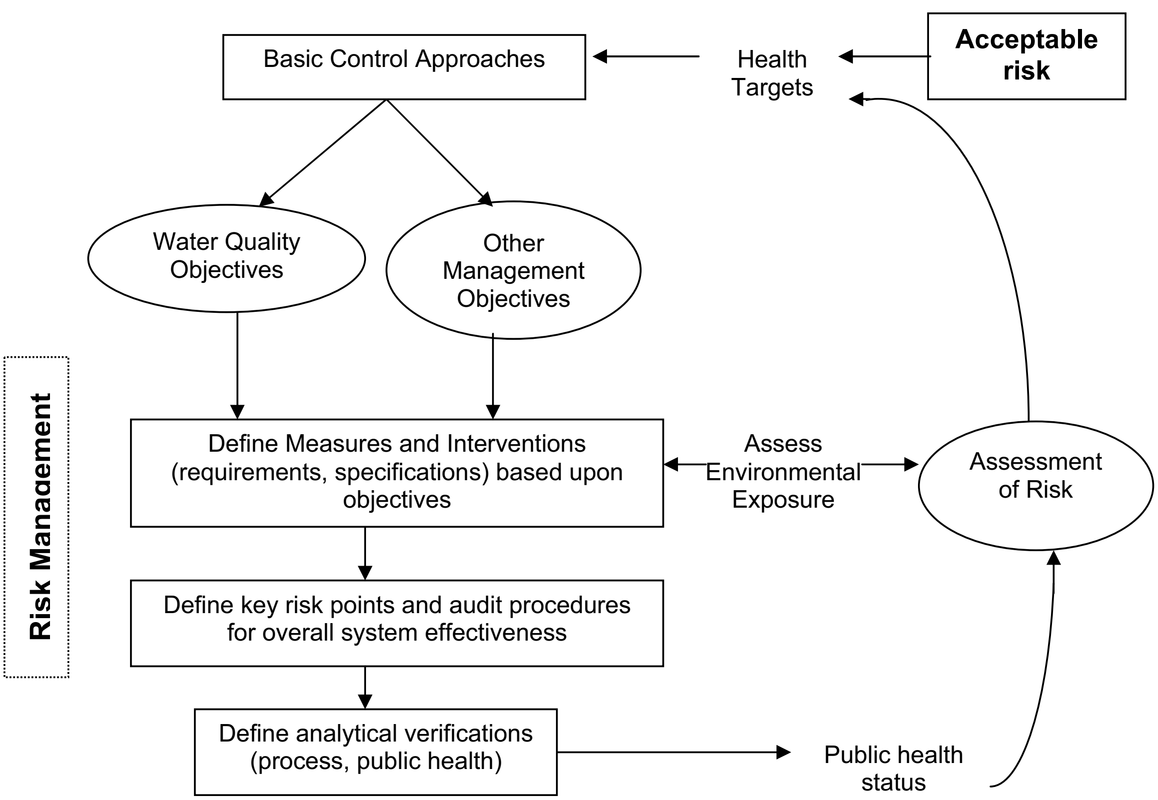


Figure 1.2: Expanded Framework (*Bartram et.al 2001*)

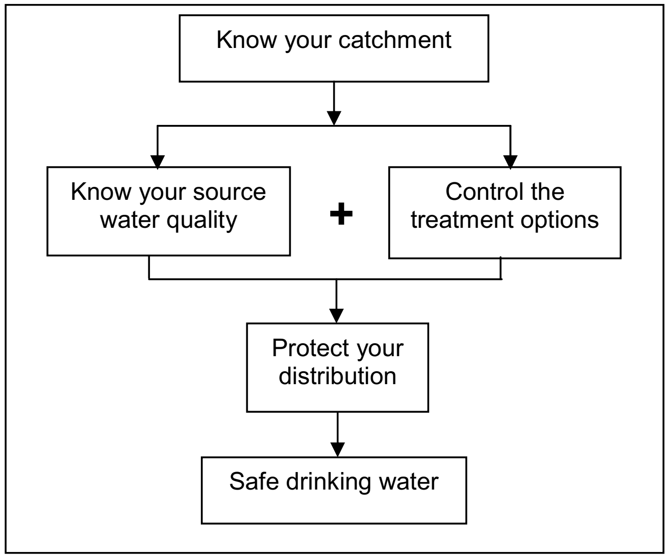


Figure 1.3 : 'Catchment to Consumer' Approach for Risk Management and Safety of Drinking Water (*Medema et al., 2003*)

1.4 Activities before Initialization & Implementation of WSP

1.4.1 Roles and Responsibilities

Roles : The process of development, implementation and maintenance of a WSP is primarily the role of the water supply organization but generally requires support and involvement from a number of supporting and regulatory agencies.

Responsibilities : The authority responsible for regulating water quality need to be engaged in the process to confirm the health based targets and customer service standards. In addition, the water quality regulator will need to commit to auditing and surveillance roles. The auditing role may be undertaken directly by the regulator or there may be a requirement for independent, third party audits.

The authorities responsible for regulating source water quality, water treatment, consumer management and use need to be involved to undertake relevant aspects of the WSP for those water supply system components. Where a single water supply organization is primarily responsible for managing a water supply system, that organization will lead the WSP. Where multiple water supply organizations are collectively responsible for different components of a water supply system, a joint working group or committee might be identified as the entity with the overall responsibility for leading the WSP.

1.4.2 Resource Commitment

In order to implement and maintain WSP in practice Identification and allocation of financial resources are required. Successfully developing, implementing and maintaining a WSP within an organization requires a firm high level commitment to the WSP and the allocation of adequate resources.

- WSP development and implementation takes many months and requires significant resources. Even a third party can document a WSP relatively readily. However, implementation of a WSP within an organization requires genuine and strong commitment at all levels within that organization. At least one person within the water supply organization needs to be dedicated to coordinating the WSP development and implementation process in a full time capacity. Numerous additional employees will need to provide timely, significant and substantive inputs for success of the process.

- A person with sufficient authority needs to enforce compliance. Further, where regulators, such as Health departments have been involved in the WSP process, communication links have been improved which ultimately flow on to improvements in system management. In the medium to longer term however, the resource input is rewarded as the WSP leads to efficiencies and better understanding of the water supply system including producing water of a good quality that consistently meets the health based targets.

1.4.3 WSP's for Multiple Systems

For water supply organizations with multiple water supply systems, two recommended steps are precisely identify distinct 'water supply systems' and decide how systems will be grouped for WSP(s). An important early decision that a water supply organization must make is how to structure its WSP(s) to ensure that all systems are most efficiently encompassed. Where a water supply organization is responsible for managing a single system, a WSP will be developed for that system. However, a complication arises where a water supply organization is responsible for managing many water supply systems. There are three ways for a water supply organization to structure WSP(s) for multiple systems:

- A single WSP can be developed for all systems
- Several WSP's can be created with each WSP covering one system or a group of related systems or
- A combination of the above, whereby a single high level WSP overarches a series of subordinate system specific WSP's.

In practice, where a water supply organization is responsible for multiple systems, a WSP for one distinct system is often developed as a 'pilot' before moving on to encompass other systems. Once the pilot WSP has become well enough developed, other systems are encompassed through an extension of the WSP programme.

1.4.4 Preliminary Assessment of System Capability to Meet Targets

Before progressing to the full development of a WSP, health based targets and system capabilities to meet these targets needs to be described and assessed.

➢ **Health based targets in relevant terms**

A preliminary analysis is undertaken to examine the capability of the water supply system to deliver water of the desired quality based on the health based targets (**Table 1.1**). To complete this step, the water supply organization should:

- Confirm the health based targets with the relevant regulatory organization
- Express health based targets such as water quality objectives and process capability requirements
- Assess the existing (or proposed) system for the presence of any required technologies, system process capabilities or evidence of compliant water quality performance and
- Document whether or not the water supply system appears *prima facie* capable, if operating according to specification, of producing water of the desired quality.

Table 1.1: Health-based targets to the water supplier (Based on Davison et al 2005)

Type of Target	Nature of target	Typical applications	Assessment	Interpretation by water supplier for WSP
Health Outcome				
Epidemiology based	Reduction in detected disease incidence or prevalence	Microbial or chemical hazards with high measurable disease burden largely water-associated	Public health surveillance and analytical epidemiology	These will need to be translated by the water supplier into water quality, performance or technology targets.
Risk assessment based	Tolerable level of risk from contaminants in drinking- water, absolute or as a fraction of the total burden by all exposures	Microbial or chemical hazards in situations where disease burden is low and cannot be measured directly	Quantitative risk assessment	
Water Quality				
	Guideline value applied to water quality	Chemical constituents found in source waters	Periodic measurement of key chemical constituents to assess compliance with relevant guideline values	These can be directly interpreted for chemical constituents that have their effects through chronic exposure and that can be readily monitored. For other chemicals and for microbial constituents, these will need to be translated by the water supplier into either performance or technology targets.
	Guideline values applied in testing procedures for materials and chemicals	Chemical additives and by-products	Testing procedures applied to the materials and chemicals to assess their contribution to drinking-water exposure taking account of variations overtime.	
Performance				
	Generic performance target for removal of group of microbes	Microbial contaminants	Compliance assessment through system assessment and operational monitoring	These can be applied directly by the water supplier in terms of the system design specification whereby technologies are selected based on their ability to meet the performance targets.
	Customized performance targets for removal of groups of microbes	Microbial contaminants	Individually assessment would then proceed as above reviewed by public health authority; would then proceed as above	These can be applied directly by the water supplier in terms of the system design specification whereby technologies are selected based on their ability to meet the performance targets.
	Guideline values applied to water quality		Compliance assessment through system assessment and operational monitoring	

- **System capability to meet health based targets**

If a system is not robust enough to the health based targets, the water supply organization may need to investigate what additional control measures and subsequent validation data are required. The WSP should still be developed to ensure that the best possible water quality is delivered at all times from the existing (or proposed) water supply system. However, the relevant health authority should be aware that the system for which the WSP is being developed is not capable of meeting the health based targets and that upgrading or improvement may be required. Importantly, the preliminary system capability assessment must consider capability under both routine and event (such as during monsoon) conditions.

1.5 Framework for Safe Drinking Water and Water Safety Plan

The chapter 4 of "World Health Organization Guidelines for Drinking Water Quality (GDWQ -2004)" outlines a preventive management framework for safe drinking water and water safety plans. It describes the principles of the WSP approach rather than being a guide to their practical application. It aims to provide recommendation to facilitate development of water safety plans focusing on organized water supplies. This framework includes WSPs, which can be implemented by those agencies responsible for supplying drinking water and improving the safety. This document can also assist supervisory and supporting organisations, such as regulators, auditors and surveillance authorities. The preventive management framework for safe drinking water comprises five key elements of which system assessment and design; operational monitoring, management plans, documentation and communication fall under WSP as shown in **Figure 1.4**.

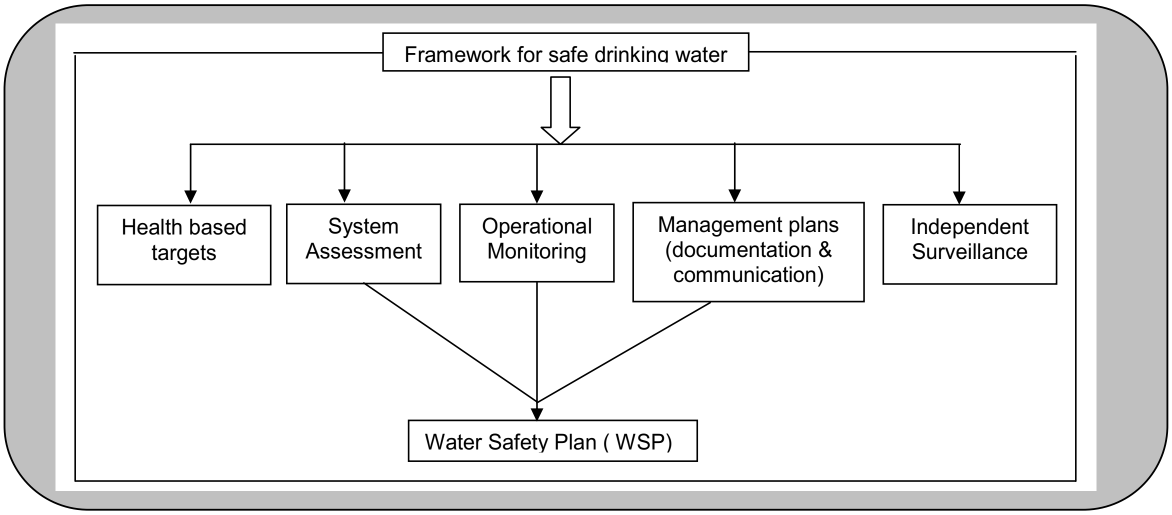


Figure 1.4: Five Key Elements for Safe Drinking Water

The brief description of the five key elements is presented below :

Setting Health Based Targets: Targets are based on an evaluation of health concerns and need to be set at a tolerable level for the community. In other words they are risk based and can be coordinated with national standards or WHO guidelines.

The health based targets define the benchmark that needs to be achieved by the water supply. It is important that health based targets defined by the relevant health authority are realistic under local operating conditions and are set to protect and improve public health. Health based targets underpin development of water safety plans and provide information with which to evaluate the adequacy of existing installations and assist in identifying the level and type of inspection and analytical verifications appropriate. Constituents of drinking water may cause adverse health effects from single exposures such as microbial pathogens and long term exposures from many chemicals compounds.

System Assessment: An assessment is conducted at all stages of treatment right from source to the treatment, storage facilities, distribution system and user to characterize the water supply scheme, identify risk and determine whether the drinking water supply meets health based standards. The system assessment will also recognize the potential controls for each identified risk.

Monitoring: It involves identifying corrective measures in a drinking water system that will collectively control identified risks and ensure that the health based targets are met. For each control measure identified, an appropriate means of operational monitoring should be defined that will ensure effective implementation and any deviation from required performance is rapidly detected in a timely manner. Operational limits for factors such as residual chlorine, total coliforms, faecal coliforms, *E. Coli*, turbidity and pH should be determined as a part of the performance measures.

Compliance monitoring is an important part of the verification process to show that the WSP is working. It will show whether water at the consumer's tap is meeting water quality standards. However it does not make the water safe to protect the health of consumers because by the time the results of compliance monitoring are available, the water will be consumed and used for domestic purposes.

Management Plans: These plans, describing actions to be taken, are set up and encompass documentation of the system assessment and monitoring plans including normal and incident operations, upgrades, improvements, supportive programmes and communication.

Surveillance: A system of independent surveillance is the continuous and vigilant public health assessment and overview of the safety and acceptability of drinking water supplies. It verifies the above mentioned components for effective operations. Surveillance contributes to the protection of public health by promoting improvement of the quality, quantity, access, affordability, and continuity of water supplies and is complementary to the quality control function of the drinking water supply agency. However it does not remove or replace the responsibility of the water supplier to ensure that a water supply is of acceptable quality and meets pre-determined health based and other performance targets.

In many cases, it will be more appropriate to use surveillance as a mechanism for collaboration between health agencies and water suppliers on improving water supply rather than resorting to enforcement, particularly where the problem lies mainly with community-managed water supplies. Surveillance requires a systematic programme of surveys that may include auditing of water safety plans, analysis, sanitary inspection, institutional and community aspects. It should cover the whole of the water supply system, including sources and activities in the catchment, transmission, and infrastructure (whether piped or un-piped), treatment plants, storage reservoirs and distribution systems.

1.6 Development of a Water Safety Plan

The aim of a WSP is to consistently ensure the safety and acceptability of a drinking water quality. A step-by-step approach for basic development and implementation of the WSP for drinking water supply is presented in **Figures 1.5 & 1.6** and discussed below.

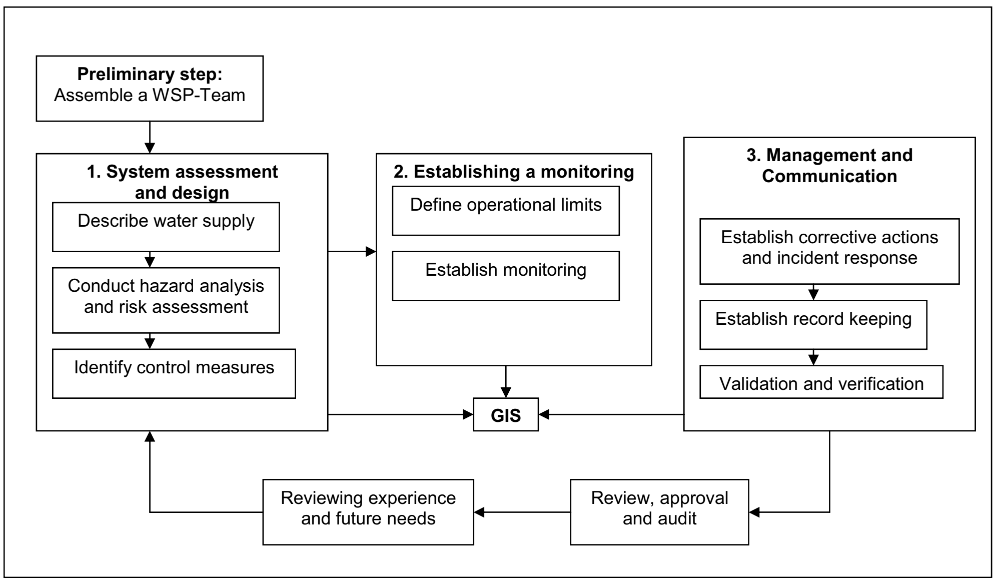


Figure 1.5: Water Safety Plan Approach

- **Assemble the Team:** Typically the team might include managers, engineers (operations, maintenance, design and capital investment), water quality control staff (microbiologists and chemists) and technical staff involved in day to-day operations. Involvement of external agencies in the field of medical, health, social and research components will enhance the scope of approach.

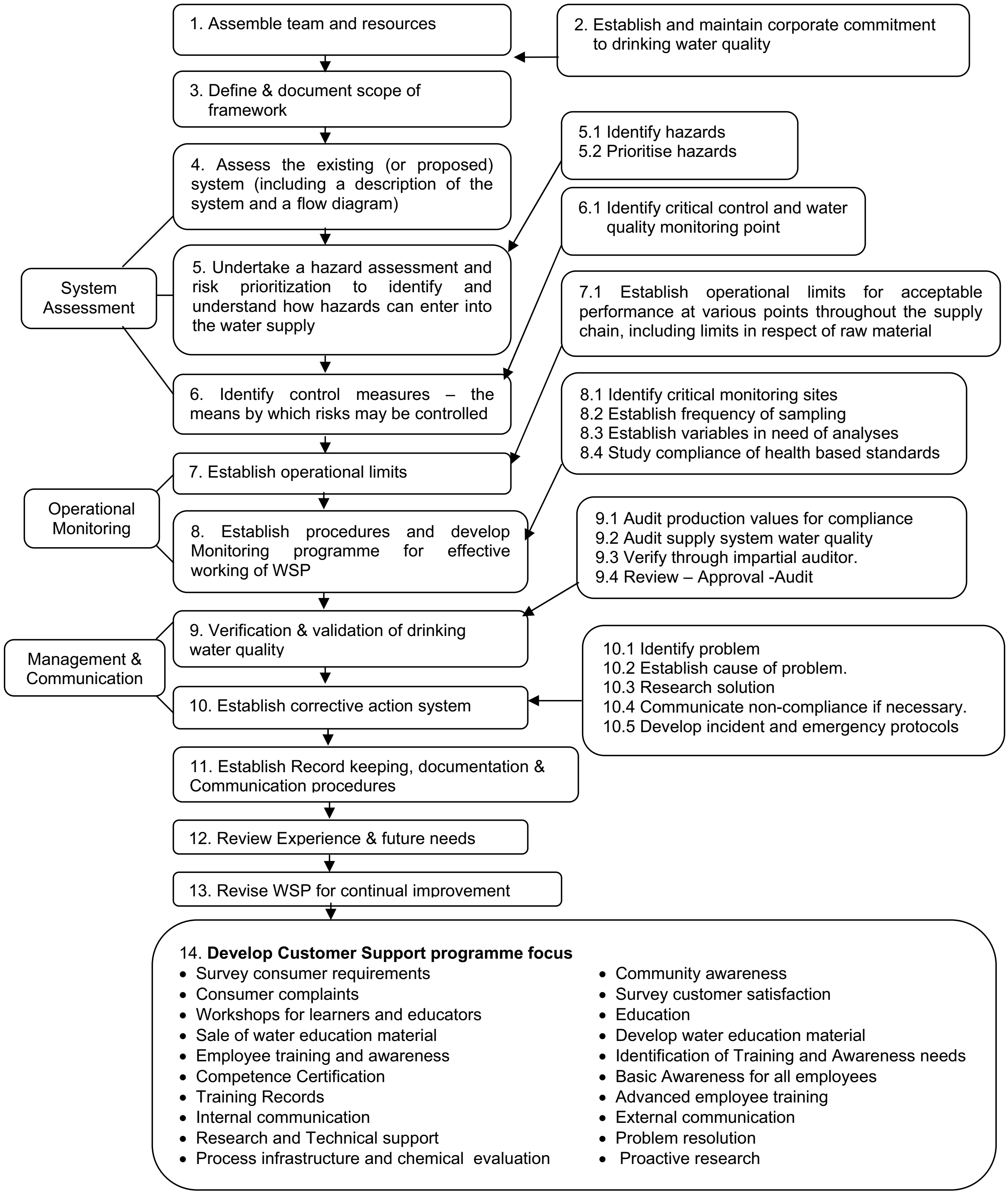


Figure 1.6: Steps involved in Development of Water Safety Plan

- **Apply WSP Methodology:** Define roles and responsibilities of identified individuals, stipulate activities and decide time frame.

- **System Assessment :**
  - Describe water supply system
  - Identify all the hazards that can affect the safety of a water supply from the catchment, through treatment and distribution to the consumer's tap
  - Assess the risk presented by each hazard and identify control measures
  - Reassess and prioritize risks for each significant hazard
  - Develop, implement and maintain the improvement plan

- **Operational Monitoring :**
  - Establish monitoring protocols
  - Define monitoring of control measures

- **Management and Communication :**
  - Establish procedures to verify the WSP (does the system meet health based targets)
  - Demonstrate that the system is consistently safe
  - Regularly review the hazards, risks and controls
  - Keep accurate records for transparency and justification of outcomes

1.7 Commitment to the Water Safety Plan Approach

While many drinking water supplies provide adequate and safe drinking water with out water safety plan, the formal adoption of a water safety plan and associated commitment to the approach can have a number of benefits. Major benefits of developing and implementing a water safety plan for these supplies include the systematic and detailed assessment, prioritization of hazards and the operational monitoring of control measures. In addition, it provides for an organized and structured system to minimize the chance of failure through oversight or lapse of management. This process increases the consistency with which safe water is supplied and provides contingency plans to respond to system failures or unforeseen hazardous events.

For the successful implementation of the water safety plan, management commitment is important. There are a number of features of water safety plan adoption and implementation and the same is elaborated below:

- Water safety plans represent an approach that demonstrates to the public, health bodies and regulators that the water supplier is applying best practice to secure water safety
- Benefits that arise from delivering a more consistent water quality and safety through quality assurance systems
- Avoidance of the limitations associated with relying on end-product testing as a means of control measures
- Potential savings as a result of adopting the water safety plan approach

Implementation of a pilot water safety plan project, alongside existing water quality management approaches, as a means of demonstrating the feasibility and advantages of the approach may facilitate acceptance of the method.

2.0 Introduction

Establishment of a qualified, dedicated team is a prerequisite and the first step in developing a WSP. This step involves assembling a team of individuals and/or stakeholders with the collective responsibility for understanding the water supply system, identifying hazards that can affect water quality and safety throughout the water supply system. It is essential that all the staff involved should feel as a part of the team and play an active role in the development of the WSP to support the WSP approach.

It is important that the WSP team has adequate experience and expertise to understand water abstraction, treatment and distribution and the hazards that can affect safety through the supply system. The team includes managers, engineers (operations, maintenance, design, and capital investment), water quality controllers (microbiologists and chemists) and technical staff involved in day-to-day operations. The team is vital to getting the WSP approach understood and accepted by everyone connected with water safety in the utility and other stake holders. Therefore, a small team that works with everyone within an organization and stake holders will be far more effective than a larger team. An early task of the team is to set out how the WSP approach is to be implemented and the methodology that will be used particularly in assessing hazards and consequence of risk. Involvement of researchers and medical professionals is essential to integrate the required information on health based statistics and identification of risk prone areas.

2.1 Engage Senior Management to Secure Financial and Resource Support

For successful implementation of the WSP, it is important that senior management supports the process. This is crucial to obtain support for changes in working practices, to ensure sufficient financial resources and to actively promote water safety as a goal of the organization. Acquiring senior management commitment may be achieved by providing clear and coherent opinion about why and how the adoption of a WSP is important and advantageous to the organization.

2.2 Identify the Required Expertise and Appropriate Size of the Team

The team will be responsible for developing, implementing and maintaining the WSP as a core part of their day-to-day activities. Involving operational staff on the team will contribute to the success of the plan through facilitating its ownership and implementation. However, depending on the size of the utility, many members of the team will also continue with their normal duties. Team members need to collectively possess the skills required to identify hazards as well as to understand how these hazards may be controlled. The team needs to have the authority to seek appropriate approvals for the implementation of WSP control measures.

A team leader should be appointed to drive the project and ensure focus. This person should have the authority to implement, organizational and interpersonal skills to ensure that project can be successfully applied. The team leader should explore opportunities with other institutions where required skills are not available within the organization. The team needs to understand the health targets which have to be achieved and have the expertise to confirm, whether the system can meet the relevant water quality standards. Define and identify the roles and responsibilities of the individuals on the team at the start of the process. For large teams it is often helpful to put together an activity/responsibility matrix.

2.3 Skills to be considered when identifying the Required Expertise for the WSP Team

- Technical expertise and operational system-specific experience
- Capacity and availability to undertake the WSP development, implementation and maintenance
- Organizational authority to report through to the relevant controlling authorities, such as the executive of an organization
- Understanding of the management systems including emergency procedures
- Understanding of the process used to communicate the results of monitoring and reporting
- Understanding the water quality targets to be met
- Appreciation of the water quality needs of the users

- Understanding of the practical aspects of implementing WSPs in the appropriate operational context
- Appreciation of the regulatory and policy environment of the organization
- Understanding the impact of proposed water quality controls on the environment and
- Familiarity with training and awareness programmes.

2.4 Time Frame to Develop the WSP

Establishment of WSP initially requires considerable time input. WSPs will increase the amount of time staff spends in the field inspecting the system. WSP enables the operators to get to know their system more effectively as they spend more time identifying and controlling risks instead of just analyzing risks. Once the WSP is established and the team becomes familiar with the system, the time input will be decreased.

2.5 WSP Team Composition for Hyderabad Metropolitan Water Supply & Sewerage Board (HMWS&SB)

Three pilot areas for WSP study in Hyderabad are Adikmet Sub zone–I, Moinbagh (under Balapur service reservoir) and Serilingampally (Chandanagar area) as shown in **Figure 2.1**, were identified by the top management of HMWS&SB and their officials along with WHO/ NEERI team. There is 24X7 water supply to Adikmet area, Moinbagh is thickly populated area with old pipelines, narrow lanes and intermittent water supply whereas Serilingampally area is provided with bulk supply by HMWS&SB and distributed by the Corporation.

The steering committee and task force for each pilot demonstration site has been created for implementation of WSP and their detail constitution is presented in **Figures 2.2 and 2.3**, respectively.

2.6 Work Plan for Water Safety Plan for Hyderabad

The first meeting of the Steering committee to create a WSP in conjunction with HMWS&SB was held on July 19th, 2006. As a result of the meeting, it was decided to develop WSP for 3 pilot areas in Hyderabad. It was also decided that the steering committee will oversee the activities of WSP. The details of project activities and time frame required for development of WSP are presented in **Table 2.1.**

Figure 2.1: Three pilot areas for WSP in Hyderabad

Steering Committee Members

(*Water Safety Plan in HMWS&SB*)

Sri M Satyanarayana
Director (Technical)
HMWS&SB

Sri A Krishna Murthy General Manager (Engg.) G & M Division No. V Narayanguda HMWS&SB	Sri K Ravindernath General Manager(Engg.) O & M Division No. II Narayanguda, HMWS&SB	Sri M Devanand Executive Engineer Serilingampally Municipality, GHMC	Sri K.S Narsappa General Manager (QAT) Central Laboratory, HMWS&SB	Sri Ch. Chinnakeshavulu Chief Water Analyst I.P.M. Narayanguda	Smt. Sridevi, Assi. Prof. Administrative Staff College of India	Dr. C. K. George, Director, Institute of Health System, Public& Private Partnership for Monitoring & Analysis	R.K.Anjali, NAANDI, NGO

Figure 2.2 : Steering Committee for Implementation of WSP

Task Force Members

(*Water Safety Plan in HMWS&SB*)

TASK FORCE ADIKMET ZONE

Designation	Name
Dy General Manager(Engg) HMWS&SB	- Sri Hanmanth Rao
Dy. Chief Water Analyst (I.P.M.)	- Sri Anjeneyulu
Technical Officer(QAT) HMWS&SB	-Sri K. Srinivas
Adminastrative Staff College of India	-Mr. Sahu
Institute of Health Services	-Sri . Raghavendra Prasad

TASK FORCE SERILINGAMPALLY

Designation	Name
Assistant Engineer Serrilingampally Mun.	- Sri Chinna Reddy
Sanitory Inspector Serrilingampally Mun.	- Sri Ravi Kumar
Project Officer Serrilingampally Mun.	- Sri Venkat Krishna
Senior Water Analyst(I.P.M.)	- Smt Rama Latha
Institute of Health Service	- Sri Pratap
Manager (Engg.)Madhapur HMWS&SB	- Sri D Krishna Reddy
Technical Officer (QAT), HMWS&SB	-Sri J Sunil Kumar

TASK FORCE MOIN BAGH

Designation	Name
Dy. General Manager (Engg) HMWS&SB	- Sri Md. Rafeeq
Senior Water Analyst (I.P.M.)	- Sri Nadeem Iqbal
Technical Officer (QAT) HMWS&SB	- Sri P Venkeateshwar Reddy
Administrative staff College of India	- Mr. Sahu,
Institute Of Health Services	-Smt. Saritha

Figure 2.3: Task Force Members for Three Pilot Areas

The first meeting of the Steering committee to create a Water Safety Plan in conjunction with the Hyderabad Metropolitan Water Supply and Sewerage Board was held on July 19th, 2006. As a result of the meeting, the following items were discussed and agreed upon:

The steering committee is to be formed of individuals from the following organizations:

- Hyderabad Metropolitan Water Supply and Sewerage Board (HMWS&SB).
- Administrative Staff College of India (ASCI).
- Institute of Health Systems (IHS).
- Institute of Preventive Medicine (IPM).
- Municipal Corporation of Hyderabad (Serilingampally Municipality)
- Naandi

A water safety plan will be written for 3 parts of Hyderabad:

- Adikmet
- Moinbag in Old City
- Serilingampally Municipality

The steering committee will oversee the activities outlined in the table:

Table: 2.1 Work Plan to Build a Water Safety Plan in Hyderabad

Project task	Project Activity	Timeline	Responsibilities	Outcome/Result
Setting up of stakeholders steering committee to monitor the project and guide HMWS&SB on implementation	Identify the stakeholders Form task force to carry out WSP Determine how often steering committee should meet (once per month), define the tasks and responsibilities of the committee Oversee socioeconomic research and needs assessment being carried out by Osmania Medical College	July 2006	WHO and USEPA will suggest appropriate staff to HMWS&SB HMWSSB will call together various stakeholders and convene the task force	Lead to awareness of the programs to the stakeholders and seek their commitment and support for the project Formulate the stakeholders committee Identify Resource persons from HMWS&SB to carry out WSP Capacity building of the stakeholders on WSP

Project task	Project Activity	Timeline	Responsibilities	Outcome/Result
Finalize socioeconomic study/ Health studies	Meet with Osmania medical college to finalize the scope of work and research for conducting socioeconomic research/needs assessment to carry out WSP in 3 areas of Hyderabad	July 2007	Osmania university researchers will create survey and receive feedback from steering committee. Researchers will pilot survey and consult steering committee to finalize survey. Steering committee will provide guidance and technical assistance as necessary to researchers	Survey tool developed for HMWS&SB to utilize in other municipalities. An understanding of basic water behavior and socioeconomics of 3 areas
Meeting of the task force	Identify the roles and responsibilities of the resource persons	June – August 2007	HMWS&SB will convene task force to discuss responsibilities and duties	To orient field staff on conducting WSP by determining work schedules and responsibilities
Conduct system description and analysis- Catchment, treatment, storage, distribution and household supply 1st Technical Meeting	Hold initial technical session to further explain WSP Collect desk based research to describe the system, including existing network data; map of the water distribution network; data regarding service reservoirs; supply tanks and major valves; water quality data; health data; socioeconomic data Define boundary limits for the WSP. Collate technical	3rd week of August,2006 In November 2006	WHO and USEPA will invite necessary WSP experts to assist with technical session HMWS&SB will arrange appropriate venue to conduct technical session and will have gathered existing maps and data as required	To understand how the system is designed and operated

Project task	Project Activity	Timeline	Responsibilities	Outcome/Result
	data covering catchments, treatment, storage ,distribution and household supply Undertake gap analysis on overall components of WSP			
Create health based targets	Organize second technical session to work with WHO/USEPA to determine health based targets for WSP	End of August 2007	HMWS&SB will engage health department to assist USEPA will recruit appropriate health specialist to assist	To create health standards to determine whether WSP is achieving its objective
Develop tools and pilot activities	Undertake assessment for overall component of WSP Work remotely with WSP experts to develop sanitary inspection forms and identify all hazards throughout the system	August – September 2007	HMWS&SB Task force will design sanitary inspection surveys	To collect data from the field on the system and understand the hazards and controls
Conduct system assessment	Undertake system analysis to identify hazardous practices and environment and choose selection points Collect data from sanitary inspection surveys, document evidence of previous problems at each component of WSP	September 2007	HMWS&SB Task Force will organize 3rd technical session and will organize data collection WHO/USEPA experts will assist with technical session	To verify information from system description and identify selection points

Project task	Project Activity	Timeline	Responsibilities	Outcome/Result
	Disseminate the above study with the engineering staff of HMWS&SB and the steering committee and seek their inputs			
Create WSP	Work with WSP experts to utilize data from each selection point to identify hazards at each component of WSP and identify control measures Undertake risk analysis based on susceptibility of population served Prepare cost estimates for recommendations identified to implement WSP Disseminate the WSP to technical group and steering committee	October 2007	HMWS&SB Task Force will formulate data into WSP matrix WHO/USEPA expert will assist remotely	To organize information collection to identify both the hazard and the corrective action to be taken
Set up Monitoring	Undertake monitoring tools for the overall component of WSP Provide training to HMWS&SB laboratory staff by sending to training hosted in Hyderabad	June – Sept. 2007	HMWS&SB will identify appropriate laboratory staff to attend training USEPA will facilitate their participation ASCI works with HMWS&SB to set up monitoring	To ensure appropriate monitoring of chemical, physical and microbial parameters are in place
Promoting community awareness	Consultant will design community awareness	July – September 2007	Naandi will design and carry out project in	Community participation is ensured

Project task	Project Activity	Timeline	Responsibilities	Outcome/Result
	program based on results of the needs assessment		consultation wit HMWS&SB	
Institutionalizing the WSP at HMWS&SB	Undertake cost effectiveness study on WSP Setting up institutional systems at HMWS&SB to implement and sustain WSP	Nov – Dec 2007	HMWS&SB Task Force will present findings and discuss with steering Committee	To utilize WSP as the basis for water management for 3 areas of Hyderabad
Developing WSP verification protocol	Undertake performance audit of WSP component Disseminating the above to technical team and steering committee	November 2007	WHO/USEPA expert will conduct audit ASCI will provide technical support	To verify that WSP is meeting its health based targets
Finalize WSP manual for 3 areas of Hyderabad city	Edit and revise the WSP based on experience Determine protocol for periodic revision of WSP based on need	Nov – Dec 2007	HMWS&SB Task Force will finalize WSP. HMWS&SB Steering Committee will approve final WSP	

3.0 Introduction

Commencement of the WSP process involves gaining an understanding of the water supply system and its context. To achieve this understanding, it is necessary to:

- Bring together a team with sufficient experience, expertise and capacity
- Understand the components of the system and what risks may occur at each component of the system
- Know what criteria or health based targets have to be achieved and
- Confirm whether the current system is capable of meeting the required criteria

Elaborate description, assessment of water purification system and documentation are the major component of system assessment.

The first task of the WSP team is to fully describe the water supply system. Where utilities do not have documentation of the water supply system, it is essential to prepare it in the field to ensure that subsequent documentation of the system, to produce nature of the raw and finished water quality is accurate to allow hazards and risks to be adequately assessed and managed. While it is accepted that there may be some room for a generic approach to be taken where works are very similar, or where liaison with outside bodies remains the same for a number of water supplies, each supply must be assessed in detail on its own data and all other steps are taken leading to a WSP exclusive to that particular supply. Many utilities may already have extensive experience of their water system and documentation.

A detailed description of the water supply system is required to support the subsequent risk assessment process. It should provide sufficient information to identify relevant types of hazards, risks and control measures. The following points may be included in the description for each water supply system.

- Source of water including the run off and / or recharge processes
- Water quality regulation or guidelines
- Any interconnectivity of sources and conditions
- Land use pattern in the catchment area

- Information on storage of water
- Water treatment details including the processes and chemicals or materials that are added to the water
- Details of water distribution
- Information on the network and service reservoir risks
- Consumer water quality requirements
- Documentation of the existing procedures

For piloting the water safety plan in Adikmet Sub-zone-I, Moinbagh –Balapur Section and Serilingampally -Chandanagar, the WSP demonstration project partners in Hyderabad were Hyderabad Metropolitan Water Supply and Sewerage Board (HMWS&SB), Department of Health, Directorate of Institute of Preventive Medicine (IPM) and Institute of Health Systems (IHS). The USEPA and WHO were collaborating and the USEPA was providing financial support. The HMWS&SB expressed an interest in piloting the water safety plan. The development and implementation of the WSP demonstration project in Hyderabad was in line with the emphasis the Government of India had placed on the need for initiating comprehensive water quality surveillance and monitoring programs, in rural and urban settings. United States Environmental Protection Agency (USEPA) and World Health Organization (WHO) had shown a keen interest in supporting and guiding the development of WSPs.

The Hyderabad city water supply sources, treatment plant capacities along with mode of supply are presented in **Table 3.1**. The Adikmet sub zone–I and Moinbagh receives water supply from Nagarjunasagar reservoir on Krishna river through Akkampally reservoir and treated at Kodandapur with conventional treatment followed by disinfection, whereas Serilingampally receives water supply from Singur dam on river Manjira and treated at Manjira phase III (Peddapuram water works) with conventional treatment followed by disinfection. This area also receives water supply from Rajampet water works from the same source.

Table 3.1 : Water Supply sources for Hyderabad city

S.No	Sources	Year Commissioned	Capacity (Mgd)	Mode of Supply
1	Osman Sagar On Musi River	1920	25	Gravity
2	Himayath Sagar on Esi River	1927	20	Gravity
3	Manjira Phase-I (Manjira Barrage)	1965	15	Gravity/Pumping
4	Manjira Phase-II (Manjira Barrage)	1981	30	Gravity/Pumping
5	Manjira Phase-III (Singur Dam)	1991	75	Gravity/Pumping
6	Manjira Phase-IV (Singur Dam)	1993		Gravity/Pumping
7	Krishna Water Supply Phase-I & II Akkampally	2004 & 2007	150	3 Stage Pumping/ Gravity

Existing Water Treatment Plants

- Asif Nagar Filter Beds : 18 MGD
- Milaram Filter Bed : 2 MGD
- Shaikpet Filter Bed : 1 MGD
- Rajampet Filter Beds- Phase-I : 18 MGD
- Kalabgoor Filter- Phase-II : 33 MGD
- Peddapur Filter Beds- Phase-III : 33 MGD
- Peddapur Filter Beds-Phase-IV : 33 MGD
- Kodandapur Filter Beds : 135 MGD

Source : HMWS&SB

3.1 GIS –based Mapping and Integrated Risk Assessment of Water Distribution System (IRA-WDS) Methodology

A Geographic Information System (GIS) integrates hardware, software, and data, for capturing, managing, analyzing, and displaying all forms of geographically referenced information. System Assessment of water distribution network for Adikmet sub-zone–I was done by GIS- mapping and model simulation studies based on Integrated Risk Assessment of Water Distribution System (IRA-WDS) for contaminant intrusion. IRA-WDS developed by Vairavamoorthy, et al. (2006) is a GIS-based Spatial Decision Support System (SDSS) incorporating Pipe Condition Assessment (PCA) model, Contaminant Intrusion Model (CIM) and Risk Assessment Model (RAM).

The three main components in IRA-WDS model are:

- Contaminant Ingress Model
- Pipe Condition Assessment Model
- Risk Assessment Model

The basic model inputs required include GIS maps for water distribution network with various attribute data such as pipe material, diameter, pipe age etc; sewer network, open drain, foul water body and data about pollution sources, their properties, soil classification, and groundwater table. A detail list of attribute information required is given in **Annexure I.**

CI model simulates movement of contaminated water from different pollution sources (open canals/drains and surface water bodies, sewers etc.) through typical soils towards drinking water distribution pipes.

PCA model assesses the condition of pipes in a water distribution network and identifies the pipes, which are subject to the most risk. The factors considered to assess the relative condition of each pipe are related to physical i.e. (physical properties of pipes), environmental (soil, groundwater, traffic load) and operational (duration of water supply, breakage) aspects of the WDS.

The risk assessment model estimates the risk of contaminant intrusion into water distribution pipes. This model uses the outputs from the contaminant ingress model (hazard) and pipe condition assessment model (vulnerability) by using appropriate weights to generate a risk score for each pipe.

The basic inputs in terms of maps of water distribution network, sewer network, roads, land use, foul water bodies, drains and canals required by IRA-WDS were provided as AutoCAD files by Central Design Cell of HMWS&SB . GIS .shp files were generated from AutoCAD files and the attribute data for each of the network feature was generated from the AutoCAD maps, from discussion with metro water authorities and field surveys.

3.2 Adikmet

3.2.1 Source: Nagarjunasagar Dam

Catchment Area at Nagarjunasagar dam on Krishna River and other details are given below:

Catchment area at dam site	: 2, 15,185 sq. km
Maximum Annual rainfall in catchment	:889 mm
Water spread area of reservoir	:285 sq .km
Live storage	:6801 Mcum (240 TMC)
Dead storage	: 5866 Mcum (207 TMC)
Storage at FRL of 179.83 m	: 12667 Mcum (447 TMC)

At full reservoir level in Nagarjunasagar, the tail end of the water spread touches Srisailam dam about 100 km away from Nagarjunasagar. At minimum water level (150 m), the water spread extends upto 85 km.

Complete 100 km stretch of the Krishna river passes through reserved forests located in Kurnool, Guntur districts on one side, and Mahaboobnagar, Nalgonda on the other side. The important reserve forests are Markapur, Nandikotkur, Amrabad and Nidgul reserve forests. These reserve forests are devoid of any permanent human settlements. But occasional migration of people is noticed for fishing and cattle grazing. There is no agricultural activity. The run-off generated from these forests does not contain any urban/domestic run-off or agricultural run-off or industrial wastewater. The reservoir thus has pristine water quality.

There are two tributaries of Krishna river i.e. Dindi river joining between Srisailam dam and Nagarjunasagar at 35 km upstream of Nagarjunasagar dam and Peddavagu joining Nagarjunasagar through Pendlipakala reservoir near Devarakonda. Both these tributaries also do not add significant pollutants through direct or indirect discharges.

3.2.2 Water Quality at Reservoir

There are no direct flows into the reservoir through Krishna river from urban run-off, agricultural run-off, domestic or industrial wastewater discharges. The Dindi river downstream of Dindi reservoir passes through Cherukupalli and Nidgul reserved forests. The surplus flows of Dindi reservoir passes through Cherukupalli and Nidgul reserved forests before reaching Krishna river.

Fifteen small scale and thirteen medium and large scale industries located in the Mahaboobnagar district lie within the Dindi catchment area. Many of the industries are not water polluting and the water demand for these industries are very meager. There is no direct discharge of the wastewaters into Dindi river. Even if traces of organic pollutants, pesticides and fertilizers reach the Dindi river, adequate dilution and natural decay has resulted in negligible concentrations in reservoir water.

As of date there is no reported adverse effect of the said pollution on stream quality in terms of other parameters of mineral constituents or physical parameters and hence not critical from pollution point of view.

Water quality of river Krishna at off-take point in the foreshore of Nagarjunasagar near Sunkishala for the period of one year in 1995-96 has been monitored by NEERI. The summary data (range values) on the physico-chemical and bacteriological quality of raw water is presented in **Table 3.2** and are discussed below.

The turbidity, which is one of the important parameters in the design of water treatment systems, has been uniformly low with a maximum of 12 NTU. Most of the other physico-chemical parameters such as TDS, alkalinity, hardness etc. do not show

Table 3.2 : Physico-chemical and Bacteriological Quality of River Krishna (October 1995 – November 1996)

S.No	Parameter	Sunkishala (surface) Range Values
	Physico-chemical	
1.	Temperature (°C)	26-31
2.	Turbidity (NTU)	0.5-2.0
3.	Total Dissolved Solids (mg/L)	180-288
4.	pH	8.3-8.8
5.	Total Alkalinity (mg/L, $CaCO_3$)	76-124
6.	Total Hardness (mg/L, $CaCO_3$)	90-122
7.	Calcium (mg/L, Ca)	21.6-32
8.	Magnesium (mg/L, Mg)	4.4-12.6
9.	Chlorides (mg/L, Cl)	27-49
10.	Sulphates (mg/L, SO_4)	28-60
11.	Fluorides (mg/L, F)	0-0.4
12.	Cyanide (mg/L, CN)	ND
13.	Sodium (mg/L, Na)	33-60
14.	Potassium (mg/L, K)	2-3
	Nutrients & Organics	
15.	Nitrite Nitrogen (mg/L, N)	ND
16.	Nitrate Nitrogen (mg/L, N)	0.05-2.5
17.	Ammonia Nitrogen (mg/L, N)	ND
18.	Total Kjeldahl Nitrogen (mg/L, N)	0-1.4
19.	Total Phosphate (mg/L, P)	0-0.4
20.	Ortho Phosphate (mg/L, P)	ND
21.	Dissolved Oxygen (mg/L)	6.4-8.7
22	Biochemical Oxygen Demand (mg/L)	1-2
23.	Chemical Oxygen Demand (mg/L)	4-16
24.	Mineral Oil (mg/L)	ND
25.	Phenolic Compounds (μg /L,C_6H_5OH)	0-0.3
26.	Anionic Detergents∗(mg/L, MBAS)	0.004-0.03
27.	Pesticides (μg /L)	0-0.17
	Biological	
28.	Total Coliforms (CFU/100mL)	0-9
29.	Faecal Coliforms (CFU/100mL)	0
	Metals	
30.	Iron (mg/L as Fe)	0.01-0.3
31.	Manganese (mg/L as Mn)	0-0.03
32.	Copper (mg/L as Cu)	0-0.02
33.	Zinc (mg/L as Zn)	0-0.07
34.	Arsenic (mg/L as As)	0-0.002
35.	Chromium (mg/L as Cr)	0-0.04
36.	Lead (mg/L as Pb)	0-0.1
37.	Mercury (mg/L as Hg)	ND

∗ – mg/L as Sodium Lauryl Sulphate ND – Not Detectable CFU – Colony Forming Unit

Source : NEERI Report, 1997

seasonal variation and are well within the permissible limit stipulated by CPCB **(Table 3.3).**

The CPCB standard for pH of raw water is 6.5 - 8.5. The pH of Krishna river water at intake point varied from 8.3 to 8.8. The higher pH values at Sunkishala of Nagarjunasagar water can be attributed to the geological formations or photosynthetic activity. Higher pH values can have adverse effect on coagulation and chlorination.

As for nutrients, a maximum of 2.5 mg/L nitrate as N was observed while the ammonia nitrogen was below detectable limits. The total phosphate concentration was in the range of BDL to 0.4 mg/L as P.

The algal population in the water samples ranged from 475 to 19,550 no.s/mL during the various seasons. The chlorophyll-a content in the surface water samples at the off take point varied from 1.8-24.3 μg/L. In keeping with the significant algal concentration in the raw water at the intake point, it is necessary to resort to pre-chlorination so as to minimize the potential problem in treatment due to algae. Such a provision for pre-chlorination should be made at the raw water inlet of the treatment plant to ensure adequate contact time for chlorine.

The level of organic pollution as indicated by the BOD_5 at 20°C values was varied from 1-2 mg/L thus conforming to the CPCB Standards for raw water source for drinking water with conventional treatment followed by disinfection (Table 3.3). The concentration of heavy metals such as arsenic, chromium, zinc and lead complied with CPCB standards. None of the samples tested indicated a pesticide concentration of more than 0.17 μg/L in raw water. Bacteriologically, the Nagarjunasagar water is fairly clean as indicated by the low coliforms concentration (0 - 9 CFU/100 mL).

As raw water turbidity at the proposed intake point has been uniformly low, it is recommended to explore the possibility of recycling the spent backwash water from the rapid sand filters to the intake point at uniform regulated rate. The recycling of the spent backwash water would promote better coagulation of incoming raw water by providing necessary nuclei in flocculation. This recycling would also lead to reuse and savings in raw water. The alum sludge with the entrapped algal particles from the clarifier should be disposed of separately.

Table 3.3 : Classification of inland surface water

S.No.	Characteristics	A@	B@	C@	D@	E@
1.	Dissolved oxygen , mg/l, min	6	5	4	4	-
2.	Biochemical oxygen demand, mg/l , max	2	3	3	-	-
3.	Total coliform organisms , *MPN 100 ml , max	50	500	5000	-	-
4.	Total dissolved solids , mg/l , max	500	-	1500	-	2100
5.	Chlorides (as Cl) , mg/l , max	250	-	600	-	600
6.	Colour , Hazen units, max	10	300	300	-	-
7.	Sodium absorption ratio, max	-	-	-	-	26
8.	Boron (as B) \ , mg/l , max	-	-	-	-	2
9.	Sulphates (as SO_4), mg/l , max	400	-	400	-	1000
10.	Nitrates (NO_3), mg/l , max	20	-	50	-	-
11.	Free ammonia (as N), mg/l, max	-	-	-	1.2	-
12.	Conductivity at 25 ^{O}C , micromhos/,cm, max	-	-	-	1.0	2.25
13.	pH value	6.5-8.5	6.5-8.5	6.5-8.5	6.5-8.5	6.0-8.0
14.	Arsenic (as As), mg/l, max	0.05	0.2	0.2	-	-
15.	Iron (as Fe), mg/l, max	0.3	-	50	-	-
16.	Fluorides (as F), mg/l, max	1.5	1.5	1.5	-	-
17.	Lead (as Pb), mg/l, max	0.1	-	0.1	-	-
18.	Copper (as Cu) , mg/l , max	1.5	-	1.5	-	-
19.	Zinc (as Zn), mg/l , max	15	-	15	-	-

* If the coliform count is found to be more then the prescribed tolerance limits , the criteria for coliforms shall be satisfied if not more than 20 percent of samples show more than the tolerance limits specified , and not more than 5 percent of samples show values more than 4 times the tolerance limits . Further , the feacal coliform should not be more than 20 percent of the coliform .
Source : Indian Standards (IS: 229 -1982).

@ A - Drinking water source without conventional treatment but after disinfection
B - Outdoor bathing (organised)
C - Drinking water source with conventional treatment followed by disinfection
D - Propagation of wildlife , fisheries
E - Irrigation , industrial cooling , controlled waste disposal

3.2.3 Kodandapur Water Treatment Plant

Raw water pumped from Nagarjunasagar is stored in Akkampally balancing reservoir (1.5 TMC) over a static head of 80 m. From this reservoir, water is drawn by gravity through open irrigation canal. Raw water is received in the raw water reservoir (9 ML) from canal to the treatment plant by gravity. This storage reservoir will allow uninterrupted water supply to treatment plant.

The water treatment plant at Kodandapur was constructed in the year 2003 to meet drinking water requirement of the Hyderabad city with Nagarjunasagar reservoir as a source of raw water. There are two treatment plants each 410 mld capacity (phase I and phase II) of which the phase I (stage I) is assessed for its performance. The plant is located 116 km away from the city of Hyderabad on Nagarjunasagar road has a capacity of 410 mld and owned by HMWS&SB. The operation and maintenance of the treatment plant is carried out through outsourcing. The treatment scheme comprises pre-chlorination, chemical addition downstream of the venturi flume in the raw water channel, flash mixing, flocculation and sedimentation in clariflocculators, rapid gravity filtration and post-chlorination. Provision has been made to bypass the raw water flow directly to stilling chamber.

For the aeration of raw water air blowers are provided at the raw water reservoir. A flow meter is installed in the venturi flume channel for raw water flow measurements. Alum is used for coagulation and chlorine gas is used for disinfection. The wastewater generated during backwashing of filters is received in tanks through an open channel provided with flat bottom venturi flume for measuring the flow of wastewater to the tanks. The backwash water after plain sedimentation, supernatant water is pumped to raw water channel for the recycling. The recycling of the spent backwash water would promote better coagulation of incoming raw water by providing necessary nuclei in flocculation. The schematic flow sheet is shown in **Figure 3.1** and the plant summary data is presented in **Table 3.4.** Flow diagram for Krishna drinking water supply for phase I showing Nagarjunasagar reservoir, Akkampally as a balancing reservoir as source , clear water pumping stations , Gunagal master balancing reservoir and gravity mains to the city is shown in **Figure 3.2.** The online turbidity meters for raw, settled and filtered water are installed for monitoring the turbidity. Online pH meters are also installed for monitoring the pH of raw and filtered water.

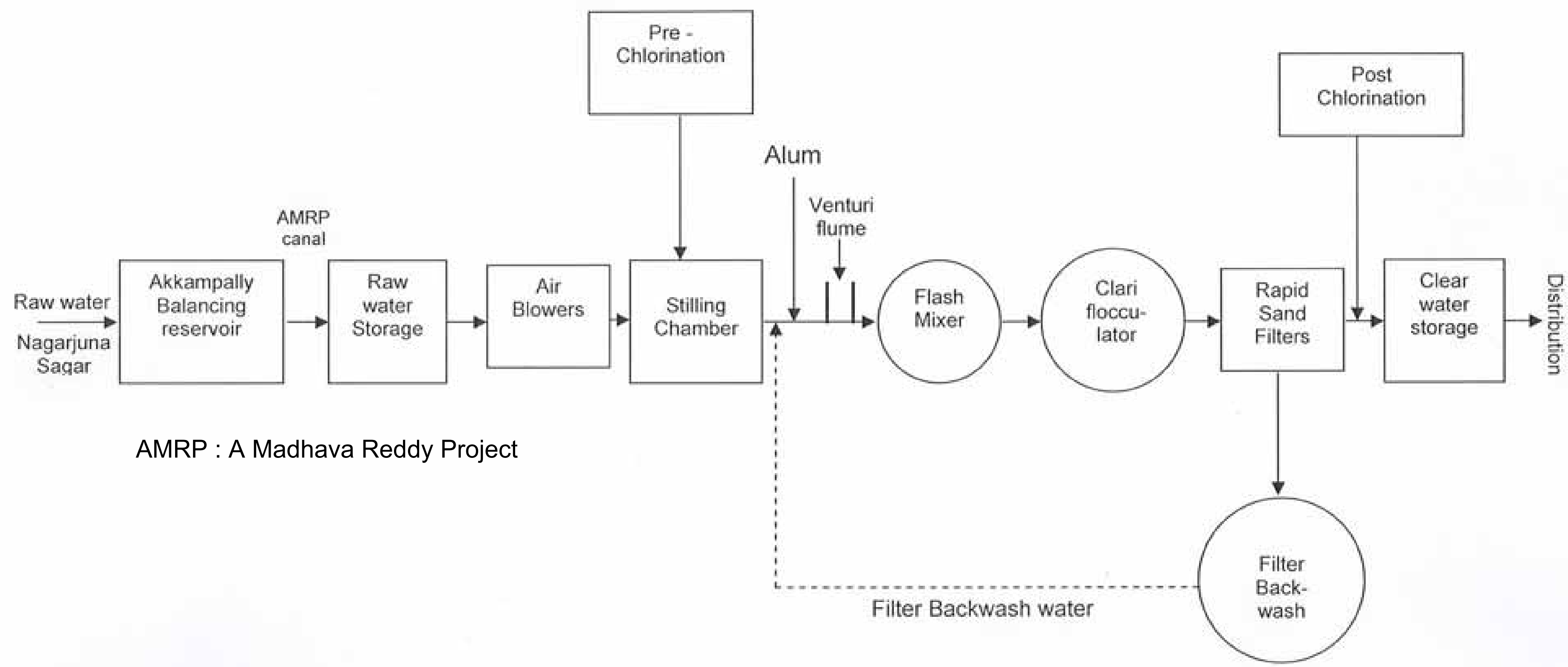


Figure 3.1 : Schematic Flow Sheet of Kodandapur Water Treatment Plant

Table 3.4 : Plant Summary Data (phase I) - Kodandapur WTP

Name and location	: 410 mld Water treatment plant at Kodandapur ,Hyderabad
Distance from city	: 116 Km
Year of construction	: 2003
Design capacity	: 410 mld
O & M Agency	: M/s Geo miller and co. ; New Delhi through HMWSSB
Raw water source	: Akkampally Balancing Reservoir
Treatment flow sheet	: Conventional
Engineering	
Raw water pumping	: By gravity
Rising main diameter	: Open Canal
Raw water reservoir	: 1 No ., two compartments each 48.4 m × 31m × 3 m;: 9000 m^3
Raw water flow measurement	: Venturi flume, flow indicator range 0-11,500 $m^{3/}$/hr : Flow meter range : 0- 12,000 m^3/hr
Pre-chlorination	: Cl_2 gas
Pre-treatment	
Coagulation	
Aeration	: Aeration through blowers
Stilling chamber	1No: 9.45 m × 9.45 m × 1.95 m SWD
-Chemicals used	: Alum
-Type of mixing	: Mechanical, flash mixer, speed ,1460 RPM, 15-HP
-Mixing Details	2 No: 4.45 m dia × 4.45 m × 4.45 m (SWD) with 60 seconds detention time
Flocculation	
-Method/Type of unit	: Mechanical
-No. & Dimensions	: 4 Nos ; 21 m dia ; 3.75 m SWD
-Detention time	: 30 minutes
Sedimentation	
- Type of unit (s)	: Circular
- No.& size of unit (s)	: 4 Nos; 30.60 m × 3.75 m SWD
-Surface overflow rate	: 36 m^3/m^2/day
-Detention Time	: 2.5 hrs
Filtration	
-Type of unit (s)	: Rapid sand filters (Declining rate)
-No. & size of unit (s)	: 20 Nos ; 4.10 m ×10.60 m each section (Area : 86.9 m^2 each section)
-Rate of filtration	: 6 m^3/m^2/hr
-Filter media	: Sand
• Sand size • Depth of sand	: ES :0.7 mm ; U.C : 1.4 :600 mm depth
-Backwash arrangements	:
• Method	: Air and water
• Wash water tank capacity	: 325 m^3
Filter backwash recovery tank	
• No. and size	: 2 Nos ;16 m dia × 2.5 m SWD
Disinfection	
- Chemicals used	: Cl_2 gas
- Type of feed	: vacuum operated
-Chlorinator Details	: capacity : 60 kg/hr (Pre-chlorination) 20 kg/hr (post –chlorination) • Average Cl_2 dose : 35 kg/hr(pre- chlorination) • Average Cl_2 dose : 18 kg/hr (post –chlorination)
Clear Water Pumping	
-Pump details	:8 w + 4s ; 1910 Hp centrifugal
Clear or Treated water reservoir capacity	: 8 ML with 2 compartments
Turbidity and P^H monitoring	: Provided online turbidity meter (Raw, clarified and filtered water, and P^H meter (Raw & filtered water)

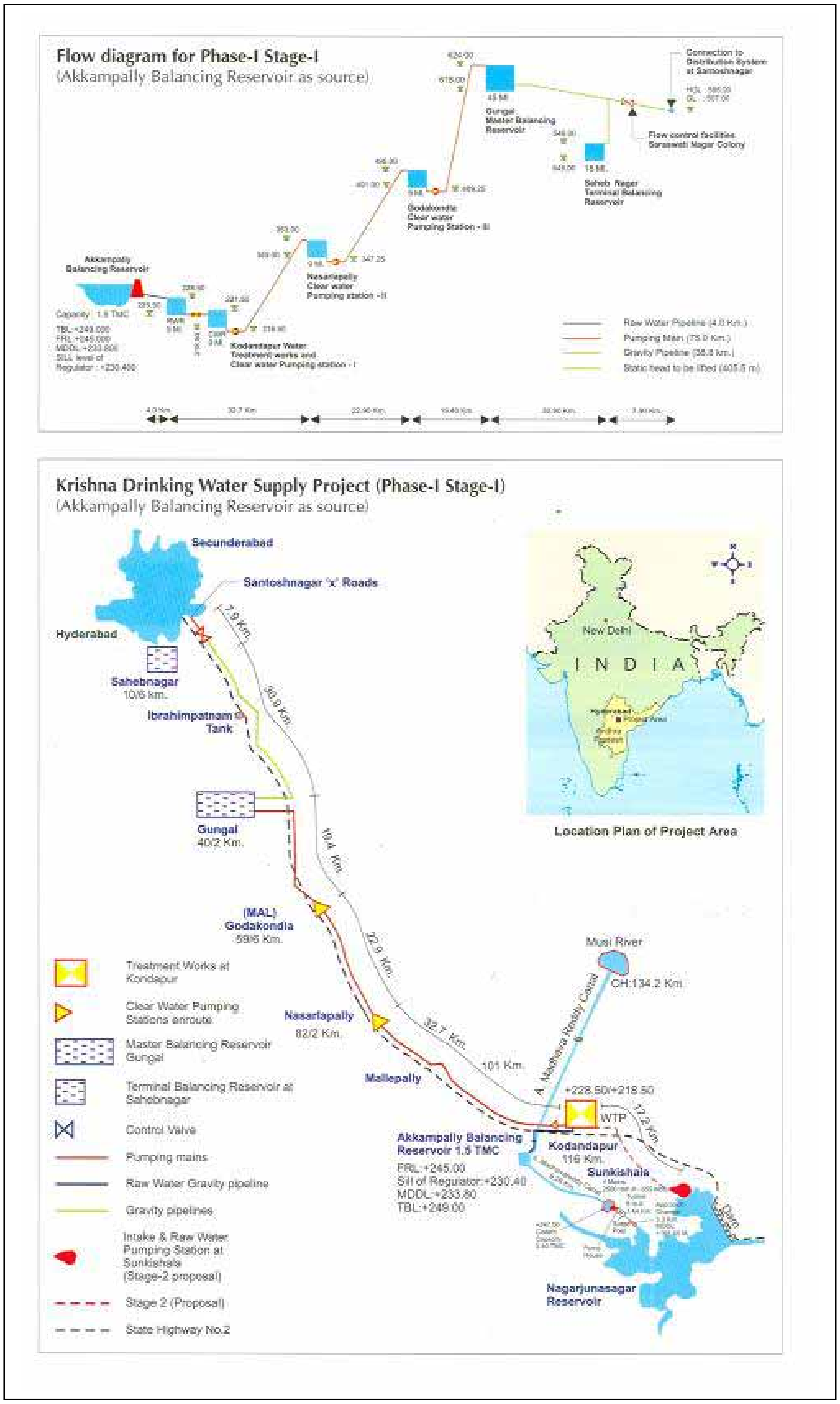


Figure 3.2: Flow diagram for Akkampally Balancing Reservoir as Source

NEERI

3.2.4 Monitoring Parameters and Frequency

At present raw, settled and clear water samples (stage II) are tested 4 hourly daily at 8, 12, 16 and 20 hrs for turbidity, pH and residual chlorine by O&M agency. Samples are also tested weekly for coliforms, TSS, Total alkalinity for raw and clear water. The average analytical results (ranges) for the years 2006 & 2007 are presented below.

Year	Parameters	Raw Water	Settled Water	Clear water
2006	Turbidity (NTU)	2.2 – 6.4	1.2 - 5.2	0.5 – 0.7
	pH	8.1 - 8.7	7.8 - 8.3	7.3 - 7.9
	Residual Chlorine(PPM)	-	1.0 -1.3	1.9 – 2.0
	Coliform (CFU/100ml)	219 -1462	-	NIL
2007	Turbidity (NTU)	2.3 - 3.6	1.7 - 2.5	0.6 - 0.8
	pH	8.2 - 8.6	8.0 - 8.4	7.8 - 8.1
	Residual Chlorine (PPM)	-	1.0	1.4 -1.9
	Coliform (CFU/100ml)	240 - 396	-	NIL

3.2.5 Plant Performance Summary (October 2007)

The Kodandapur water treatment plant (Phase I) with a design capacity of 205 mld (Phase I - stage II) was evaluated for its performance under WSP programme by NEERI. Physico-chemical quality parameters for raw, settled and finished water from Kodandapur (**Table 3.5**) are within the limits recommended by CPHEEO **(Table 3.6)**.

- Plant inflow is of vital importance for effective operation and control of various units, it ranged from 180-268 mld and is marginally overloaded as per design capacity.

- Raw water pH is high (8.3 to 8.8), it is necessary to adjust pH to the optimum range of 6.8 - 7.8 with acid or addition of excess coagulant for effective coagulation and chlorination.

- Dissolved Oxygen in aeration chamber ranged between 7.6 and 8.3 mg/L

Table 3.5 : Physico-chemical and Bacteriological Quality of Raw, Settled and Finished Waters at Kodandapur Water Treatment Plant

S.No.	Parameter	Raw water (mg/L)	Settled (mg/L)	Clear Water Reservoir (mg/L)
1.	pH	8.5	8.3	8.1
2.	Conductivity (μmhos/cm)	350	340	335
3.	Turbidity (NTU)	2	0.9	0.8
4.	Total Alkalinity as $CaCO_3$	120	115	116
5.	Total Hardness as $CaCO_3$	116	114	108
6.	Chlorides as Cl	40	42	38
7.	Nitrates as NO_3	0.5	0.8	0.5
8.	Sulphates as SO_4	33	36	37
9.	Sodium as Na	27	27	28
10.	Potassium as K	3.3	3.5	3.5
11.	Fluorides as F	0.1	0.1	0.1
12.	Total Phosphates	0.1	BDL	BDL
13.	Total Dissolved Solids	210	204	201
14.	Total Colifiorms (CFU/100ml)	TMC	9	0
15.	Faecal Coliforms (CFU/100ml)	0	0	0

Note: All values are expressed in mg/L, except pH and Conductivity

BDL : Below detectable limit
TMC: Too Many to Count

Table 3.6 : Recommended Guidelines for Physical and Chemical Parameters of Drinking Water
(CPHEEO, Ministry of Urban Development, Govt. of India)

I) Physical and Chemical Standards :

Sl. No.	Characteristics	*Acceptable	**Cause for Rejection
1.	**Turbidity (NTU)**	1.0	10
2.	Colour (Units on platinum cobalt scale)	5.0	25
3.	Taste and Odour	Unobjectionable	Objectionable
4.	pH	7.0 to 8.5	6.5 to 9.2
5.	Total dissolved solids (mg/L)	500	2000
6.	Total hardness as $CaCO_3$ (mg/L)	200	600
7.	Chlorides as Cl (mg/L)	200	1000
8.	Sulphates as SO_4 (mg/L)	200	400
9.	Fluorides as F (mg/L)	1.0	1.5
10.	Nitrates as NO_3 (mg/L)	45	45
11.	Calcium as Ca (mg/L)	75	200
12.	Magnesium as Mg (mg/L)	30#	150
13.	Iron as Fe (mg/L)	0.1	1.0
14.	Manganese as Mn (mg/L)	0.05	0.5
15.	Copper as Cu (mg/L)	0.05	1.5
16	Aluminium asAl(mg/L)	0.03	0.2
17	Alkalinity (mg/L)	200	600
18	Residual chlorine (mg/L)	0.2	More than 1.0
19	Zinc as Zn (mg/L)	5.0	15.0
20	Phenolic compounds as Phenol (mg/L)	0.001	0.002
21	Anionic detergents as MBAS (mg/L)	0.2	1.0
22	Mineral Oil (mg/L)	0.01	0.03
Toxic Materials			
23	Arsenic as As (mg/L)	0.01	0.05
24	Cadmium as Cd (mg/L)	0.01	0.01
25	Chromium as Hexavalent Cr (mg/L)	0.05	0.05

Sl. No.	Characteristics	*Acceptable	**Cause for Rejection
26	Cyanides as CN (mg/L)	0.05	0.05
27	Lead as Pb (mg/L)	0.05	0.05
28	Selenium as Se (mg/L)	0.01	0.01
29	Mercury as Hg (mg/L)	0.001	0.001
30	Polynuclear aromatic hydrocarbons (PAH) (µg/L)	0.2	0.2
Radio Activity+			
31	Gross Alpha activity (Bq/L)	0.1	0.1
32	Gross Beta activity (Bq/L)	1.0	1.0

Notes :

1.* The figures indicated under the column "Acceptable" are the limits upto which the water is generally acceptable to the consumers.

2.** Figures in excess of those mentioned under "Acceptable" render the water not acceptable, but still may be tolerated in the absence of alternative and better source but upto the limits indicated under column "Cause for Rejection" above which the sources will have to be rejected.

3.# If there are 250 mg/L of sulphates, magnesium content can be increased to a maximum of 125 mg/L with the reduction of sulphates at the rate of 1 unit per every 2.5 units of sulphates.

4.+ It is possible that some mine and spring waters may exceed these radio activity limits and in such cases it is necessary to analyse the individual radionuclides in order to assess the acceptability or otherwise for public consumption.

II) Bacteriological Quality of Drinking Water [a]

Organisms	Guideline Value
All water intended for drinking	
E. coli or thermotolerant coliform bacteria [b]	Must not be detectable in any 100 ml sample
Treated water entering the distribution system	
E. coli or thermotolerant coliform bacteria [b]	Must not be detectable in any 100 ml sample
Total coliform bacteria	Must not be detectable in any 100 ml sample
Treated water in the distribution system	
E. coli or thermotolerant coliform bacteria [b]	Must not be detectable in any 100 ml sample
Total coliform bacteria	Must not be detectable in any 100 ml sample. In case of large supplies, where sufficient samples are examined, must not be present in 95 % of samples taken throughout any 12 month period.

[a] Immediate investigative action must be taken if either E.coli or total coliform bacteria are detected. The minimum action in the case of total coliform bacteria is repeat sampling,. these bacteria are detected in the repeat sample, the cause must be determined by immediate further investigation.

[b] Although E.coli is the more precise indicator of faecal pollution, the count of thermotolerant coliform bacteria is an acceptable alternative. If necessary, proper confirmatory test must be carried out. Total coliform bacteria are not acceptable indicator of the sanitary quality of rural water supplies, particularly in tropical area where many bacteria of no sanitary significance occur in al most all untreated supplies.

Pre-chlorination

- Pre-chlorination while improving the quality of raw water ,also aids in coagulation and in the control of biological growth in settling tanks and filters
- Addition of chlorine may be standardized through laboratory testing for chlorine demand. Add chlorine in stilling chamber proportional to the raw water flow
- Mixing of chlorine in stilling chamber is not uniform
- Ensure uniform dispersion of chlorine through a perforated pipe across the width of chamber

Coagulation and Flocculation

- The reported alum dose was 5 mg/L. Rate of alum dose was not consistent.
- Conduct jar test for optimum dose of alum for ensuring satisfactory coagulation of water.
- Ensure uniform dispersion of coagulant and add the solution through a perforated pipe placed across the entire width of raw water channel just upstream of measuring weir. The turbulence generated at the weir would facilitate mixing of chemical.
- Poor flocculation due to low suspended solids
- Mechanical gadgets such as flocculator paddles, sludge scraper -bridge were found in working order. The sludge bleeding is done continuously
- Retention of a part of the sludge for longer period in the flocculator improves the efficiency of flocculation and sedimentation

Filtration

- Rapid sand filters are backwashed once in 24 hours as a matter of routine with no regard to filtrate turbidity or the headloss development
- Fill filter backwash storage tanks to its maximum capacity one by one, so as to provide adequate settling time during recycling of backwash water

Post-chlorination

- Disinfection has been effective as confirmed by absence of coliform group of organism in the finished water and adequate residual chlorine at clear water reservoir

Laboratory

- Observed turbidity for raw water was 4 – 5 , for settled 1.0 and for clear water 0.8 NTU
- Samples collected from laboratory taps are not representative one
- Plant laboratory is well equipped for effective plant control
- Laboratory instruments need to be calibrated for accuracy of test results
- Ensure online monitoring of turbidity and pH which are in operation and store the data for plant control. The data needs to be evaluated and timely control measures to be implemented
- Document and maintain water quality data, plant inflow and outflow at centralized place
- Optimize treatment facilities in view of very low turbidity of raw water, high algal production and high pH. Conduct field trials with respect to effective pre-chlorination, recycling of filter backwash, and best possible alum dose

Reservoirs

- Adequate residual chlorine was observed at Gunagal and Sahebnagar reservoirs
- Monitor and document hourly residual chlorine at balancing reservoirs and service reservoirs

The finished water from Kodandapur is pumped to Gunagal MBR through three stages pumping.

3.2.6 Salient Features of Raw, Finished Water Conveying Mains and Clear Water Reservoirs

Kodandapur

- 2200 mm dia MS Raw Water Main from Akkampally Madhava Reddy Project (AMRP) canal to Water Treatment Plant
- 9 ML Capacity Clear Water Reservoirs -2 Nos
- 8 Nos . of pumps to pump 410 mld of clear water (with 50% standby)
- 2200 mm MS pumping main from WTP at Kodandapur to Clear Water Reservoir over a static head of 135 m at Nasarlapally for a length of 34 km to transmit 410 mld of finished water

Nasarlapally

- 9 ML Capacity Clear Water Reservoirs – 2 Nos.
- 8 Nos. pumps to pump 410 mld of water (with 50% standby)
- 2200 mm dia MS pumping main from CWR at Nasarlapally to CWR at Godakondla over a static head of 146 m for length of 23 km to transmit 410 mld of finished water

Godakondla

- 9 ML Capacity Clear Water Reservoirs -2 Nos.
- 8 Nos. pumps to pump 410 mld of water (with 50% standby)
- 2200 mm dia MS pumping main from CWR at Godakondla to Master Balancing Reservoirs (MBR) at Gunagal over a static head of 133 m for a length of 19 km to transmit 410 mld of finished water

Gunagal

- 22.5 ML Capacity Master Balancing Reservoirs -2 Nos.
- 1800 mm MS Gravity main from MBR at Gunagal to Santhoshnagar 'X' Roads for a length of 38 km to join existing water supply system

Saheb Nagar

- 18 ML Capacity Terminal Balancing Reservoir – 1 No.
- After treatment ,clear water conveyed to city by three stage pumping over a distance of 75 km , to a MBR at Gunagal and then by gravity over a distance of 40 km to join existing zonal distribution reservoirs in the city at Santhoshnagar 'x' roads
- Disinfection is practiced at all the clear water reservoirs and MBR

3.2.7 Storage - Water Transmission System for Adikmet

- Water supplied to pilot area through MBR at Gunagal
- GLSR of DD colony (Adikmet Reservoir) is fed from transmission main of 2200 mm MS reduced to 1200 mm MS
- From 1200 mm main to 600 mm MS Main forms the inlet to the existing GLSR at DD colony

- Capacity of GLSR at DD colony : 5.45 ML (1.2 MG) with two compartments
    - Outlet of reservoir 700 mm CI divides into two branches : 400 mm CI (DMA II) and 500 mm CI (DMA I) reduced to 450 mm CI
    - 500 mm outlet supply water to Adikmet sub-zone –I
    - Adikmet Reservoir : Supplied by gravity
- Apart from area supplied by gravity, small part of the pilot area in DD colony supplied by pumping due to topography of the area (11m above MSL at the Adikmet reservoir). Pumping area covers around 300 connections to the north of pilot area. The Adikmet sub- zone –I receives water supply by gravity from DD colony reservoir.

3.2.8 Water Distribution System

Finished water conveyed from Krishna water supply system through the Master Balancing Reservoir (MBR) at Gunagal is stored at service reservoir of D.D. Colony (Adikmet reservoir). The water supply to the pilot area from this reservoir is 24 x 7. The existing distribution mains are of Asbestos Cement (AC), Reinforced Cement Concrete (RCC), Cast Iron (CI) and Ductile Iron (DI). The AC and RCC pipes were laid before 1985. The CI mains have been laid after 1985, and DI pipes were laid since last 2 years.

The District Metering Area (DMA) concept has been applied in this pilot zone to have a better accountability of the inflow and water consumption. Two DMA'S have independent feeder mains (**Exhibit 3.1**). DMA-I is fed by existing 500 mm main type CI and DMA-II is fed by 400 mm main. There are three outlets from the existing Adikmet Reservoir, two of these are under gravity and the other is pumped. Out of two gravity outlets, the one is 500 mm CI reduced to 450 mm CI. This outlet supplies water to major part of the pilot area including parts of Ramanthapur and Golnaka area. It is reported that at present this outlet is closed and the Shivam reservoir is connected to this outlet to feed these areas. The other branch is 400 mm CI that is reduced to 300 mm CI. The outlet from Shivam low lying reservoir (LLR) is interconnected to this 400 mm main type CI at Shivam main road. These main supplies to Sai Baba Nagar, Sharada Nagar, Bathakama Kunta, Shivam, Ramanthapur and Golnaka area under gravity (**Figure 3.3**). The third outlet supplies water to the north of pilot area during 5 AM to 8 AM on alternate days.

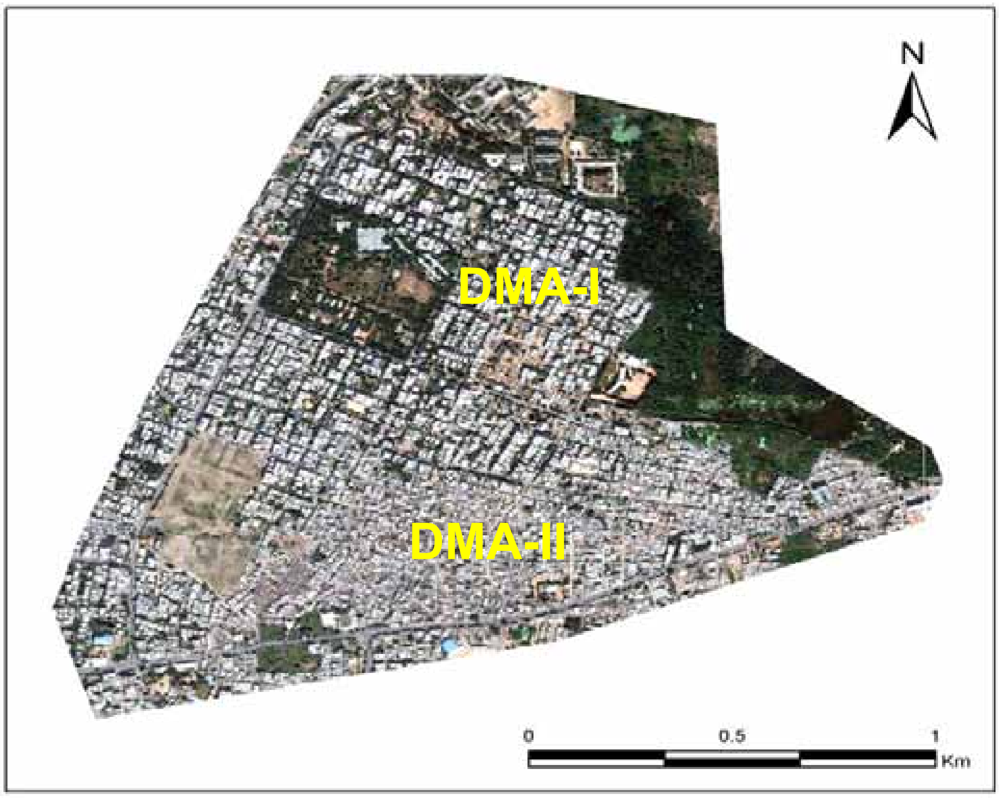


Exhibit 3.1 : District Metering Area (DMA) - I and DMA - II in Adikmet sub-zone - I

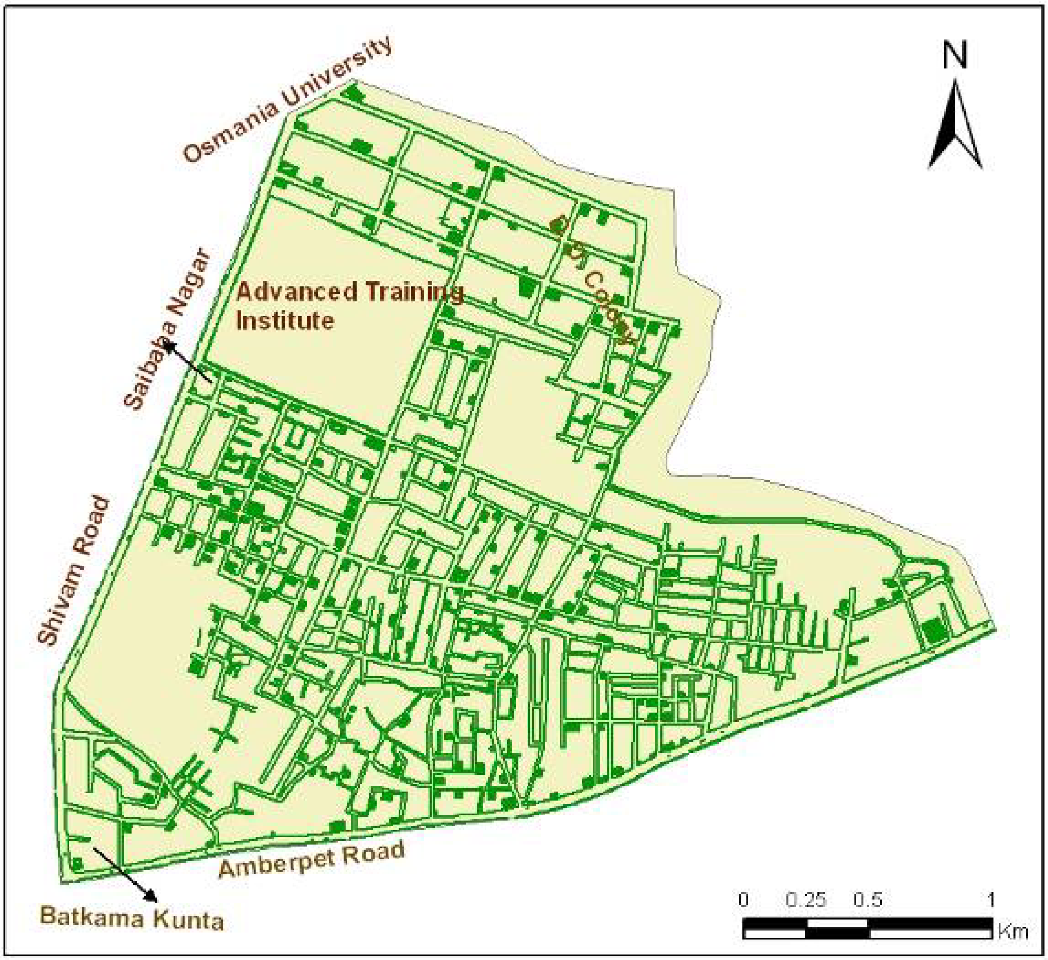


Figure 3.3 : Pilot Area: Adikmet Sub zone - I

There are about 4900 service connections in the pilot area with 300 service connections supplied by pumping on alternate days. This is a 100mm outlet from pump house located in HMWS&SB premises at DD Colony.

There are total 928 pipes in the water distribution network of the pilot area. The total length of supply network is 68.99 km. The pipe diameters are 100 mm, 150 mm, 250 mm, 300 mm, 400 mm, 450 mm, 500 mm, 700 mm. The material-wise distribution shows that there are 427 pipes of RCC material laid in the year 1975, 13 pipes of AC laid in the year 1978, 285 pipes of CI material laid in the year 1996, and 203 pipes of DI laid in the year 2005.

Flow and Pressure : It is reported that the peak flow in the supply main remains 2644 m^3/hr and the supply pressure is about 1.0 kg/cm^2. The details of pressure gauges and locations in the study area are given in **Table 3.7**.

Leakage in the system: From door to door survey, it is reported that 2,347 meters are fixed in pilot area. The quantity of water drawn in DMA – I is 1.44 MG, in DMA – II it is 2.03 MG, and in DMA – III it is 0.11 MG. The Unaccounted Flow of Water (UFW) in pilot area (DMA –I : 56 % , DMA –II: 71 % and DMA – III : 54 %) is reported to be 2.3 MG i.e. 64.24 % of total supply (**Table 3.8)**.

Breaks and Bursts : The number of pipe breaks attended by authorities is reported to be 720 per year and the total number of bursts per year in the system are 272.

Open Drains : There are two lined open drains in the pilot area. The length of these drains is approximately 200m. Width and depth for both the drains is reported to be approximately 3m. Presently, the open drains are covered by cement roads and the habitation along the road is categorized as notified slum (**Exhibit 3.2**). The domestic waste from the houses and sewers of this built-up area is carried through these drains (**Exhibit 3.3**). Solid waste dumping is also practiced in the backyard of the houses near the drain and is also likely to be carried with wastewater flowing through the drain (**Exhibit 3.4**).

Foul water body: There is one low lying area of 47,476 m^2, where, water gets collected in rainy season. It is reported that depth of water in the foul water body ranges from 1 to 1.5 m.

Table 3.7 : Pressure Gauge Details and Locations in Adikmet

S.No.	Pressure Gauge Details	Locations
1	PG 1 600 mm	D.D. Colony
2	PG 2 500 mm	,,
3	PG 3 150 mm	,,
4	PG 4 100 mm	,,
5	PG 5 100 mm	SBH Colony
6	PG 6 200 mm	,,
7	PG 7 100 mm	C.E. Colony
8	PG 8 150 mm	,,
9	PG 9 100 mm	,,
10	PG 10 600 mm	,,
11	PG 11 500 mm	,,
12	PG 12 450 mm	Srinivasa Nagar Colony
13	PG 13 200 mm	Red Building
14	PG 14 450 mm	,,
15	PG 15 150 mm	M.K. Nagar
16	PG 16 200 mm	,,
17	PG 17 250 mm	Vinayak Nagar
18	PG 18 100 mm	Rahath Nagar
19	PG 19 100 mm	Turab Nagar
20	PG 20 450 mm	Durga
21	PG 21 150 mm	Gangabowli
22	PG 22 200 mm	,,
23	PG 23 200 mm	Bathkamakunta
24	PG 24 200 mm	,,
25	PG 25 100 mm	,,

There are 6 Pressure Guages on 100 mm diameter

Table 3.8 : Water Budget in Pilot area : ADIKMET – 24 X 7 (As on 30-06-2007)

A Meters fixed ------------------------------ 2473
B Meters Raised --------------------------- 1154
C Door to door Survey ------------------- Completed
D Qty Drawn (Avg)------------------- DMA – 1 ------- 1.44 MG
DMA - 2 ------- 2.03 MG
DMA - 3 ------- 0.11 MG

Total 3.58 MG

E Billed Qty -------------------- DMA - 1 0.64 MG
PSP & OTHERS 0.06
DMA – 2 ------- 0.55 MG
PSP & OTHERS 0.03

Total 1.28 MG

F UFW ---------------------- **3.58 – 1.28 = 2.30 MG @ 64.24%**

G PSP'S ---------------------- DMA –1 --------- 9
DMA– 2 --------- 25

Total 34

H Total Connections ---------------- DMA- 1 --------- 2172
DMA – 2 -------- 2770

Total 4942

I Bills issued – DMA –1--- 2170 (2) (M – 1770-1797-1878-1955-2170-R-304-290-278-217-185)
DMA –2--- 2766 (4) (M – 1823-1824-1760-1881-1985-R-928-986-1006-875-745)
Total 4936 3593-3621-3638-3836-4006 -1232-1276-1284-102-930
FEB- MAR-APR- MAY-JUN -FEB-MAR-APR-MAY-JUN

J Demand ----------------- DMA – 1--- --12.64 lakhs
DMA – 2 -- --- 9.23 lakhs

Total 21.87 Lakhs

		31-05-2007
K Collection	-------------------- DMA – 1--- --12.70 lakhs	12.09 lacks
	DMA – 2 --- -- 6.73 Lakhs	5.40 lacks
	Total 19.43 Lakhs	**17.49 Lacks**
L CLN	-------------------- DMA – 1--- --1607	1593
	DMA- 2 --- --1437	1226
	Total 3044 – 61.00 %	**2819- 57.11%**

Leakages

Area/Month	July	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	June	Total (l/yr)
DMA-I	66	58	32	31	30	29	31	38	43	41	35	42	466
DMA-II	105	77	51	45	42	38	37	45	46	45	41	38	610

Exhibit 3.2 :Open Drain Covered by Road

Exhibit 3.3 :Built Up on both sides of Drain

Exhibit 3.4: Solid waste dumping in the backyard of houses near Open Drain

Sewer Network : The sewer network of pilot area which carries domestic waste to the Amberpet Sewage Treatment Plant (STP) is reported to be 30 - 33 years old. Pipe material is mainly of RCC and Stoneware Pipes (SWP). Minimum diameter of the sewers is 100 mm and maximum 400 mm. Recently 339 MLD sewage treatment plant with UASB and aeration technology at Amberpet has commissioned.

Soil : The soil in the study area is mostly silty and gravelly sand. Classification obtained from HMWS&SB shows that various types of soils in the pilot area are Dark brownish silty sand, Greyish silty sand, Brownish silt sand and gravelly sand. The properties of soil are given in **Table 3.9.**

Traffic: There are two major roads in the pilot area. Roads were surveyed during field visit for classification of traffic density as 'Busy' on main road and national Highway; 'Medium' on the internal roads and 'Low' traffic in slum areas.

Groundwater : The quality of groundwater in Adikmet is good. However, no well water is used for drinking purpose. The groundwater table is high and at some of the places it is likely to be above the sewers or water supply pipes as well. The data on groundwater table measured at 15 locations in the study are given in **Table 3.10.**

3.2.9 Model simulation Results

Model simulation results delineating SPCZ (Highlighted in Red colour) in Adikmet sub-zone I are shown in **Figure 3.4.** These pipes are likely to be within the contaminant zone of the pollution sources (sewers, canal/open drains and foul water bodies).

PCA values obtained from PCA model were classified in 5 classes to rank the relative pipe condition. The statistics of pipe condition obtained by model simulation (**Table 3.11)** indicates that about 65 % pipes are in class **"Good to Very Good**", 32 % pipes are in "**Medium**" condition and about 2 - 3 % pipes are in "**Very Bad to Bad**" condition. The mapping of results from PCA model is given in **Figure 3.5**.

Model simulations obtained for risk of contaminant intrusion into each of the pipe in the supply network indicated that overall there are 52% pipes under "**Medium risk**", 45% under "**Low risk**" and only 2 to 3% pipes are under "**High to Very High Risk**" (**Table 3.12**). GIS-mapping of Risk-areas in water supply network of Adikmet sub-zone I

Table 3.9: Soil Properties in Pilot Area: Adikmet

Soil type	Properties						
	Saturated Volumetric Content	**Saturated Hydraulic Conductivity**	**Soil Characteristic Curve Coefficient**	**Air Entry Head**	**Pore Size Index**	**Bulk Density**	**Fraction Organic Content**
	$\theta_S(m^3/m^3)$	$K_s(cm/hr)$	b	$\Psi_b(cm)$	λ_b	$\rho_b(g/cm^3)$	F_{oc}
Gravelly Sand	0.43	0.60	0.08	7.02	1.67	1.65	0.01
Brownish Silty Sand	0.54	0.06	0.08	7.02	1.67	1.95	0.01
Greyish Silty Sand	0.71	1.36	0.08	7.02	1.67	1.86	0.01
Dark Brownish Silty Sand	0.46	0.37	0.08	7.02	1.67	2.0	0.01

Table 3.10 : Ground Water Levels in Adikmet Pilot Area, Hyderabad Implementing 24 x 7 water supply, on 28.5.2007

Sr. No.	Address	Water level from Measuring Point (m)	Height of the Measuring point from the Ground (m)	Water Level Below Ground Level (m)
1.	Central Excise Colony	2.2	0.6	1.6
2.	Ganga Bowli	2	0.6	1.4
3.	Pochammabasti	2	0.5	1.5
4.	Batakammakunta	3	0.45	2.55
5.	Batakammakunta	1.4	0.35	1.05
6.	Pochammabasti	1.4	0.5	0.9
7.	Near red building, Bharat Nagar	6.3	1.3	5.05
8.	Dhobigalli	3.3	0.55	2.95
9.	Kummarwari	2.5	0.55	1.95
10.	Turab Nagar	4.7	0.5	4.2
11.	Erukalabasti	3.4	0.4	3.0
12.	Mallikarjuna Nagar	3.4	0.2	3.2
13.	Vinyak Nagar	13.5	0.45	13.05
14.	Ramakrishna Nagar	5.4	0.7	4.7
15.	Ayyapa Temple	2.55	0.4	2.15

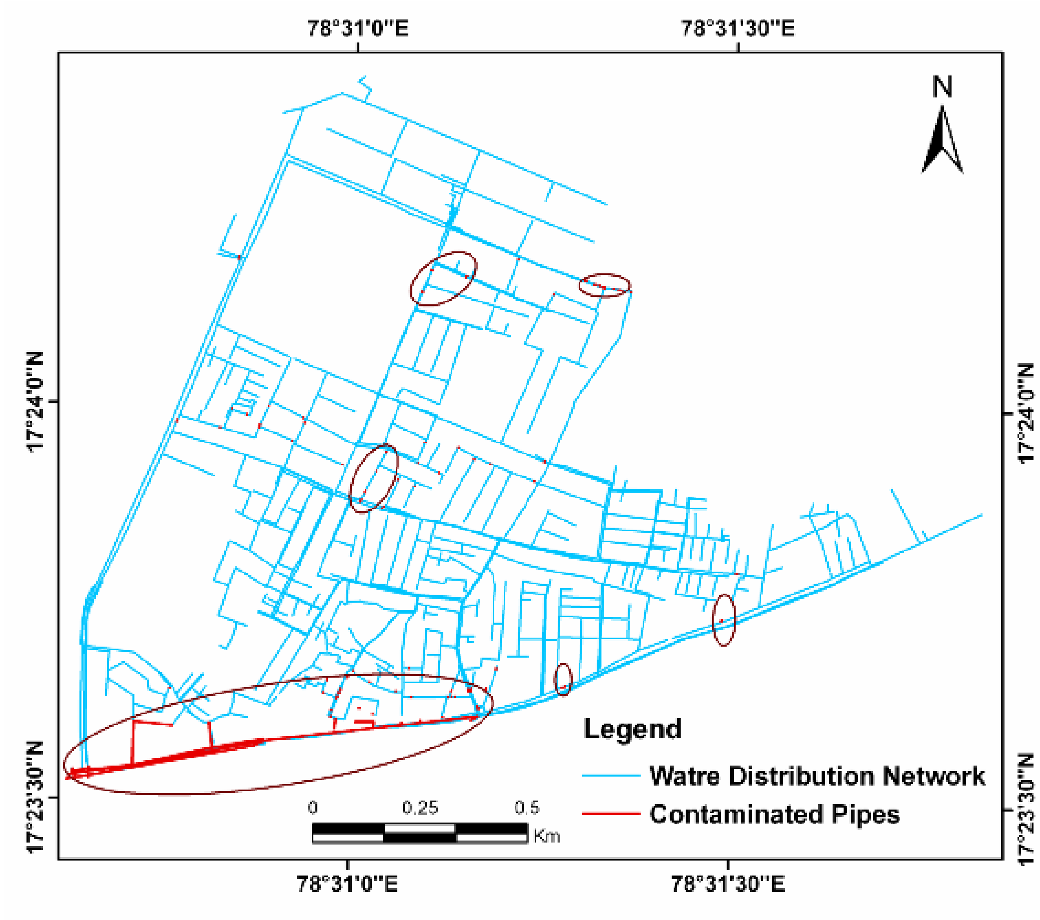
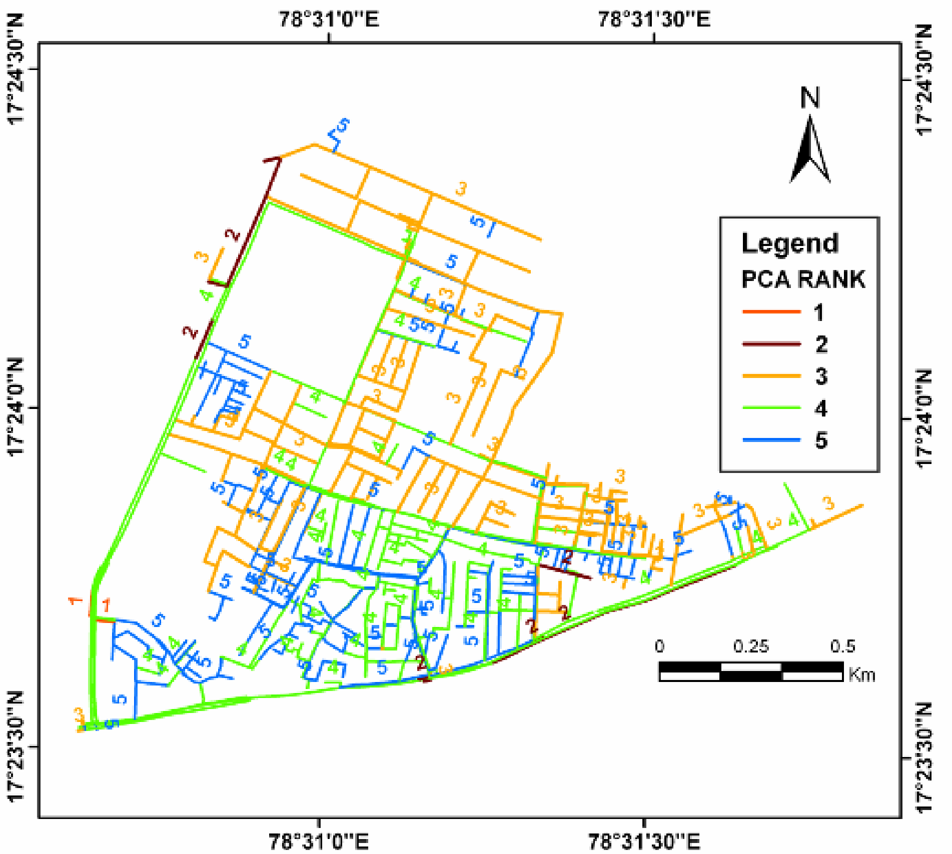


Figure 3.4 : Section of pipes in Contaminated Zones in WDS of Adikmet

Table 3.11 : Pipe Condition Assessment Statistics : Adikmet

PCA Rank	PCA Index	Classification	No. of Pipes	%
1	0	Very Bad	3	0.32
2	0-0.252	Bad	15	1.61
3	0.50-0.58	Medium	293	31.57
4	0.71-0.84	Good	327	35.23
5	0.92-1.0	Very Good	290	31.25



PCA Rank	PCA Classification	PCA Index	No. of Pipes	Percentage (%)
1	Very Bad	0	3	0.323
2	Bad	0.252	15	1.61
3	Medium	0.50-0.58	293	31.57
4	Good	0.71- 0.84	327	35.23
5	Verv Good	0.92 – 1.0	290	31.25

Figure 3.5 : Relative Condition of Pipes in WDS of Adikmet

Table 3.12 : Risk Assessment Statistics :Adikmet

Risk Rank	Risk Index	Classification	No of Pipes	%
2	0.3	Very High	3	0.32
3	0.45-0.54	High	17	1.83
4	0.63-0.82	Medium	490	52.80
5	0.86-1.0	Low	418	45.04

is given in **Figure 3.6.** The risk map indicates that 3 pipes are under **Very High Risk** and 17 pipes are under **High risk.** Detail map of "Very High Risk" and "High Risk" points in Adikmet sub-zone -1 is presented in **Figure 3.7.**

3.3 Moinbagh

3.3.1 Source: Nagarjunasagar Dam

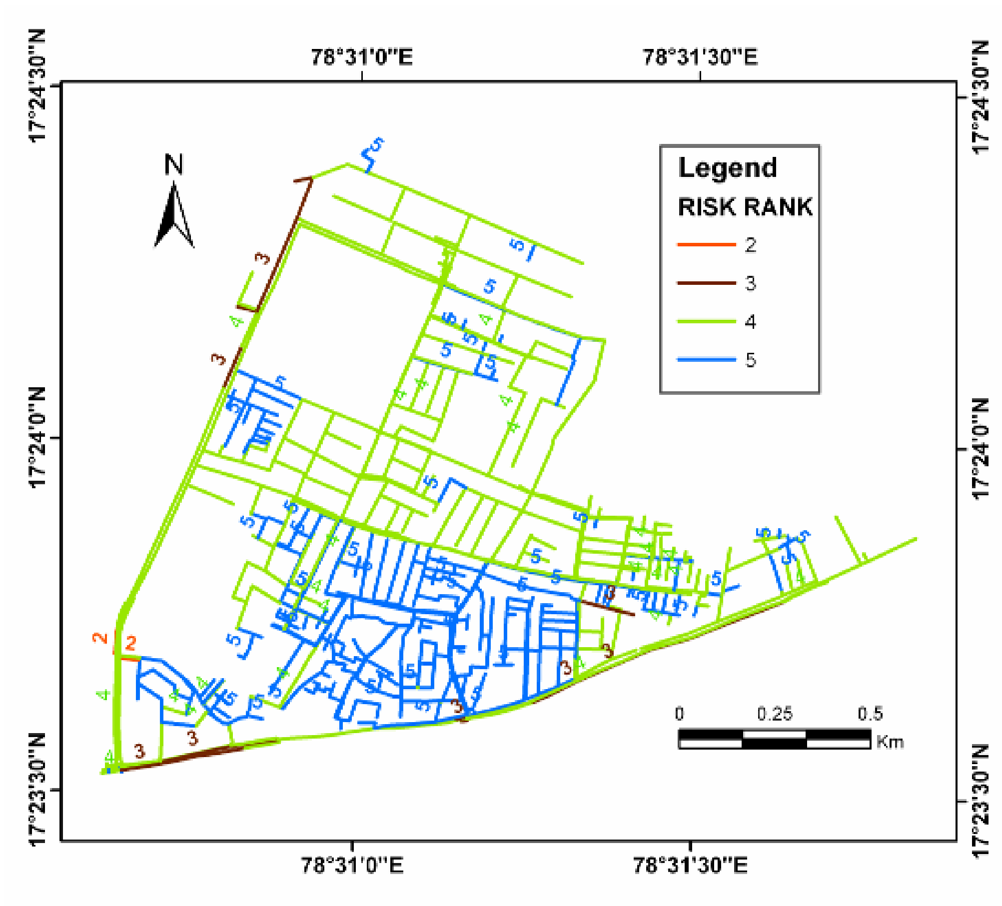
Raw water source for Moinbagh is same as that for Adikmet. Source assessment for Nagarjunsagar is same as that given in Section 3.2.

3.3.2 Storage - Water Transmission System

- Water supplied to pilot area through Terminal balancing reservoir at sahebnagar
- GLSR of Balapur Reservoir is fed from outer ring main 2200 mm MS line
- From 1200 mm PSC main to 1000 mm MS Main forms the inlet to the existing GLSR at Balapur
- Capacity of GLSR at Balapur : 21ML(4.62 MG)
    - 1000 mm outlet supply water to Moinbagh area
    - Balapur Reservoir : Supplied by gravity

3.3.3 Water Distribution System

Moinbagh is thickly populated area with old pipelines, narrow lanes and the water supply to the pilot area is intermittent. There are three supply zones: Balapur Zone, Aliabad Zone & Santosh Nagar Zone. Treated water is conveyed from Krishna water supply scheme to the Balapur reservoir, Aliabad reservoir and Santosh Nagar reservoir. Water is supplied from Balapur reservoir from 9 a.m. to 12 O'clock on alternate days and from Santosh Nagar reservoir from 10 p.m. to 12 O'clock on alternate days. There is a Booster supply of 100 HP to Uppuguda covering LalitaBagh, Bhaiyalal Nagar, Maruti Nagar, Part of Shivaji Nagar & Tanaji Nagar. It is reported that head of 1 to 1.5 m is maintained at Moinbagh and Aliabad Reservoir. There are about 5000 service connections in the pilot area. The main areas covered in water supply are Riyasat Nagar, Lalita Bagh, Santosh Nagar, Kumarwadi, Mohammad Nagar and Jawed Nagar. The details of water supply in the pilot areas are as follows :



Risk Rank	*Risk Classification*	Risk Index	*No. of Pipes*	*Percentage (%)*
2	**Very High**	**0.3**	**3**	**0.32**
3	**High**	**0.45- 0.54**	**17**	**1.83**
4	**Medium**	**0.63- 0.82**	**490**	**52.8**
5	**Low**	**0.86- 1.0**	**418**	**45.04**

Figure 3.6 : Risk Mapping of pipes of WDS in Adikmet sub-zone - I

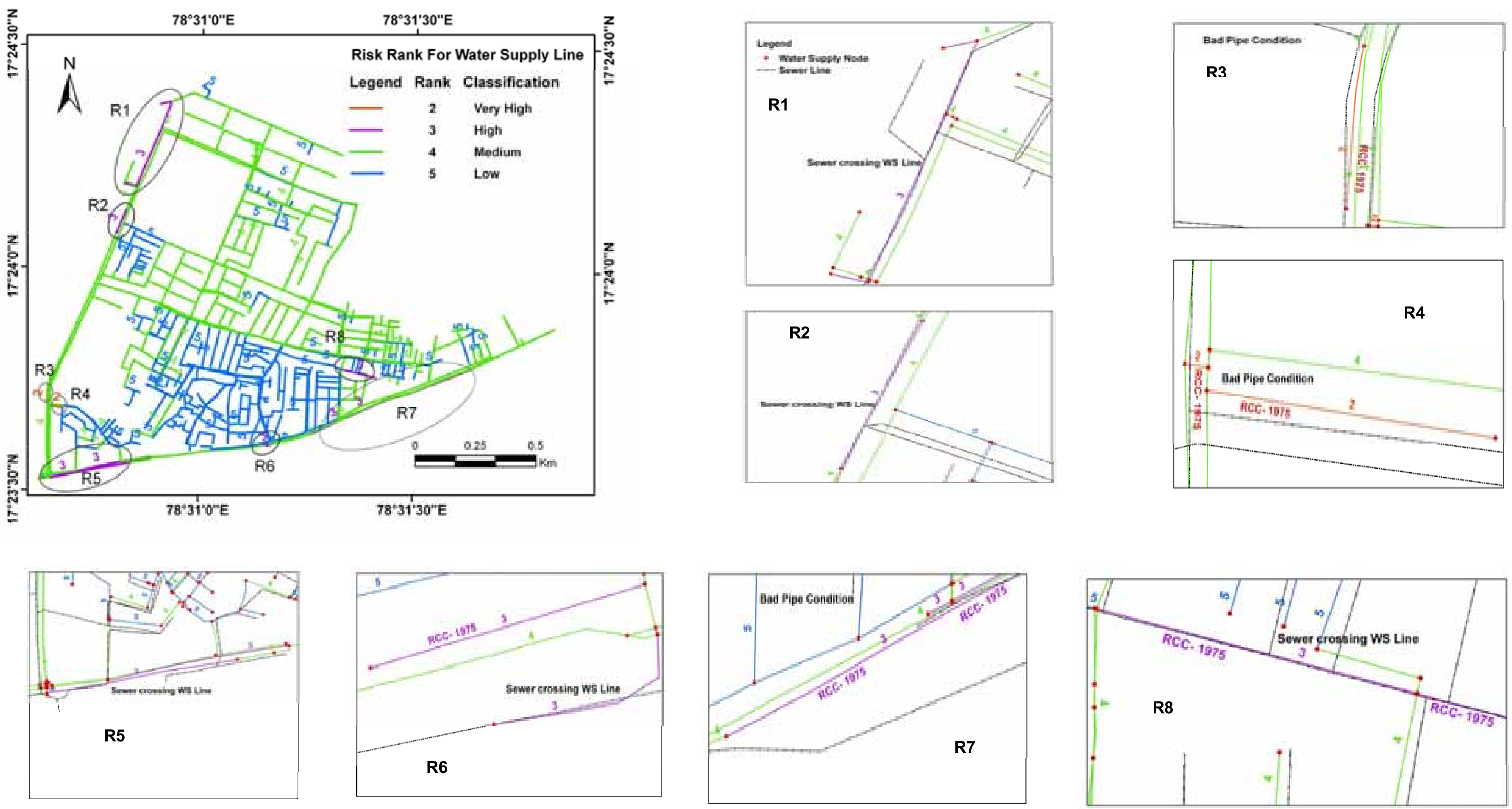


Fig 3.7: Detail Map of High Risk Points in Adikmet Sub Zone-1

- From Santosh Nagar reservoir there is one on-line Booster which supplies to Kumarwadi and there are two supply lines under gravity for Mohammad Nagar & Jawed Nagar respectively.
- Reservoir in Aliabad area supplies by on-line booster to Uppuguda which covers LalitaBagh, Bhaiyalal Nagar, Maruti Nagar & some part of Shivaji Nagar.

The existing distribution mains in Moinbagh are of Asbestos Cement (AC), Reinforced Cement Concrete (RCC), Cast Iron (CI) and Ductile Iron (DI). The AC and RCC pipes were laid before 1998. The CI mains have been laid after 1996, and DI pipes have been laid since 2002. The bury depth of water supply lines varies from 0.8 to 1.5 m.

There are total 788 pipes in the water distribution network. The pipe diameters within the pilot area are 75 mm,100 mm, 150 mm,175 mm, 200 mm, 250 mm, 300 mm, 350 mm, 400 mm, 500 mm, and the total length of supply network is 34.18 km. The pipe age in water supply network varies from 2 to 14 years old. There are 37 pipes of RCC/AC installed in the year 1996, CI pipes have been laid since 1998 to 2002 and DI pipes have been laid since 2002 onwards. The pipe details of existing distribution network are given in **Table 3.13.**

The selected pilot area for GIS - based mapping and Integrated Risk Assessment of water distribution system in Moinbagh : Balapur Section in Hyderabad city, India is about 1.54 km^2. This is an old city area in Hyderabad. Main localities of this area are Lalita Bagh, Riyasat Nagar, Moinbagh, Santosh Nagar and Kumarwadi. The contour elevation in the pilot area ranges from 501 to 518 m. The land use pattern in Moinbagh is mainly of residential and commercial type. The types of houses in this area are single and two storied bungalows. Independent houses were seen and rarely multi-storied buildings were also observed during field visit **(Exhibits 3.5 and 3.6)**.

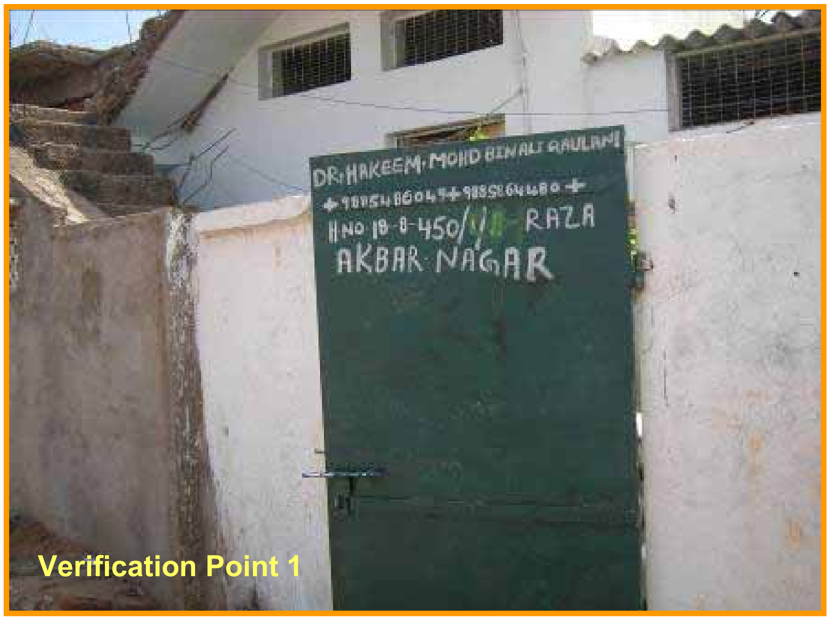
Leakage in the system: It is reported that the quantity of water drawn is 28.00 MGD. The UFW in the system is reported to be 11.50 MGD i.e. 41% of total supply. The UFW include leakage in the system and unauthorized water consumption **(Table 3.14)**.

Breaks in pipes : Number of pipe breaks in the study area attended by authorities has been reported to be 20 per year.

Table 3.13 : Pipe details of Water Supply Network in Moinbagh

Installation Year	Pipe Material	No. of Pipes
1996	RCC/AC	37
1998	CI	35
1999	CI	10
2000	CI	128
2001	CI	77
2002	CI/DI	420
2003	DI	9
2004	DI	13
2005	DI	42
2006	DI	17

Exhibit 3.5 : Builtup in pilot area : Moinbagh



Verification Point 1

Verification Point 2

Exhibit 3.6 : Field Based assessment for contamination of drinking water supply

Table 3.14 : Water Audit in Moinbagh (January-2008)

<table>
<tr><td rowspan="11">System Input Volume (corrected for known errors)

28.00 MGD</td><td rowspan="5">Authorized Consumption

16.50 MGD</td><td rowspan="2">Billed Authorized Consumption

13.50 MGD</td><td>Billed Meter Consumption (Including Water exported)
10.03 MGD</td><td rowspan="2">Revenue Water

13.50 MGD</td></tr>
<tr><td>Billed Un metered Consumption
3.72 MGD</td></tr>
<tr><td rowspan="3">Unbilled Authorized Consumption

3.00 MGD</td><td>Unbilled Metered Consumption
0.40 MGD</td><td rowspan="9">Non-Revenue Water (NRW)

14.50 MGD</td></tr>
<tr><td>Unbilled metered Consumption(PSPs)
0.85 MGD</td></tr>
<tr><td>Unbilled Un metered Consumption
1.50 MGD</td></tr>
<tr><td rowspan="6">Water Loss

11.50 MGD</td><td rowspan="3">Apparent Loss

5.75 MGD</td><td>Unauthorized Consumption(Illigal)
3.50 MGD</td></tr>
<tr><td>Customer Metering Inaccuracies
0.75 MGD</td></tr>
<tr><td>Data Handling Errors
1.50 MGD</td></tr>
<tr><td rowspan="3">Real Loss

5.75 MGD</td><td>Leakage on Transmission and Distribution Mains
4.00 MGD</td></tr>
<tr><td>Leakage and overflows at Utility's Storage Tanks
0.80 MGD</td></tr>
<tr><td>Leakage on Service Connection up to point of Customer metering
0.95 MGD</td></tr>
<tr><td colspan="3">**UFW**
Water Losses*100 / Allotted Quantity = 11.50*100 / 28.00 = **41.07%**</td><td colspan="2">The difference between System input Volume Billed Authorized Consumption</td></tr>
</table>

* Obtained from the Operation & Maintenance Division No.II Asmangadh, Hyderabad

Bursts in pipes : There are a number of contributing factors to pipe bursts. The key factors are - pipe material, diameter, age, internal pressure, soil conditions, and traffic loading. As reported by local authorities, total number of bursts per year in the system is 142.

Open Drain : There is one major unlined open drain carrying surface runoff and wastewater from residential area in study zone. The width of the drain varies from 18 to 25 m along its length and depth varies from 2 to 4 m at various places. The drain carrying all the waste water is lined on the side walls and has rectangular cross-section. Length of the drain is approximately 3.83 km. The domestic waste from the houses and sewers of built–up area in the study zone is carried through the open drain **(Exhibits 3.7 and 3.8)**. Solid waste dumping is observed in the drain and gets carried with wastewater flowing through the drain

Soil : The soil in the study area is mostly silty and gravelly. Classification shows that various types of soils in the pilot area are Redish brown silty sand, Brownish silty sand, Yellowish Brown silty sand and Reddish gravelly Murrum. The properties of soil are given in **Table 3.15**.

Traffic : As stated earlier, there are two major roads in the pilot area. Roads were surveyed during field visit for classification of traffic density as 'Busy' and 'medium'. The main roads with dense traffic were classified as 'Busy Traffic' roads. Roads in the internal areas such as Riyasat Nagar, Moinbagh, LalitaBagh were observed to have less traffic and were classified as 'Medium Traffic' roads.

Groundwater : The groundwater table is high at some of the places like Jamal colony and Riyasat nagar. The data on groundwater table measured in the study area are given in **Table 3.16.**

3.3.4 Model Simulation Results

Model simulation results delineating SPCZ (Highlighted in Red colour) in Moinbagh area are shown in **Figure 3.8.** Simulation results were obtained from PCA model to assess the relative condition of each pipe in the network (**Figure 3.9)** indicate that about 51 % pipes are in class **"Good to Very Good"**, 46 % pipes are in "**Medium**" condition and about 3 % pipes are in "**Very Bad to Bad**" condition. Model simulations for Moinbagh

Exhibit 3.7 : Open Drain Carrying Sewage

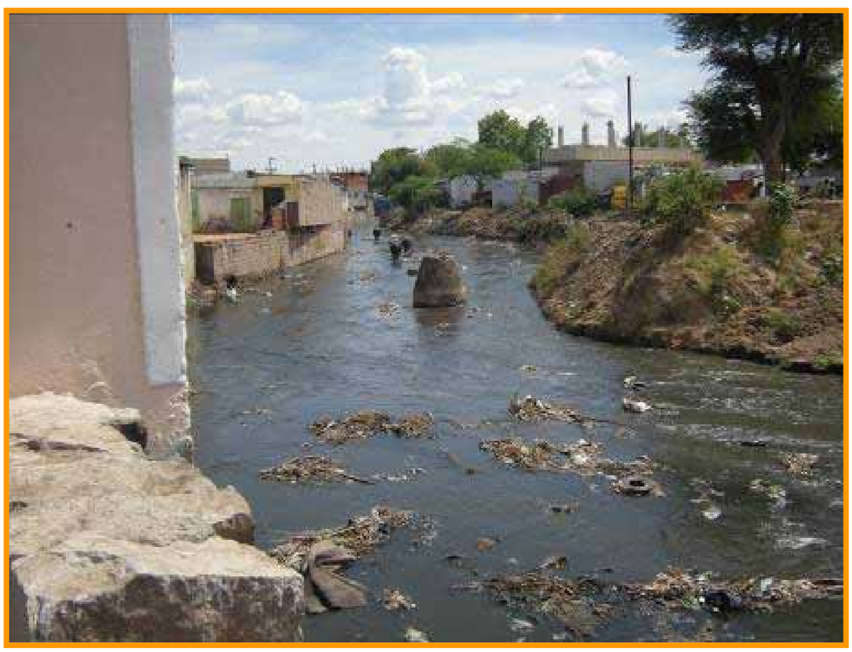


Exhibit 3.8 : Habitation near Open Drain

Table 3.15 : Soil Properties in Pilot Area : Moinbagh

Soil Type	Properties						
	Saturated Volumetric Content	Saturated Hydraulic Conductivity	Soil Characteristic Curve Coefficient	Air Entry Head	Pore Size Index	Bulk Density	Fraction Organic Content of the Soil
	$\theta_S(m^3/m^3)$	K_s(cm/hr)	b	Ψ_b(cm)	λ_b	$\rho_b(g/cm^3)$	F_{oc}
Redish Brown Silty Sand	0.29	4.86	2.2	17.7	0.892	2.14	0.0022
Yellowish Brown Silty Sand	0.49	0.8892	0.15	38.9	0.56	2	0.0023
Brownish Silty Sand	0.46	2.0232	5.38	68.1	0.38	2.04	0.002
Redish Gravelly Murrum	0.43	3.96	2.67	7.02	1.67	2.02	0.0031

Table 3.16: Ground Water Levels in Moinbagh

SL No.	Address	Water level from Measuring Point (m)	Height of the Measuring point from the Ground (m)	Water Level Below Ground Level (m)
1.	H. No. 18-8-253/24/A, Jamal Colony	1.2	0.2	1.0
2.	H.No. 18-8-223/106,Near Masjid-e-Hafizia, Riyasat Nagar	9.4	0.4	9.0
3.	Near Masjid-e-Mohammdia, Riyasat Nagar	3.6	0.4	3.2
4.	H. No. 18-8-117/2/A/3,Riyasat Nagar	9.6	0.4	9.1
5.	H. No. 18-8-245/10/1,Riyasat Nagar	7.8	0.4	7.4
6.	H.No. 18-8-223/45 Riyasat Nagar,Moinbagh	2.4	0.4	2.0
7.	Aliabad Zone	2.4	0.4	2.0

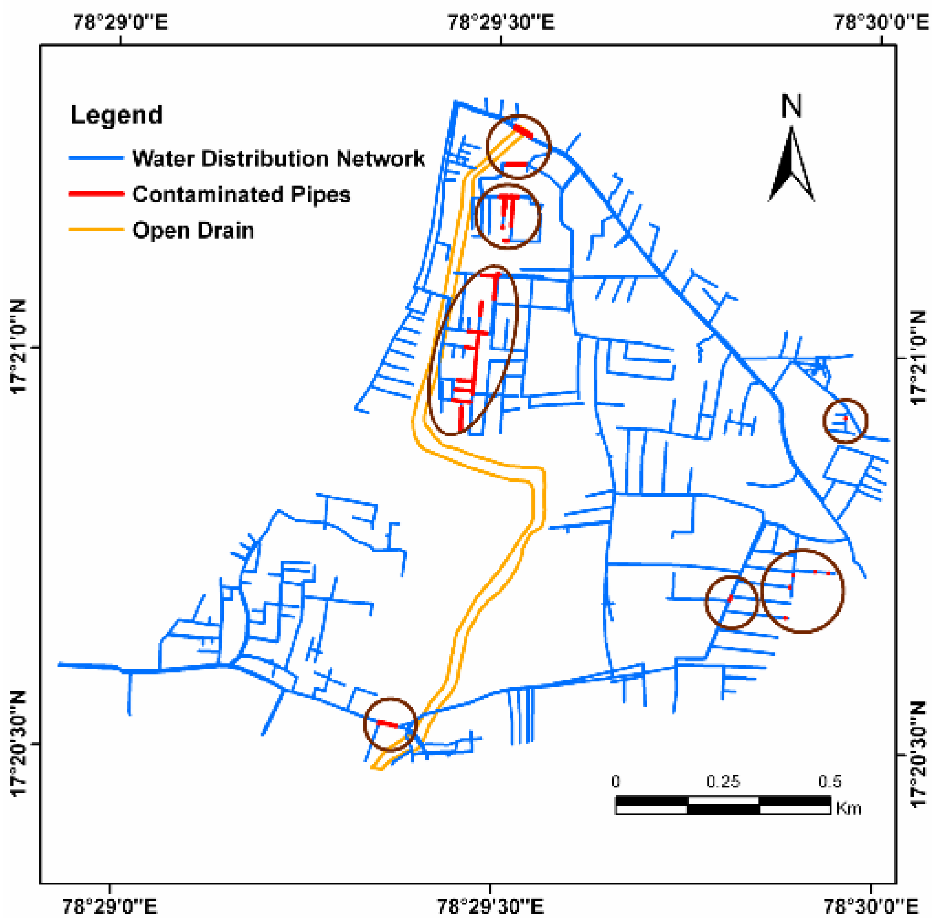
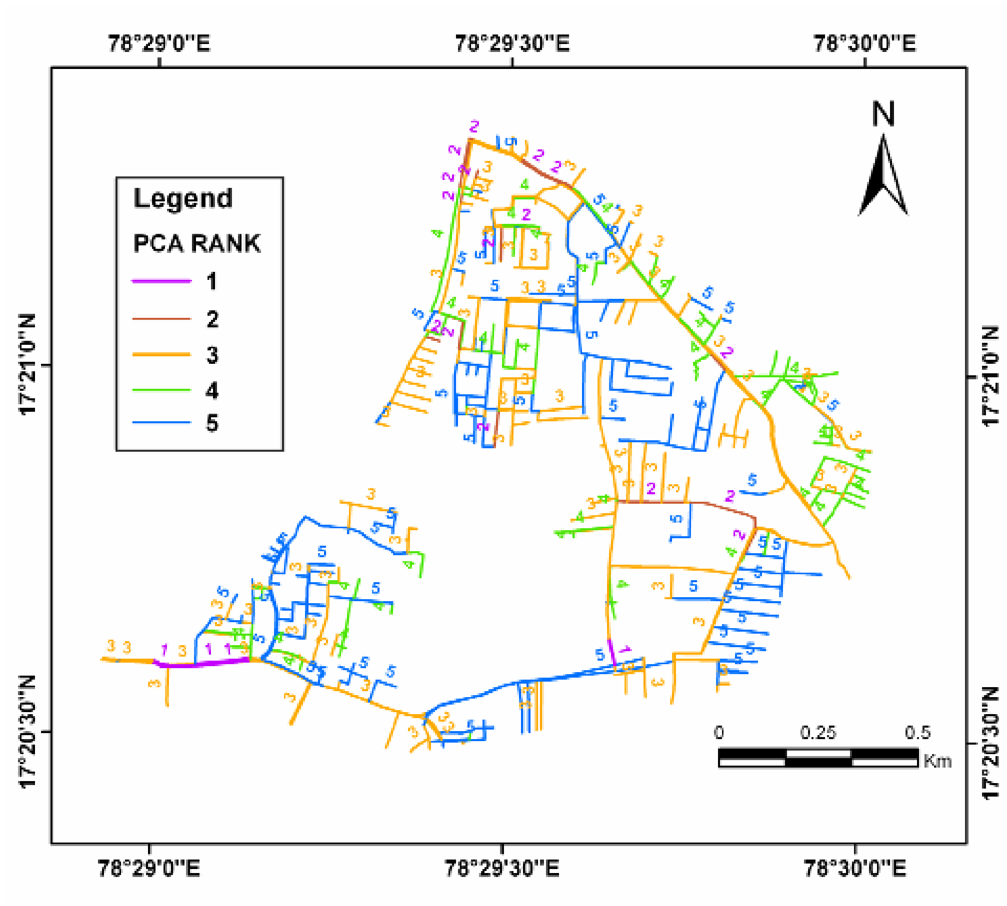


Figure 3.8 : Section of Pipes in Contaminated Zone in Water Distribution System of Moinbagh



PCA Rank	PCA Classification	PCA Index	No. of Pipes	Percentage(%)
1	Very Bad	0	6	0.76
2	Bad	0.252	21	2.66
3	Medium	0.50-0.58	362	45.94
4	Good	0.71- 0.84	142	18.02
5	Very Good	0.92 – 1.0	257	32.62

Figure 3.9 : Relative Condition of Pipes in WDS of Moinbagh

provided the relative risk of contaminant intrusion into each of the pipe in the supply network. The results indicate that overall there are 59% pipes under "**Medium risk**", 38% under "**Low risk**" and only 2 to 3% pipes are under "**High to Very High Risk**. GIS-mapping of Risk-areas in water supply network of Moinbagh is given in **Figure 3.10.** Detail map of "Very High Risk" and "High Risk" points in Moinbagh is presented in **Figure 3.11.**The statistics of pipe condition assessment obtained by model simulation is given in **Table 3.17** and that of risk assessment in **Table 3.18.**

3.4 Serilingampally

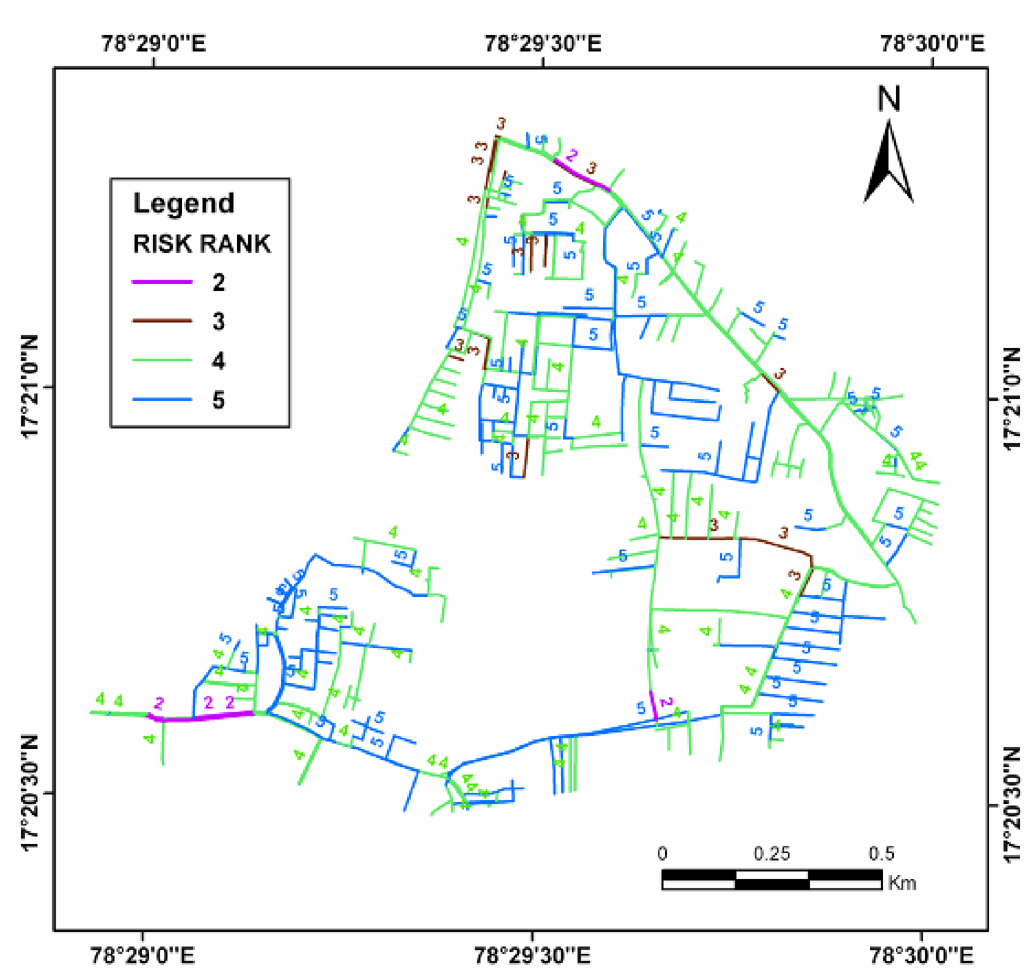
3.4.1 Source : Singur Dam

Serilingampally area receives water supply from Singur dam on river Manjira and treated at Manjira phase I and III (Rajampet & Peddapur water works) with conventional treatment followed by disinfection. The area covered under pilot study is provided with bulk supply by HMWS&SB and distributed by the municipal corporation.

Water quality at Manjira Barrage and Singur dam : Water quality on river Manjira at Manjira Barrage and Singur dam has been monitored monthly by HMWS&SB. The summary data (range values) on the physico chemical and bacteriological quality of raw water is presented in **Table 3.19**.

3.4.2 Treatment works

Rajampet (Manjira Phase I -1965): The Manjira barrage(Near Sanga Reddy, about 60 km from Hyderabad) is situated on the river Manjira and is the source of water supply to Hyderabad. The capacity of this barrage is 42.47 MCM (1.5 TMC) and the water is drawn to Rajampet Water Works through gravity system. This water works was commissioned in the year 1965 and an average water drawl is 68.1 MLD (15 MGD). The water works consists of a pre-settling tank (size: 53.54 m x 45.72 m x 6.09 m) and has a detention time of 4 hours. Alum dosing is done by flash mixing. The water after pretreatment and alum dosing is subjected to clariflocculation in two numbers of clariflocculator of the size 39.62 m x 4.87 m. After clariflocculation the water is treated in rapid gravity filters. These are 9 in numbers of size 10.06 m x 10.06 m and the treated water is chlorinated and stored in a CWR of 3.2 ML capacity. The treated water is pumped in two stage pumping. The plant summary data is presented in **Table 3.20.**



Risk Rank	Risk Classification	Risk Index	No. of Pipes	Percentage(%)
2	Very High	0.15 - 0.3	7	0.88
3	High	0.45 -0.575	19	2.41
4	Medium	0.60 - 0.846	464	58.88
5	Low	0.86 - 1.0	298	37.81

Figure 3.10 : Risk Mapping of pipes of WDS in Moinbagh

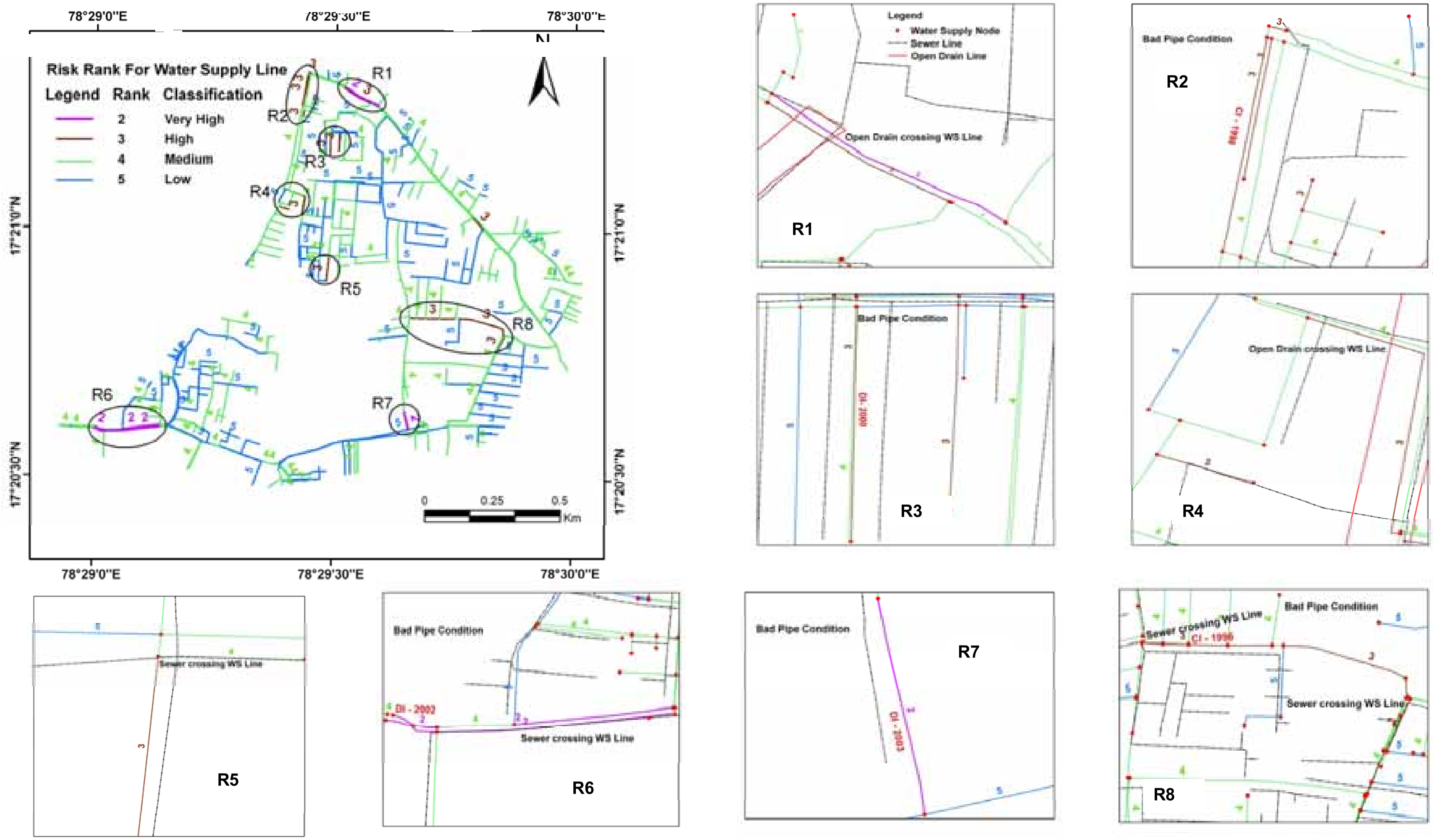


Fig 3.11 : Detail Map of High Risk Points in Moinbagh

Table 3.17 : Pipe Condition Assessment Statistics : Moinbagh

PCA Index	PCA Rank	Classification	No. of Pipes	% Pipes
1	0	Very Bad	6	0.76
2	0.215-0.358	Bad	21	2.66
3	0.429-0.587	Medium	362	45.94
4	0.68-0.787	Good	142	18.02
5	0.959-1.0	Very Good	257	32.62

Table 3.18 : Risk Assessment Statistics :Moinbagh

Risk Index	Risk Rank	Classification	No of Pipes	% Pipes
2	0.15-0.30	Very High	7	0.89
3	0.45-0.59	High	19	2.41
4	0.60-0.846	Medium	464	58.88
5	0.85-1.87	Low	298	37.82

Table 3.19 : Physico-chemical and Bacteriological Quality of Raw water sources of Manjira and Singur (June 2008 – June 2009)

S.No	Parameter	Range Values	
		Manjira	**Singuru**
1.	Turbidity (NTU)	4-80	3-60
2.	Total Dissolved Solids (mg/L)	150-220	160-230
3.	pH	7.2-8.2	7.6-8.2
4.	Total Alkalinity (mg/L, $CaCO_3$)	98-136	100-136
5.	Total Hardness (mg/L, $CaCO_3$)	76-126	88-122
6.	Dissolved Oxygen (mg/L)	4.8-6.2	2.8-6.4
7.	Conductivity (μ mhos/cm)	220-338	260-380
8.	Chlorides (mg/L, Cl)	20-32	14-42
9.	Sulphates (mg/L, SO_4)	9-18	8-20
10.	Fluorides (mg/L, F)	0.2-0.3	0.2-0.3
11.	Nitrite as NO_2 (mg/L)	Nil	Nil
12.	Total Coliforms (MPN/100mL)	1100-2400	1100-2400

MPN- Most Probable Number

Source : HMWS&SB

Table 3.20: Plant Summary Data(Phase I)-Rajampet water works

Name and Location	18 mgd Manjira water supply system at Rajampet
Manjira River	Manjira Barrage: Capacity: 1.50 TMC Sill level +1626.00 FRL +1651.75
Drawl	Intake well of Manjira Barrage on River (50' dia.)
Year of commissioning	1965
Pumps at Intake well (MB)	
Vertical Turbine	1+1
BHP	750
Duty	950 lps
Head	40 m
Hours of pumping	22
Raw water transmission mains	
Intake well to Treatment works	Rajampet – 5 km
Size & Type of pipe	1200 mm &1000 mm,CI/PSC
Treatment works	
Type	Rapid Gravity Sand Filters
Pre-Settling Tank/Primary clarifiers	1 No (Rectangular)
Size	180' x 150'
Retention Period	4 hrs
Secondary Clarifiers/Clariflocculators	2 Nos (Circular)
Size	130' dia
Post-Chlorination	0 to 6 kg/hr
Alum Solution Tank	2 Nos
Capacity	20 Cum
Filter Beds	9 Nos (2 MGD each)
Surface Rating	109 Gallons/Sft/Hr
Clear Water Reservoirs at Treatment Works	0.3 MG

Table 3.20 Continued

No. of Pumps+Motors	4 Nos
Type of Pumps	Horizontal, Centrifugal
Duty	6900 GPM
Head	67 m
Hours of pumping	22
BHP/KW	625 & 675 HP
Capacity (Air Content)	88 Cum/each
Electrical Sub-Stations	
Source	R.C Puram & Kandi
Step down	11/3.3 KV
Clear water Transmission	
1st stage pumping at Rajampet and Kalabgoor	
Treatment works to Patancheru	24 km
Size & type of pipe	1000 mm & 975 mm, CI/PSC
2nd stage of pumping at Patancheru	
Patancheru to Lingampally/Hydernagar	11 km
Size & Type of Pipe	900 mm CI&PSC
Balancing Reservoirs	
Lingampally	2 Nos – 9 MG each
Transmission trunk mains attached with Head works	
Pumping mains	120 km.
Gravity mains	130 km

Peddapur (Manjira Phase III): The Singur dam (About 75 km from Hyderabad) is on the river Manjira with a storage capacity of 849 MCM (30 TMC). It is completely prohibited area and there is no human activity in the vicinity of 15 km. This water is utilized in Manjira phases III and IV.

- Manjira Phase III (1990)– Average withdrawal 136 MLD (30 MGD)
- Manjira Phase IV – Average withdrawal 136 MLD (30 MGD)

The water after clariflocculation is filtered through the dual media filters, which are 8 & 12 in numbers in phase III and IV respectively. The treated water is chlorinated and stored in clear water reservoirs. The chlorine demand is determined and required dose is given such that 0.2 ppm residual chlorine is maintained at the consumer end. The plant summary data is presented in **Table 3.21.**

Water quality at Treatment works : Treated water quality at Rajampet and peddapur is monitored monthly by HMWS&SB. The summary data (range values) on the physico chemical and bacteriological quality of treated water is presented in **Table 3.22**.

3.4.3 Water Distribution System

The selected Pilot area for GIS – Based Mapping and Integrated Risk Assessment of Water Distribution System is the part of Serilingampally in Hyderabad city, India. The selected study zone area is about 2.14 km^2 .The area is bounded by Lingampally Village on west, Adarsh Nagar on South, Jawahar Nagar and Hafeezpet on east and National Highway on North side **(Figure 3.12)**. Main localities of this area are Chanda Nagar, Tara Nagar, HUDA Colony, Shanti Nagar and Shivaji Nagar. The contour elevation in the pilot area ranges from 549 to 570 m. The land use pattern in Serilingampally is mainly of residential and commercial type. The types of houses in this area are single and two storied bungalows. Independent houses were seen and rarely multi-storied buildings were also observed during field visit **(Exhibit 3.9).**

The water supply to the pilot area is intermittent. There are about 3000 service connections. Major source of water is from Singur dam. There is one off-take point on Phase III Manjira line (70m head), which is of 150 mm diameter. Water from this off-take point is taken to Overhead Tanks (OHT) everyday **(Exhibit 3.10).**The other Manjira mainline is of 150 mm diameter (50m head). The water supply from this point is on alternate days. There are three OHTs in the study area. Water from OHTs is

Table 3.21: Plant summary Data (Phase III)-Peddapur water Works

Name and location	33 mgd Manjira water supply at Peddapur
Manjira River	Singur Dam: Capacity: 30.00 TMC Sill level +510.60 FRL +523.60
Drawl	Jack well No. I at Singur Dam on Manjira River (10 m dia.)
Year of commissioning	1990
Raw water transmission mains	
Jack well No.I to Jack well No.II (Singur System)	Singur Dam – 0.6 km
Size & Type of Pipe	1200 mm- 2 rows + 1600 mm-1 row
Jack well No.II, near Singur Dam to Treatment works	Peddapur – 26 km
Size & Type of Pipe	2000 mm RCC
Treatment works	
Location	Peddapur
Capacity	33 MGD
Type	Dual Media Filters
Pre-Settling Tank/Primary clarifiers	3 Nos (Circular)
Size	51 m Dia..
Retention Period	3 hrs
Secondary Clarifiers/Clariflocculators	3 Nos (Circular)
Size	50 m Dia..
Chlorination	
Pre-Chlorination	0 to 6 kg/hr
Post-Chlorination	0 to 15 kg/hr
Alum Solution Tank	4 Nos
Capacity	36.8 Cum each
Filter Beds	8 Nos,4.12 MGD each
Surface Rating	15 Cum/Sqm/Hr

Table 3.21 Continued

Clear Water Reservoirs at Treatment Works	3.0 MG
No. of Pumps+Motors	6 Nos
Type of Pumps	Horizontal, Centrifugal
Duty	486 lps
Head	150 m
Hours of pumping	22
BHP/KW	1000 KW
Air Vessel	
Nos	2 (Peddapur)
Electrical Sub-Stations	
Source	Kandi & Sadasivpet
Stepdown	132/6.6 KV Peddapur
Clear water Transmission	
Peddapur to Singur	18 km
Size & Type of pipe	1625 mm OD-MS
Balancing Reservoirs	
Singur	2 Nos – 3 MG each
Singur to Lingampally	26.80 km,1200 mm PSC
Transmission trunk mains attached with Head works	
Pumping mains	120 km
Gravity mains	130 km

Table 3.22 : Physico-chemical and Bacteriological Quality of Treated water at Rajampet and Peddapur water works (June 2008 – June 2009)

S.No	Parameter	Range Values			
		Raw water		Treated Water	
		Manjira	Singur	Manjira (Rajmpet)	Singur (Peddapur)
1.	Turbidity (NTU)	4-80	3-60	1-3	1-3
2.	Total Dissolved Solids (mg/L)	150-220	160-230	100-210	150-220
3.	pH	7.2-8.2	7.6-8.2	7.2-8.2	7.0-8.1
4.	Total Alkalinity (mg/L, $CaCO_3$)	98-136	100-136	96-130	98-132
5.	Total Hardness (mg/L, $CaCO_3$)	76-126	88-122	74-122	86-120
6.	Dissolved Oxygen (mg/L)	4.8-6.2	2.8-6.4	5.0-6.8	3.9-6.6
7.	Conductivity (µ mhos/cm)	220-338	260-380	210-334	250-370
8.	Chlorides (mg/L, Cl)	20-32	14-42	18-32	12-40
9.	Sulphates (mg/L, SO_4)	9-18	8-20	8-16	6-18
10.	Fluorides (mg/L, F)	0.2-0.3	0.2-0.3	0.2-0.3	0.2-0.3
11.	Nitrite as NO_2 (mg/L)	Nil	Nil	Nil	Nil
12.	Total Coliforms (MPN/100mL)	1100-2400	1100-2400	Nil	Nil
13.	*E.Coli* (MPN/100mL)	-	-	Nil	Nil

MPN - Most Probable Number

Source : HMWS&SB

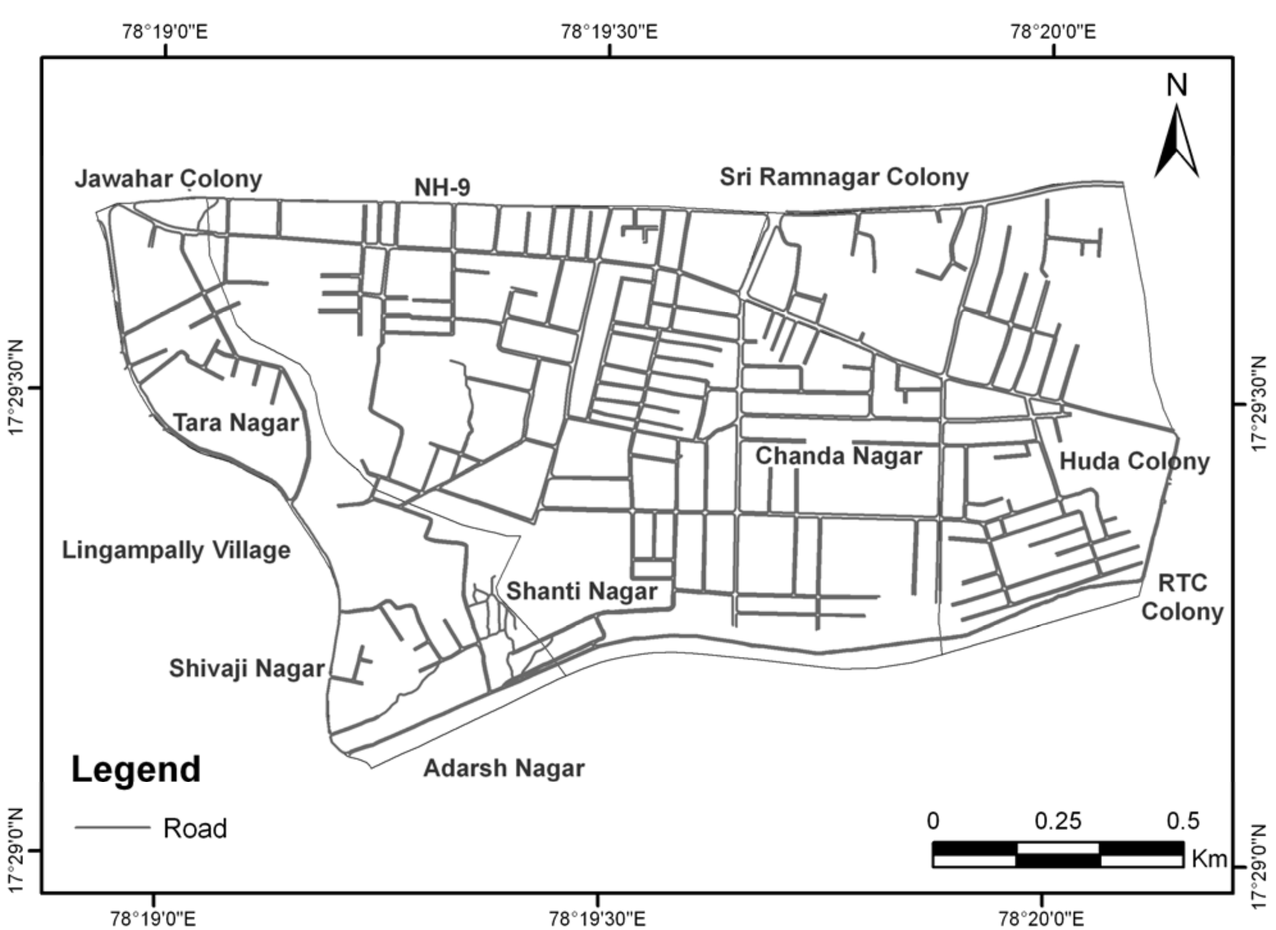


Figure 3.12: Pilot Area: Serilingampally, Hyderabad

Exhibit 3.9: Builtup in pilot area - Serilingampally

Exhibit 3.10: Water Supply Network connected to Manjira Line

supplemented by groundwater extracted from bore well. The duration of water supply is one hour on alternate days.

The existing distribution mains in Serilingampally are of Asbestos Cement (AC), Reinforced Cement Concrete (RCC), Cast Iron (CI) and Ductile Iron (DI), Polyvinyl Chloride (PVC), and High density Polyethylene (HDPE). The AC and RCC pipes were laid on 1988. The PVC pipes were laid on 1996.The HDPE pipes were laid on 1998.The CI and DI mains have been laid on 2005. The bury depth of water supply lines varies from 1.0 to 1.2 m.

Leakage in the system: It is estimated that the quantity of water drawn is 7.5 MGD. There are no systematic records of leakage measurements. Therefore, data for leakage rate and unauthorized consumption could not be obtained. The UFW in the system is considered to be 2.25 MGD i.e. 30% of total supply. The UFW include leakage in the system and unauthorized water consumption.

Sewer Network : The sewer network of the pilot area carries domestic waste to septic tanks. There are five septic tanks in the study area .The overflow from septic tanks flows through the open drain. There is no proper collection system and sewage Treatment Plant (STP) in the pilot area. The sewer network is mainly of type RCC and Stoneware Pipes (SWP). The reported length of the sewer network is 23.9 km. About 90% of the network comprises of SWP material. The bury depth of the sewer pipes varies from 1.5 to 2.2 m. The minimum and maximum diameters of the sewers are 150 mm and 350 mm, respectively. The field survey for verification of existing network and discussions with local authorities provided the information about the location and functioning of the sewerage system (**Exhibit 3.11**).

Soil : The soil in the study area is mostly silty and gravelly. Classification shows that various types of soils in the pilot area are Grayish silty sand and Brownish silty sand. Characteristics for these soils are given in **Table 3.23.**

Soil corrosivity is the major factor for deteriorating condition of underground pipes. Some soils are corrosive and water supply pipes are more prone to deterioration in more corrosive soils. The degree of deterioration also depends on the pipe material. Sandy soils are high up on the resistivity scale and therefore considered as the least corrosive, while clayey soils are more corrosive.

Exhibit 3.11: Sewage overflow from septic tank

Table 3.23: Soil Properties in Pilot Area: Serilingampally, Hyderabad

Soil Type	Properties						
	Saturated Volumetric Content	Saturated Hydraulic Conductivity	Soil Characteristic Curve Coefficient	Air Entry Head	Pore Size Index	Bulk Density	Fraction Organic Content of the Soil
	θ_S(m^3/m^3)	K_s(cm/hr)	b	Ψ_b(cm)	λ_b	ρ_b(g/cm^3)	F_{oc}
Brownish Silty Sand	0.44	0.38	2.13	68.1	0.38	2.08	0.001
Grayish Silty Sand	0.41	0.04	7.54	68.1	0.38	2	0.001
Grayish Silty Sand	0.66	0.59	3.12	68.1	0.38	1.91	0.005
Grayish Silty Sand	0.52	0.71	10.12	68.1	0.38	1.99	0.0017

Traffic : There are two major roads in the pilot area. Roads were surveyed during field visit for classification of traffic density as ‘Busy’ and ‘medium’. The main roads with dense traffic were classified as ‘Busy Traffic’ roads and these in the internal areas such as Chanda Nagar, Tara Nagar, Shanti Nagar were observed to have less traffic and were classified as ‘Medium Traffic’ roads.

Groundwater Table : The quality of groundwater in Serilingampally area is good. However it is reported that no well water is used for drinking purpose. Groundwater table in the pilot area ranges from 6 to 9 m (**Table 3.24).**

Pollution Sources : Slum area with narrow lanes, absence of wastewater collection and treatment system, crossing of water supply and sewer pipes (**Exhibit 3.12**) are some of the causes of contamination of treated water.

3.4.4 Model Simulation Results : Model simulation results delineating SPCZ (Highlighted in red colour) in Serilingampally are shown in **Figure 3.13.** Simulation results were obtained from PCA model to assess the relative condition of each pipe in the network indicate that about 95 % pipes are in class “Good to very Good”, 4% pipes are in “Very bad to bad” condition **(Figure 3.14)**. Model simulations for serilingampally provided the risk of contaminant intrusion into each of the pipe in the supply network. The results indicate that overall 95% pipes are under “Low risk”; 3 to 4% pipes under “Medium risk” and 1 to 2% under high to very high” risk. GIS mapping of water supply network of Serilingampally is given in **Figure 3.15.** Detail map of “High Risk” points in serilingampally area is presented in **Figure 3.16.**

The statistics of pipe condition assessment obtained by model simulation is given in **Table 3.25** and that of risk assessment in **Table 3.26.**

Table 3.24: Groundwater Levels in Pilot Area- Serilingampally, Hyderabad

Sl. No.	Area	Water Level Below Ground (m)
1.	Tara Nagar, Serrilingampally	9.0
2.	Huda Colony, Serrilingampally	6.0
3.	Indira Nagar, Chanda Nagar, Serilingampally	8.0

Exhibit 3.12: Supply Line close to Sewer Line

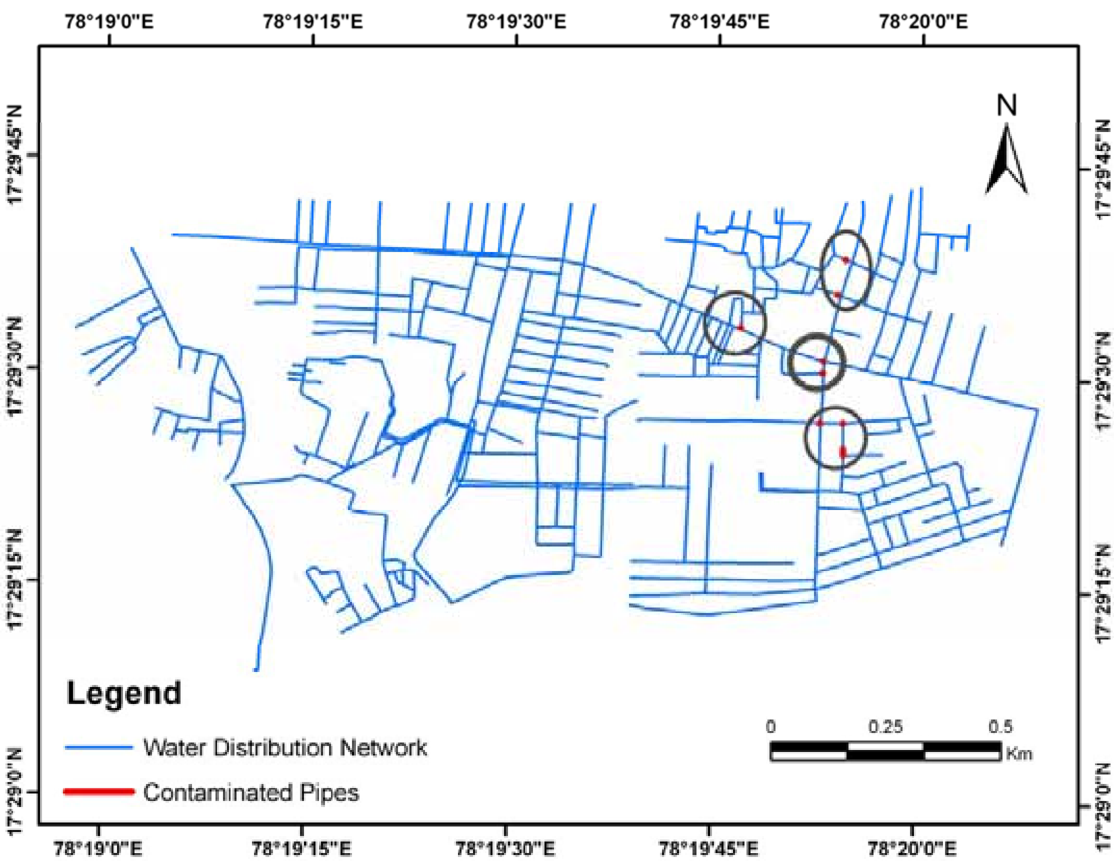


Figure 3.13: Sections Of Pipes In Contaminated Zone In Serilingampally

PCA Rank	PCA Index	Classification	No. of Pipes	% Pipes
1	0	Very Bad	6	0.91
2	0.38	Bad	22	3.34
4	0.759-0.823	Good	534	81.03
5	0.861-1	Very Good	97	14.72

Figure 3.14 : Relative Condition Of Pipes In Serilingampally

Risk Rank	Risk Index	Classification	No of Pipes	% Pipes
2	0.38	Very High	1	0.15
3	0.5-0.526	High	7	1.06
4	0.689-0.72	Medium	22	3.33
5	0.878-1	Low	629	95.4

Figure 3.15 : Risk Mapping of Pipes of Water Distribution System in Serilingampally

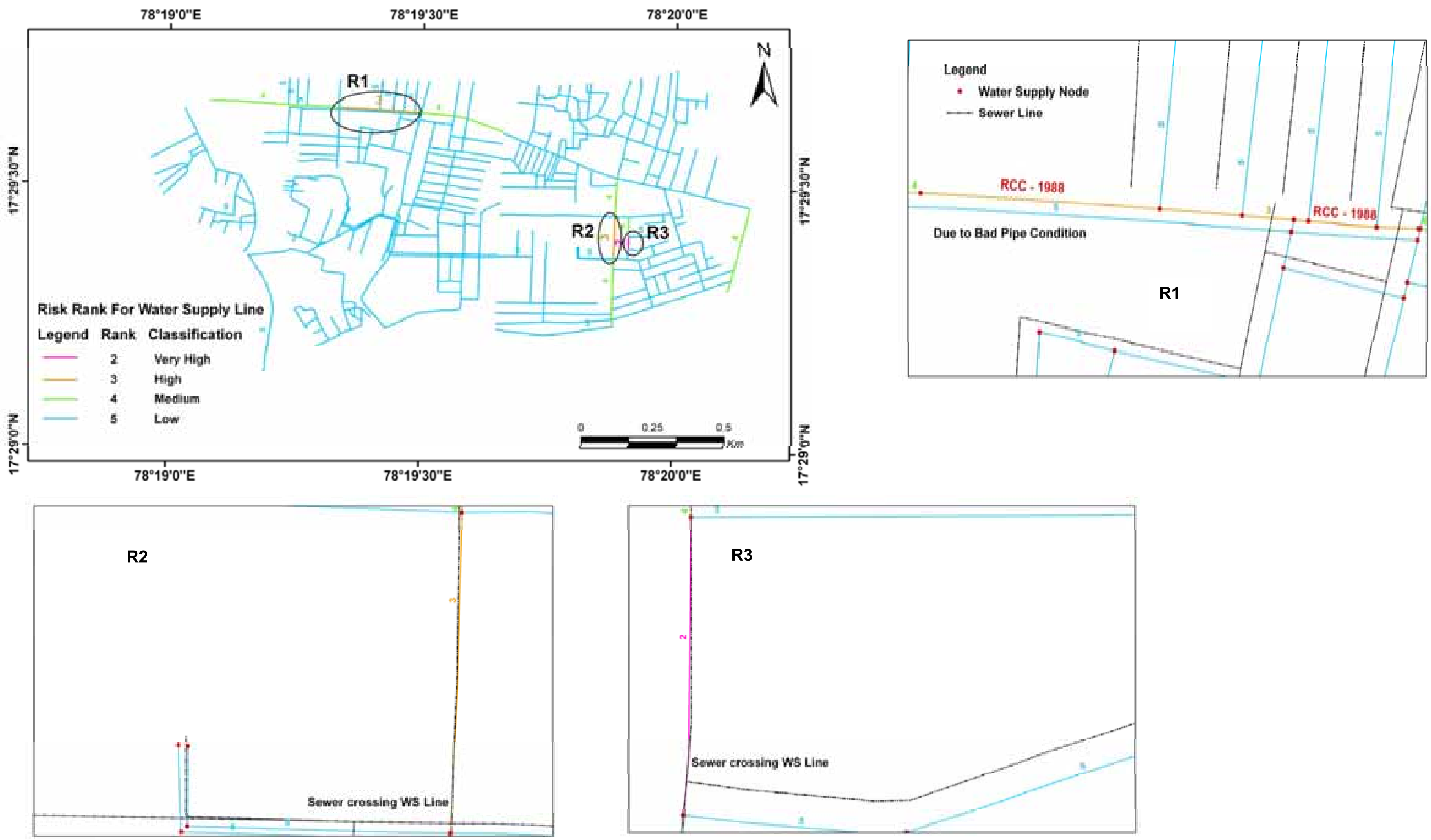


Fig 3.16 : Detail Map of High Risk Points in Serrilingampally

Table 3.25 : Pipe Condition Assessment Statistics : Serilingampally

PCA Index	PCA Rank	Classification	No. of Pipes	% Pipes
1	0	Very Bad	6	0.91
2	0.38	Bad	22	3.34
4	0.759-0.823	Good	534	81.03
5	0.861-1	Very Good	97	14.72

Table 3.26 : Risk Assessment Statistics : Serilingampally

Risk Index	Risk Rank	Classification	No of Pipes	% Pipes
2	0.38	Very High	1	0.15
3	0.5-0.526	High	7	1.06
4	0.689-0.72	Medium	22	3.33
5	0.878-1	Low	629	95.4

4.0 Introduction

Identification of hazards, hazardous events and assessment of the risks determine the control measures, reassess and prioritize the risks, develop, implement and maintain concurrently. For clarity, each of these is being presented as separate steps as they involve a number of activities. In essence these steps constitute the system assessment which identifies the potential hazards in each part of the water supply chain, the level of risk presented by each hazard and the appropriate measures to control the identified risks to ensure the water supply is safe, the standards and targets are met and health is protected.

4.1 Hazards and Hazardous events

The WSP team is required to assess in terms of hazards and hazardous events. Hazard identification involves assessment of historic information and events as well predictive information based on utilization of expert knowledge such as an operator's detailed knowledge of particular aspects of the treatment and supply systems. Hazard identification involves site visits as well as desk studies. Visual inspection of aspects such as the area surrounding abstraction points and elements of treatment may reveal hazards that would not have been identified through desk studies alone.

Hazards are defined as physical, biological or chemical agents that can cause harm to public health. Hazardous events are defined as an event that introduces hazards to, or fails to remove them from the water supply. The heavy rainfall (hazardous event) may promote the introduction of microbial pathogens (hazards) into source water.

Typical hazards affecting a catchment, associated with treatment, within a distribution network and affecting consumer premises are given in **Table 4.1.**

4.2 Hazards and Vulnerability in Pilot Areas

The hazards identified based on site visits as well as desk studies for 3 pilot areas are presented in **Tables 4.2 through 4.4** for Adikmet, Moinbagh and Serilingampally, respectively, and discussed below.

Table 4.1 : Typical Hazards Affecting Catchment, Treatment, Distribution Network and Consumer Premises

Hazardous Event (Source of Hazard)		Associated Hazards (and issues to consider)
Catchment		
Meteorology and weather patterns	:	Flooding, Rapid changes in source water quality
Seasonal variations	:	Changes in source water quality
Agriculture	:	Microbial contamination, Pesticides and Nitrate
Run-off during Monsoon	:	Microbiological contamination
Raw water storage	:	Algal blooms and toxins, stratification
Flooding	:	Quality and sufficiency of raw water
Recreational use	:	Microbiological contamination
Treatment		
Any hazard not controlled / mitigated within the catchment	:	As identified in catchment
Power supplies	:	Interrupted treatment / loss of disinfection
Capacity of treatment works	:	Overloading treatment
Disinfection	:	Reliability Disinfection by-products
Chemical dosing	:	Ineffective coagulation and pre-chlorination
Inadequate Mixing	:	Ineffective treatment
By-pass facility	:	Inadequate treatment
Treatment failure	:	Untreated water
Unapproved treatment chemicals (Alum)	:	Contamination of water supply
Contaminated Treatment Chemicals	:	Contamination of water supply
Blocked filters	:	Inadequate particle removal
Inadequate filter media depth	:	Inadequate particle removal
Instrumentation failure	:	Loss of control
Distribution Network		
Any hazard not controlled / mitigated within treatment	:	As identified in treatment

Hazardous Event (Source of Hazard)		**Associated Hazards (and issues to consider)**
Mains burst	:	Ingress of contamination
Pressure fluctuations	:	Ingress of contamination
Intermittent supply	:	Ingress of contamination
Opening / closing valves	:	Reversed or changed flow disturbing deposits Introduction of stale water
Use of unapproved materials	:	Contamination of water supply
Third party access to hydrants	:	Contamination by backflow Increased flow disturbing deposits
Unauthorised connections	:	Contamination by backflow
Leaking service reservoir	:	Ingress of contamination
Unprotected service reservoir access	:	Contamination
Contaminated land	:	Contamination of water supply through wrong pipe type
Consumer Premises		
Any hazard not controlled / mitigated within distribution	:	As identified in distribution
Unauthorised connections	:	Contamination by backflow
Lead pipes	:	Lead contamination

Table 4.2 : Identified Hazards Based On Site Visits And Desk Studies For Distribution Network In Adikmet

S.No.	Pipe-id	Area/Location	Near Road/ House No.	Risk Classification	Possible Cause
1	36	Batkama Kunta	2-2-1074-6 & 2-2-1074-11/4	High	Sewer Crossing WS
2	41	Sriramna Theatre		High	Sewer Crossing WS
3	51	Kumarwadi	2-2-1109	High	Sewer Crossing WS
4	54	Kumarwadi		High	Sewer Crossing WS
5	56	Kumarwadi	2-2-1109	High	Sewer Crossing WS
6	132	Shivam Road (Pump Room), HMWSSB / TCE/ CH/ STR		High	Open Drain crossing WS
7	152	Shivam Road (Pump Room), HMWSSB / TCE/ CH/ STR		High	Open Drain crossing WS
8	183	Shivam Road (Near Seagal Hotel), Madhuri Shop, Tilak Nagar Road		Very High	Due to Bad Pipe Condition
9	188	Shivam Road (Near Seagal Hotel, Madhuri Shop, Tilak Nagar Road)		Very High	Due to Bad Pipe Condition
10	250	Shivam Road (Near Seagal Hotel, Madhuri Shop, Tilak Nagar Road)		Very High	Due to Bad Pipe Condition
11	322	Turab Nagar(Near Pit Area)		High	Open Drain crossing WS
12	366	Turab Nagar(Near Pit Area)		High	Open Drain crossing WS
13	369	Turab Nagar(Near Timber Mart)		High	Open Drain crossing WS
14	828	D.D.Colony		High	Sewer Crossing WS
15	863	D.D.Colony		High	Sewer Crossing WS

S.No.	Pipe-id	Area/Location	Near Road/ House No.	Risk Classification	Possible Cause
16	865	D.D.Colony		High	Sewer Crossing WS
17	872	D.D.Colony	2-2-1109	High	Sewer Crossing WS
18	922	D.D.Colony	2-2-1109	High	Sewer Crossing WS
19	930	D.D.Colony	2-2-1109	High	Sewer Crossing WS
20	931	D.D.Colony	2-2-1109	High	Sewer Crossing WS

Table 4.3 : Identified Hazards Based On Site Visits And Desk Studies For Distribution Network In Moinbagh

S. No.	Pipe Id	Area/Location	Near Road/H. No.	Risk Classification	Possible Cause
1	96	Narhari Nagar	18-8-441/2/B	Very High	Due to Bad Pipe Condition
2	100	Narhari Nagar	18-8-441/2/B	Very High	Due to Bad Pipe Condition
3	103	Narhari Nagar	18-8-441/2/B	Very High	Due to Bad Pipe Condition
4	110	Narhari Nagar	18-8-411/2/B	Very High	Due to Bad Pipe Condition
5	137	Narhari Nagar	18-8-411/2/B	Very High	Due to Bad Pipe Condition
6	164	Fatesha Nagar	18-8-244/D/35	Very High	Due to Bad Pipe Condition
7	774	Kumar Wadi	17-3-189/2	Very High	Open Drain crossing WS
8	333	Flourescent Public School, Moinbagh		High	Sewer Crossing WS
9	349	Near Mubarak Daula Colony, Moinbagh	18-8-117/A/1	High	Due to Bad Pipe Condition
10	358	Near Mubarak Daula Colony, Moinbagh	18-8-117/A/1	High	Due to Bad Pipe Condition
11	359	Edi Bazar, Moinbagh	18-8-51/4/57	High	Due to Bad Pipe Condition
12	360	Edi Bazar, Moinbagh	18-8-51/4/57	High	Due to Bad Pipe Condition
13	362	Edi Bazar, Moinbagh	18-8-51/4/57	High	Sewer Crossing WS
14	364	Edi Bazar, Moinbagh	18-8-51/4/57	High	Sewer Crossing WS
15	439	Raja Nagar/Fatesha Nagar	18-8-450/C/15	High	Sewer Crossing WS
16	570	Aryasamaj Mandir/ Edi Bazar,Near Police Station	18-2-270	High	Due to Bad Pipe Condition

S. No.	Pipe Id	Area/Location	Near Road/H. No.	Risk Classification	Possible Cause
17	587	Mohamad Nagar, Near Riyasat Nagar Zone	18-8-646-/4/71	High	Sewer Crossing WS
18	610	Riyasat Nagar Zone, Near Nala/south Central Railway	18-8-646/4/55	High	Open Drain crossing WS
19	695	Edi bazar, Kumarwadi (Close to Nala)	18-8-534/11/13	High	Due to Bad Pipe Condition
20	703	Near Aluibagh	18-8-485/24	High	Nearby Sewer Line
21	747	Jawid Nagar, Near Kumarwadi	18-8-531/A	High	Due to Bad Pipe Condition
22	768	Jawid Nagar, Near Kumarwadi	18-8-531/A	High	Due to Bad Pipe Condition
23	770	Kumar Wadi	17-3-189/2	High	Sewer Crossing WS
24	781	Jawid Nagar, Near Kumarwadi	18-8-531/A	High	Due to Bad Pipe Condition
25	783	Jawid Nagar, Near Kumarwadi	18-8-531/A	High	Due to Bad Pipe Condition
26	788	Jawid Nagar, Near Kumarwadi	18-8-531/A	High	Due to Bad Pipe Condition

Table 4.4 : Identified Hazards Based On Site Visits And Desk Studies For Distribution Network In Serilingampally

S.No.	Pipe Id	Area/Location	Near Road/H.No.	Risk Classification	Possible Cause
1	45	Near HDFC Bank, Chanda Nagar	Near M.C.S.Kalyanamandapam	High	Due to Bad Pipe Condition
2	48	Near HDFC Bank, Chanda Nagar	Near M.C.S.Kalyanamandapam	High	Due to Bad Pipe Condition
3	49	Near HDFC Bank, Chanda Nagar	Near M.C.S.Kalyanamandapam	High	Due to Bad Pipe Condition
4	53	Near HDFC Bank, Chanda Nagar	Near M.C.S.Kalyanamandapam	High	Due to Bad Pipe Condition
5	57	Near HDFC Bank, Chanda Nagar	Near M.C.S.Kalyanamandapam	High	Due to Bad Pipe Condition
6	59	Near HDFC Bank, Chanda Nagar	Near M.C.S.Kalyanamandapam	High	Due to Bad Pipe Condition
7	476	Huda Colony, Chanda Nagar	Near Park	Very High	Sewer Crossing WS
8	526	Huda Colony, Chanda Nagar	Near OHT	High	Sewer Crossing WS

4.2.1 Adikmet

Hazards in the System

- The major hazards in the pilot area are two open drains, overflowing sewers, foul water body and high groundwater table.

- During the field survey for verification of existing network, it was observed that in some areas, the sewers are full during peak hours. The contaminated water from the sewers also flows on the ground.

- Foul water body is another hazard for the water distribution network of the pilot area since the supply lines are located close to the foul water body.

Vulnerability of the System

- Loose pipe joints, leaky sewers and cross-connection of sewers with water supply lines are the major causes of contaminating water supply.

- In addition to leakage from the corroded pipes, poor pipe joints, leakage at the valves, illegal connections which contribute unaccounted for water (UFW) are the vulnerable situations for contaminant intrusion.

- There are 605 pipes of 100 mm diameter and 138 pipes of 150 mm diameter in the pilot area. The installation year for these pipes is mainly 1975 and 1996. In general, small diameter pipes are more likely to break because of thinner pipe walls which make them more vulnerable to the effects of corrosion. With this set up of 30 to 35 years old network and small diameter pipes, the number of pipe breaks attended by authorities (720 per year) and the total number of bursts per year in the system (272) are quite high indicating vulnerability of system to contaminant intrusion.

- Assessment of Vulnerability of the network for contaminant intrusion considers corrosive category of pipes, leakage, and number of breaks and bursts in the system. Since, most of the water supply network is below the ground, soil corrosivity is the major factor for deteriorating condition of underground pipes. Some soils are corrosive and water supply pipes are more prone to deterioration in more corrosive soils. The degree of deterioration also depends on the pipe material. Sandy soils are high up on the resistivity scale and therefore considered as least corrosive, while clayey soils are more corrosive. The soil in the study area is mostly silty and gravelly sand indicating moderate to low corrosive category. However, during field survey some of pipes at consumer end were found to be highly corroded indicating the major factor contributing to leakage.

4.2.2 Moinbagh

Hazards

- The major hazard in the pilot area is the unlined open drain.
- In some areas, groundwater table is high, which may cause contamination of supply lines.
- During the field survey, it was observed that large habitation is occupying the land near to the open drain. The drain being un-lined, zone of contamination is formed in the soil from which the contaminants can ingress into the distribution network during non-supply hours.
- Places of crossing of supply lines and sewers are the points of hazards for distribution system.

Vulnerability

Loose pipe joints, leaky sewers and cross-connection of sewers with water supply lines are the vulnerable points in the system for contaminating water supply.

- Poor pipe joints, leakage at the valves, illegal connections which contribute unaccounted for water (UFW) are the vulnerable situations for contaminant intrusion.
- There are 37 pipes of RCC/AC installed in 1996, approximately 350 pipes of CI laid from 1998-2001, and remaining 501 pipes of DI laid after 2002. Even though network mixture of old and new pipes, large UFW makes the system vulnerable.

- Intermittent water supply makes the system more vulnerable.

- Number of pipe breaks attended by authorities (20 per year) and the total number of bursts per year in the system (142) indicating vulnerability of system due to pressure fluctuation.

- Assessment of Vulnerability of the network for contaminant intrusion considers corrosive category of pipes, leakage, and number of breaks and bursts in the system. Since, most of the water supply network is below the ground, soil corrosivity is the major factor for deteriorating condition of underground pipes. Some soils are corrosive and water supply pipes are more prone to deterioration in more corrosive soils. The degree of deterioration also depends on the pipe material. Sandy soils are high up on the resistivity scale and therefore considered as least corrosive, while clayey soils are more corrosive. The soil in the study area is mostly silty and gravelly indicating moderate to low corrosive category.

4.2.3 Serilingampally

Hazards

- Septic tanks, open drains

- Places of crossing of supply lines and sewers are the points of hazards for distribution system

Vulnerability

- Intermittent water supply makes the system more vulnerable.

- Poor pipe joints, leakage at the valves, illegal connections which contribute unaccounted for water (UFW) are the vulnerable situations for contaminant intrusion.

- There are 470 pipes of AC installed in 1988, approximately 92 pipes of RCC laid in 1998, 26 pipes of PVC laid in 1996, 24 pipes of HDPE laid in 1998, 25 pipes of CI laid in 2005 and remaining 22 pipes of DI laid in 2005. Even though network mixture of old and new pipes, large UFW makes the system vulnerable.

- Number of pipe breaks attended by authorities (20 per month) and the total number of bursts per year in the system (20 per month) indicating vulnerability of system due to pressure fluctuation.

4.3 Assessment of risk

The risk assessment process involves comprising estimation of likelihood/frequency and severity/ consequence, based on judgment of WSP team or semi-quantitative approach as presented in **Table 4.5**. Assessment should be relevant to the point in the flow diagram where the hazard or hazardous event could affect the safety of the supply system.

Output of hazard assessment and risk assessment using semi-quantitative approach for 3 pilot areas is given **Tables 4.6 through 4.8**.

4.4 Dealing with Risk

Any hazard classified as high or very high risk should have in place, or requires urgently, validated controls or mitigation. Any hazard classified as low or moderate risk should be documented and kept under regular review. The team documents whether these events need urgent attention.

4.5 Working with Stakeholders

Identification of a hazard does not mean the water authority is responsible for the cause. Many hazards are naturally occurring. The WSP approach requires water utilities to work with other stakeholders to make them aware of their responsibilities and the impact that their actions have on the utilities ability to supply safe drinking water. The WSP approach promotes dialogue, education and collaborative action to remove or minimize the hazards.

Table 4.5 : Semi-quantitative Risk Matrix Approach (from Deere et al., 2001)

		Severity / Consequence				
Likelihood or frequency		Insignificant or No Impact (Rating 1)	Minor Compliance Impact (Rating 2)	Moderate Aesthetic Impact (Rating 3)	Major Regulatory Impact (Rating 4)	Catastrophic Public Health Impact (Rating 5)
	Almost Certain/ Once a day (Rating 5)	5	10	15	20	25
	Likely/ Once a week (Rating 4)	4	8	12	16	20
	Moderate /Once a Month (Rating 3)	3	6	9	12	15
	Unlikely / Once a year (Rating 2)	2	4	6	8	10
	Rare /Once every 5 years (Rating 1)	1	2	3	4	5

Risk Score	< 6	6-9	10-15	>15
Risk Rating	Low	Medium	High	Very High

Table 4.6 : Hazard Scoring & Risk Characterization for Adikmet

S. No.	Hazard event/Source/Cause	Likelihood Score	Severity Score	Risk Score	Risk Classification
1	Contamination due to crossing of water supply line with sewer	3	3	9	Moderate
2	Back-siphoning of contaminated water	3	3	9	Moderate
3	Sewer connected to storm water drains	4	2	8	Moderate
4	Dumping of Solid Waste into open drains	4	2	8	Moderate
5	Contamination introduced during repairs	4	3	12	Moderate
6	Tampering due to unrestricted access & illegal connection to treated water pipes	4	3	12	Moderate

Table 4.7 : Hazard Scoring & Risk Characterization for Moinbagh

S.No.	Hazard event/Source/Cause	Likelihood Score	Severity Score	Risk Score	Risk Classification
1	Residential Settlement without sewage treatment & disposal system	5	3	15	High
2	Open drains (unlined) carrying sewage & sullage	5	4	20	Very High
3	Contamination due to crossing of water supply line with sewer	4	2	8	Moderate
4	Dumping of Solid Waste into open drains	4	2	8	Moderate
5	Contamination introduced during repairs	4	3	12	Moderate
6	Tampering due to unrestricted access & illegal connection to treated water pipes	4	3	12	Moderate

Table 4.8 : Hazard Scoring & Risk Characterization for Serilingampally

S.No.	Hazard event/Source/Cause	Likelihood Score	Severity Score	Risk Score	Risk Classification
1	Contamination due to crossing of water supply line with sewer	3	3	9	Moderate
2	Residential Settlement without sewage treatment & disposal system	5	3	15	High
3	Sewer connected to storm water drains	4	2	8	Moderate
4	Open drains (lined) carrying sewage & sullage	5	4	20	Very High
5	Contamination introduced during repairs	4	3	12	Moderate
6	Tampering due to unrestricted access & illegal connection to treated water pipes	4	3	12	Moderate

5.0 Introduction

While evaluating the utility of applying quality improvement program on the health benefits, it is essential to have time series data on population status, basic infrastructural amenities provided, demographic details, epidemiological status, reported cases of water borne diseases etc is essential. With the scarcity of organized water supply faced by Hyderabad city, there were no efforts done to correlate the information on water quality reports and health data from the Primary Health Centers and Private hospitals.

While planning the activities on implementation of Water Safety Plans in selected Zones, it was decided to initiate the work on compiling the health related particulars for the period of 5 years. This task was awarded to two organizations viz., "The Institute of HEALTH Systems" (IHS) and "Department of Health (DOH), Govt.of A.P." The main objective of the study by IHS was to conduct the baseline survey for gastrointestinal risk assessment in the pilot areas. The DOH conducted a study to review the impact of implementation of WSP with specific reference to reduction, if any, in cases of water borne diseases. The time period suggested for the study was four to six months after the implementation of 24 x 7 water supply in the Adikmet zone.

Summary finding of both the tasks successfully completed by the two organizations are presented in this chapter. The detailed reports are available on WHO web site.

5.1 Assessing Acute Gastroenteritis Risks Associated With Water Quality and Sanitation in Hyderabad City

5.1.1 Preamble

The quality of drinking water is a vital element of public health and well-being. Contaminated water is one of the causes of diarrhea diseases which kills 2.4 million persons globally, each year (WHO, 2005). According to WHO estimates, diarrhea diseases are responsible for about one-fifth of deaths among 'children under five' in the developing countries (WHO, 1997). Poverty, poor sanitation, hygienic practices, lack of sufficient and good quality drinking water, malnutrition, crowded living, inadequate access to health care, etc., contribute to waterborne diseases. Therefore, strategies to improve water quality, in conjunction with improvements in sanitation and personal hygiene can play a crucial role in breaking this vicious cycle of waterborne disease epidemics and will bring substantial health gains.

One of the most effective means of consistently ensuring the safety of a drinking-water supply is through the use of a comprehensive risk assessment and risk management approach that encompasses all steps in water supply from catchment to consumer (WHO, 2005). World Health Organization guidelines on water quality term these approaches as Water Safety Plans (WSPs). The WSP approach has been developed to organize and systematize a long history of management practices applied to drinking-water and to ensure the applicability of these practices. The WSP is guided by health-based targets and drinking water supply surveillance.

The Hyderabad Metropolitan Water Supply and Sewerage Board (HMWS&SB) which caters to the drinking water needs of about 6.5 million people has developed pilot WSPs in three areas, in collaboration with the WHO and the USEPA. Each site represents three major modes of water supply in Hyderabad city. In two of the areas-Adikmet and Moinbagh, the HMWS&SB is providing water to the consumer. Adikmet has comparatively newly laid systems with 24X7 water supply. Moinbagh in the old city receives intermittent water supply and has water supply and sewerage systems that were mostly laid about 70 years ago. Serilingampalli is an adjoining municipality of Hyderabad and receives bulk water supply from HMWS&SB which is then provided to consumers by the Municipal Corporation. Epidemiological surveys provide more reliable data of disease burden and its association with exposure to risks. However no such surveys have been done in Hyderabad in recent times. The variations in the socioeconomic profile of communities and drinking water system parameters within the HMWS&SB service area are required to be generated. Site specific data can be compared over a period of time to assess impact of the Water Safety Plan. The Scientific Working Group was selected in Hyderabad to establish Health Based Targets in support of the WSPs.

5.1.2 Objectives

The overall objective of the survey is to establish baseline information on water quality linked health outcome indicators to guide and evaluate the implementation of the WSPs in three pilot areas. The study aims to:

- Estimate incidence of waterborne diseases
- Estimate intra-household and distribution point prevalence of drinking water Contamination
- Assess relative risk relationship between exposure factors and health outcomes
- Assess socioeconomic determinants influencing exposure to risks and disease burden.

5.1.3 Methodology

Population Survey: The target population in the project areas of the study was "household residents" defined as a group of persons normally living together and taking food from a common kitchen as defined by National Sample Survey Organization (NSSO) of India guidelines and directives of GOI, 2006. The Census of India treats households who do not live in buildings or census houses but live in the open on roadside, pavements, in hume pipes, under fly-over and staircases, or in the open in places of worship, mandaps, railway platforms, etc., as Houseless Households. Such households were also included in the survey. However, Institutional Households which are a group of unrelated persons who live in an institution and take their meals from a common kitchen such as boarding houses, messes, hostels, hotels, rescue homes, jails, ashrams, orphanages, etc., were excluded from the survey.

Sampling Scheme: Each of the project areas had clearly demarcated slum and non-slum areas. The objective of sampling was to ensure a representative sample from the two strata. A feasible approach was to sample clusters within respective strata. Here again sampling frames of ultimate clusters were not readily available. Ultimate clusters of households were therefore selected from primary sampling units within respective strata. Census Enumeration Blocks (EB) was used as primary sampling units. The EBs formed for the 2001 decennial census. Each village or urban area has an integral number of enumeration blocks. The average size of an EB is around 125 households. Accordingly each of the project area covered about 140-150 EBs. The Registrar General of India (RGI) has master census abstracts (MCA) for each EB.

A list of the EBs in each of the project area was sought from the RGI, along with an extract containing identification information, total population and number of households in each EB and a copy of the rough sketches of the EBs. The Enumeration Blocks were classified into slum and non-slum strata based on identification information and landmarks in the rough sketches and consultation with RGI and HMWS&SB officials. A total of 20 Enumeration Blocks were randomly selected from each project area based on proportional stratification of EBs into slum and non-slum EBs. The information about total population further allowed for random selection of clusters based on probability proportionate to size (PPS). A current list of households in each EB was prepared by door to door survey in each of the selected EB. This updated house list formed the sampling frame for selection of the ultimate cluster of households. 25 households were selected by simple random sampling procedure.

5.1.4 Estimation of Sample Size

In order to compute the sample size, we needed to specify certain statistical decision rules, such as the maximum tolerable type-1 error and required precision. In addition we had to specify provisional estimates of some of the key parameters that were being studied. We estimated required sample size based on:

- An assumed incidence rate of waterborne diseases
- Prevalence of intra-household contamination of drinking water and
- Prevalence of source point contamination of drinking water supply

Assumed incidence of gastroenteritis:

Very few studies were available to facilitate an estimation of incidence of waterborne diseases in the selected areas. A cross-sectional survey among 3573 households in Hyderabad done by Mohanty et.al (2002) reported a mean incidence of 37.39 cases of gastroenteritis per 1000 population, during a period of one month prior to the survey. However there are 4 additional factors that to be considered before we assumed a rate based on the aforesaid study for estimation of sample size. They included: (1) trends in waterborne disease incidence (2) seasonal variation in waterborne diseases (3) intra-city variation in waterborne diseases incidence rate and (4) the period of recall. The present survey is proposing to collect the data that was necessary to assume a conservative estimate of incidence during a specified period to reasonable estimate of actual incidence of waterborne diseases in the project areas. Mohanty* et.al. had surveyed and collected data on incidence of waterborne diseases in the household before 30 days prior to the interview. Given our understanding that the principal risks to human health associated with consumption of unsafe water in these areas are microbiological in nature, trends in gastroenteritis incidence appear to be a reasonable indicator of trends in waterborne diseases. Surveillance data do not indicate any significant decline in gastroenteritis trends in the years subsequent to the survey. Seasonality of gastroenteritis in Hyderabad has been well established and historically, the incidence of gastroenteritis is lowest in November and December, the period corresponding to the survey (Mahapatra and Reddy 2001).

Two of the project areas (Adikmet and Moinbagh) fall in zones that reported a rate higher than the mean incidence rate. Taking the above into consideration, the mean incidence rate reported by the survey appears to be a conservative estimate and hence do not require any adjustments on account of the first three factors mentioned above. However the fourth factor, i.e., the period of recall which the present survey is proposing to collect the data has implications for the assumed incidence rate. Similar surveys have adopted a recall period ranging from one week to a month. Ceteris paribus, a smaller recall period will mean a larger sample size. However when the incidence of gastroenteritis is significantly high as is assumed in the case of the project areas, there is a likelihood of greater “recall bias”. To minimize the recall bias a one week recall period for the current survey was proposed. Since the study design includes cluster sampling, the effect of the cluster design must be factored in to the sample size. The design effect (*D*) is the ratio of variance of the estimate obtained.

The third area, Serilingampalli was not included in the through cluster sampling and variance of the same estimate obtained from an equal sized simple random sample. The design effect is usually greater than one and denotes the factor by which the sample size calculated under simple random sampling scheme needs to be increased to keep the desired precision unchanged, while adopting a cluster sampling scheme. The NFHS-2 survey in India selected enumeration blocks as the primary sampling units in urban areas with probability proportionate to size, followed by systematic sampling of 30 households within each sampling unit. In the survey, the design effect estimated for the parameter “children under 3 years with diarrhoea in the past two weeks” for urban areas of AP was 1.026 (IIPS and ORG Macro, 2000). However unlike the NFHS-2, the present study proposes to collect similar information for all members of the selected household.

Given that gastroenteritis is likely to cluster within a household we assume a higher design effect of 1.5. Under a simple random sampling scenario which accepts a

5% type-1 error corresponding to 95% level of confidence and assumes a confidence limit of about 20% around the incidence rate, the survey requires to cover about 4958 individuals in each of the project area. The average household size in Hyderabad Municipal Corporation area as per the 2001 Census is 5.5 (GOI, 2003). Accordingly the survey covered approximately 900 households. After taking into consideration the design effect of 1.5 due to cluster sampling, the sample required will be 1344 households.

Assumed prevalence of intra-household contamination:

Routine monitoring done by the IHS for the HMWS&SB indicates that 43.6% of the household stored water samples were contaminated by pathogenic bacteria (IHS, 2006). Findings of an unpublished study done through the Institute reporting that 38.5% of the stored water samples were contaminated (Eshcol, 2006). We therefore assume that the prevalence of intra-household contamination of drinking water in the project areas will be about 35%.

Given the high prevalence rates assumed we assume smaller confidence intervals 10% of 15% and other statistical decision rules remain same as that for sample size estimation based on the other 2 parameters. Depending on the confidence interval assumed, a sample of 480 or 1080 households will be required for the study.

Assumed prevalence of source point contamination:

Routine monitoring done by the IHS for the HMWS7SB between February 2005 and February 2006 indicate that 1.5% of the piped water samples were contaminated (IHS, 2006). We therefore assume that the prevalence of source point contamination of drinking water in the project areas will be the same. Assuming a confidence interval of 20%, 5% error and a design effect of 1.5, we require a sample size of 9456 households. Greater the sample size, greater will be the precision of estimates of the various parameters. A sample size of 1500 households comprising of 500 households per site was fixed for the study.

5.1.5 Interviews and filling in Respondent Survey Form

A questionnaire was administered to an adult household member after obtaining informed consent. The questionnaire was designed to obtain information on the following:

- Household characteristics including number of people in household; age of household members; education qualifications and general socioeconomic characteristics.

- Acute Gastroenteritis Episodes: The respondent was requested to recall Acute Gastroenteritis episodes, if any, of all household members. For each episode, information about symptoms, signs, medical attendance etc. were collected. Recall was aided by a prompt list of symptoms.

- Hygiene and Sanitation including hand washing practices; accessibility of toilet facility; food storage practices and practices regarding use of spoiled food; outside eating habits; cleaning practices & cleaning agents for utensils; laundry practices, status of sewage in the vicinity of household etc.

- Water use practices including water source type and access; drinking water source used when away from home; water storage practices; water treatment practices; perception of water quality etc.

5.1.6 Case Definition of Acute Gastroenteritis

The case definition of acute gastroenteritis was based on self-reporting and as used here was:

- Diarrhoea three or more times in a 24-hour period, or
- Bloody diarrhoea , or
- Vomiting together with at least one other symptom (diarrhoea, abdominal pain/cramps, fever)
- In the four weeks prior to the interview
- In the absence of a known non-infectious cause

Respondents were excluded if they considered their symptoms to be due to non-infectious causes of diarrhoea or vomiting such as Crohn’s disease, ulcerative colitis, excess alcohol, pregnancy, menstruation, or medication known to cause vomiting (e.g. Chemotherapy).

5.1.7 Collection of Water Sample from Households

During the household visits, the participants were asked to offer some drinking water. 100 ml of water was collected directly from the tumbler offered. The sample was collected irrespective of being consumed by the household, contamination occurred at the source, during transit, or during storage, preserved and analysed at the IHS Water Quality Testing Laboratory on the same day. A second sample was collected from the source from which the household collects drinking water. If the household had a water supply connection, then the sample was collected at the point of delivery of municipal water to the household. This may be a directly available municipal tap or a tap leading to a sump or an overhead tank. If the household collects water from a street tap, information about the location of tap was obtained and a sample collected from there.

5.1.8 Laboratory Testing

Coliform bacteria and *E.coli* are the most common microbial contaminants of water in these areas. Samples were tested by a standard plate count method using "CHROMagar" as the media. CHROMagar is a chromogenic agar which differentiates between *E.coli* and other coliforms. The method can enumerate *E. coli* and total coliform in a single test and report results in CFU/100 ml which will be useful for quantifying human exposure to pathogens and risk characterization to determine probability of infection. Plates were incubated for 24 hours between 37 and 44 ^{0}C. *E.coli* was identified by blue colonies and other coliforms by mauve colonies. Number of colonies were counted under a colony counter and results reported in colony forming units per ml (CFU/ml).

5.2 Analysis and Conclusions

5.2.1 Burden of Gastroenteritis

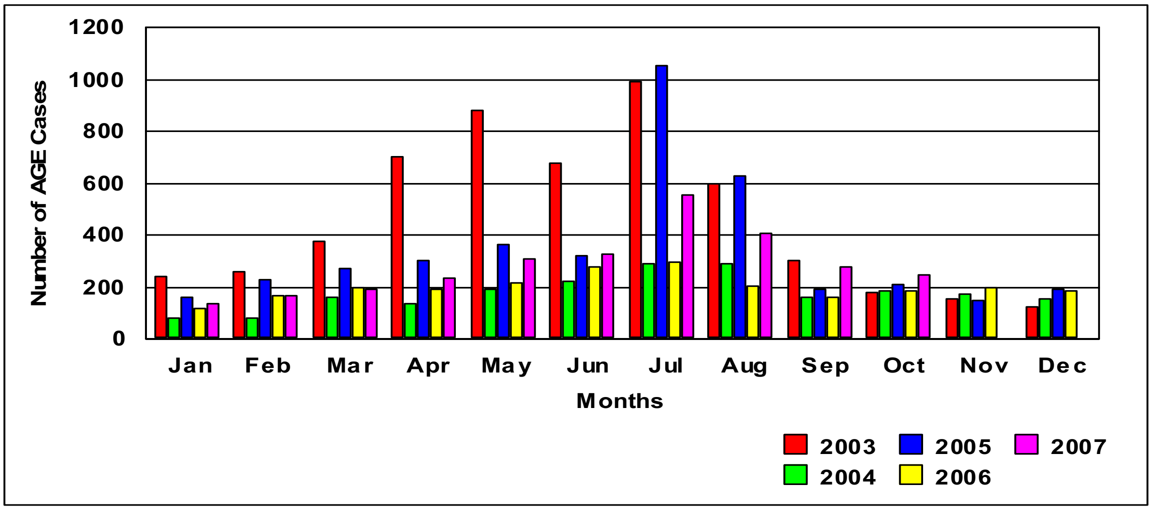
The survey indicates that acute gastroenteritis is an important public health parameter in study areas. The survey reported a mean weekly incidence of 22.23 per 1000 population (CI ±3.50). On extrapolation based on seasonal trends available from surveillance data, the annual community incidence rate of acute gastroenteritis in the survey areas is estimated around 875 per 1000 population. In addition to the disease burden, acute gastroenteritis entails a significant financial burden. About 85% of the cases had received medical care from a doctor. The mean expenditure on treated cases of gastroenteritis was estimated to be around Rs.732/-. Further, 45% of the cases resulted in loss of work, college or school days. Mean days lost was about 4.78 days per case.

Survey findings indicate that the magnitude of acute gastroenteritis is much higher than suggested by the existing surveillance system. The number of Gastroenteritis cases captured by the public health surveillance system from January 2007 to September 2007 is depicted in **Figure 5.1.** Survey was carried out during May 20,2007 to July 10,2007.The monthly incidence rates extrapolated from surveillance data for the period corresponding to the survey ranges from 0.06 to 0.11 per 1000 population. Obviously, there is a wide discrepancy between community incidence rates reported by the survey and surveillance incidence data. The reasons for such a large discrepancy can be mostly explained by the health seeking behaviour of the people living in Hyderabad and the coverage of the surveillance system. Currently the surveillance system covers only large public hospitals in the city.

Findings from the current study indicate that some people may not seek medical treatment if symptoms are not very serious. Even when they seek treatment, they tend to approach private providers. Only 2.38% of the cases who accessed medical care sought treatment from government hospitals which are covered by the surveillance system. 93% of cases who accessed medical care sought treatment from the private sector. About 55% sought treatment from private doctors and 38% from private hospitals. Reliance on private doctors is especially high in slum areas. Given that local private doctors are the primary point of contact for those seeking medical care, there is need to involve them in routine surveillance especially in the context of monitoring of Water Safety Plans. The Integrated Disease Surveillance Programme (IDSP) of the Government of India is currently being implemented in the State. The IDSP seeks to enlist support of private providers for surveillance of common diseases. Operationalization of the programme in the pilot areas on priority basis is likely to provide incidence data for monitoring of WSPs on a routine basis.

5.2.2 Risks for Acute Gastroenteritis

Key variables were assessed to understand their possible role in risk for gastroenteritis. Though the data did not indicate statistically significant risk for gastroenteritis on account of many socioeconomic variables, the risk for gastroenteritis



Source: Public Health Surveillance system and IHS, Hyderabad

Figure 5.1: Monthly Acute Gastroenteritis cases in Hyderabad

in slum areas was almost twice that of non slum areas (RR 1.99, 95% CI 1.44-2.75). Relative Risk for Acute Gastroenteritis on account of some of the key variables is presented in **Table 5.1.**

Findings of the study indicate a statistically significant risk for gastroenteritis in the pilot areas as a whole on account of contamination of drinking water source. Overall, 13.33% household source water samples were contaminated with coliforms. *E.Coli* was isolated in 4.33% of the household source water samples. However, the risk was not significant in slum areas. Compared to other areas, prevalence of source water contamination in slum areas of Moinbagh which accounted for more than one third of the gastroenteritis cases was lower than that in non slum areas. This may be on account of significant improvements in water and sanitation infrastructure and third party monitoring in slums following an epidemic of gastroenteritis in 2005. A statistically significant risk for gastroenteritis in the sites as a whole on account of contamination of stored drinking water was established by the study. However, the risk was not significant for slum areas.

Risk of Gastroenteritis is significantly lower in households having Metro domestic connections and significantly higher in households using pit taps as a drinking water source. About 33% of slum households and 20% of non slum households depend on pit taps for drinking water. Pit taps are illegal pipe connections established by residents by digging a pit and directly tapping into the underground main pipe lines in areas where there is low pressure in the supply system. Pit taps pose a significant risk for gastroenteritis (RR 3.484, 95% CI 2.388-5.03) as they are more vulnerable to contamination. Their base is not cemented and there is water stagnation around the tap. In many instances the surroundings are unsanitary. Since water supply is intermittent, surrounding water is sucked into the pipes during periods where there is no supply. Significant risk for source water contamination with *E. coli* was associated with not having a metro domestic connection (RR 2.543 95% CI, 1.585- 4.084) and using pit taps as a drinking water source (RR 2.383 95% CI, 1.486- 3.814).

While some water use practices such as using the same utensil used for drinking for retrieving water from container were seen as risk for gastroenteritis, others such as not treating water did not appear to be a risk factor for gastroenteritis. In the sites as a whole, using the same utensil used for drinking for retrieving water from storage container was associated with a statistically significant risk of gastroenteritis (RR 2.017 95% CI 1.29-3.11). However, the risk was not significant in slum

Table 5.1: Relative Risk for Acute Gastroenteritis

Risk Factors	Slum			Non Slum			Overall		
	RR	95%	CI	RR	95%	CI	RR	95%	CI
Contamination of Source water with *E.Coli*	0.708	0.124	3.27	4.377	2.21	8.265	2.453	1.362	4.325
Contamination of Storage water with *E.Coli*	1.413	0.669	2.83	4.417	2.32	8.17	2.541	1.569	4.027
Contamination of Source water with Coliforms	1.905	1.048	3.35	2.483	1.31	4.64	2.108	1.361	3.23
Contamination of Storage water with Coliforms	1.084	0.645	1.81	2.491	1.4	4.442	1.715	1.165	2.517
Not having a metro domestic connection	2.389	1.409	4.08	3.597	2.02	6.416	3.235	2.194	4.78
Having Pit Tap as Main Drinking Water Source	2.95	1.793	4.87	3.567	2.0	6.342	3.484	2.388	5.083
Using utensil used for drinking for retrieving water from container	1.67	0.878	3.06	2.683	1.44	4.946	2.017	1.293	3.11
Not Treating Water	1.373	0.837	2.25	1.396	0.78	2.504	1.415	0.966	2.07
Respondent's Perception that water is not safe to drink without treating	1.76	1.05	2.93	0.842	0.46	1.52	1.971	1.35	2.873
Poor sanitary status	2.494	1.459	4.3	2.439	1.37	4.357	2.735	1.853	4.045

Source: IHS, Hyderabad

households. Treating water was not found to be associated with a statistically significant lowering of risk for gastroenteritis. More than half (52%) of the households treating water used locally available candle filters.

About 37% of the respondents felt that it was not safe to drink water without treatment. Respondents' perception that water is not safe to drink without treating was associated with a risk for gastroenteritis (RR 1.971 95% CI 1.351-2.873) in the survey areas. The risk was not significant in slum areas. Respondents attributed about 48% of the cases to water contamination. Over 60% of these cases were attributed to consuming contaminated water at home. A mechanism to gather client feedback and provide prompt attention may have an impact on improving water quality and bringing down incidence of gastroenteritis.

Poor sanitary environment as assessed by sewage overflows, excreta in the vicinity and garbage accumulation nearby household premises pose a significant risk for gastroenteritis (RR 2.735 95% CI 1.853-4.045). Poor sanitary environment was associated with a significant risk for *E. coli* contamination of stored water samples (1.975 95% CI 1.408-2.771). About 7.5% of households in slums and 4.5 % households in non slums had visible animal or human excreta within the household premises. About 31% of respondents did not perceive washing hands with soap was important after defecation. Only 35% of respondents from slums of Adikmet perceived hand washing with soap to be important after defecation. 29% of water samples stored in household were contaminated with coliforms. *E.Coli* was isolated in 8.13% of stored water samples tested. Prevalence of stored water contamination was higher in slum households (34%) compared to non slum households (25%). Contamination of stored water samples is significantly higher than source samples indicating intra-household contamination. These findings indicate need for making residents aware of basic hygiene practices.

5.3 Water safety plan and the role of department of Health

Globally it is estimated that acute diarrhoea contribute 39% of diseases caused due to water sanitation and hygiene related disorders. Quality of drinking water is one of the most important factors responsible for occurrence of diarrhoeal diseases. A systematic review of environmental interventions to prevent diarrhoeal diseases reported about 15% to 17% median reduction in incidence of diarrhea. The quality of drinking water is a vital element of public health and well-being. Poor quality of drinking water and inadequate sanitation are major causes of early mortality, disease and economic burden for communities. Hyderabad city was facing frequent water borne disease outbreaks since 2004 **(Figure 5.2).** The stake holders in the WSP are Hyderabad metropolitan water supply and sewerage board (HMWS&SB) and the Department of health (DOH), Govt. of A.P.

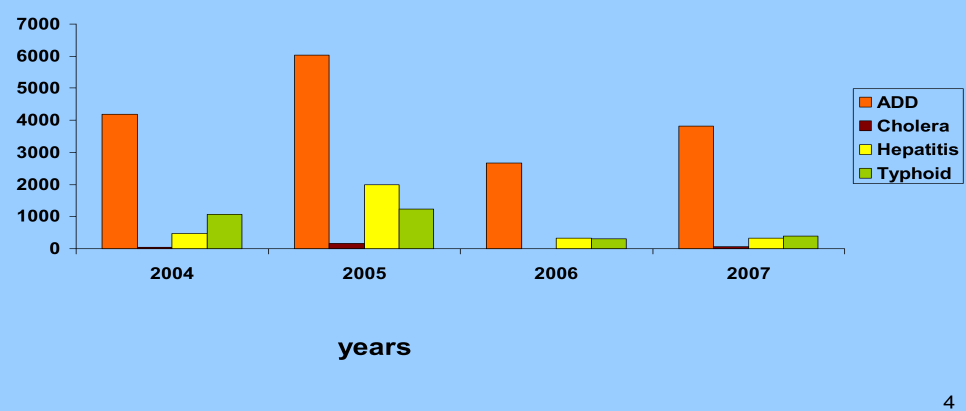
The water safety plan was implemented in Adikmet (population: 44,487) covering ward-2 and block-2 of Hyderabad Municipal corporation. As a part of the plan, twenty four hours water supply was supplied in the area. The Adikmet area is covered by an NGO managed urban health centre under the municipal corporation of Hyderabad and is served by two multi purpose health workers. The DOH conducted a study to assess the impact of water safety plan on the incidence of waterborne diseases in Adikmet area for four months after the implementation of the WSP.

Two other areas viz., Moinbagh (population=59,000) from Hyderabad Municipal corporation and Serilingampally (population=26,000) from the neighboring Rangareddy district were selected for comparison. Moinbagh is a part of the catchments of Rakshapuram urban health centre located in the older parts of the city (ward 18 and Block 8 of the municipality) and is served by two multi purpose health workers. Serilingampally area is covered by serilingampally primary health centre which is under the administrative control of the district medical and health officer of Rangareddy district. The area is served by one multi purpose health worker. Both the areas receive water on alternate days.

5.3.1 Surveillance for water-borne diseases

The health department monitors the occurrence of waterborne diseases through the surveillance of certain identified diseases on monthly and weekly basis. Under the monthly disease reporting system, data about number of cases due to 45 diseases is collected from the Primary Health Centres, District hospitals and Medical college hospitals. Waterborne diseases covered under this reporting system are acute diarrhoeal disease, cholera, typhoid and hepatitis. Under the recently implemented Integrated Disease Surveillance Project (IDSP), data about nine core and two state-specific diseases are collected from the sub centre level onwards on a weekly basis. At the sub-centers, multipurpose health workers conduct syndromes surveillance and

Figure 5.2 : Reported cases of Water borne diseases at Hyderabad-sentinel surveillance report 2004-07



Source: Department of Health, Hyderabad

collect the information about these diseases while the Medical Officers at Primary health centers and district hospitals conduct presumptive surveillance. Under IDSP, Acute diarrhoeal disease, cholera and typhoid are kept under weekly surveillance.

5.3.2 Impact of Water Safety Plan

Surveillance data of waterborne diseases from monthly report as well as IDSP from Adikmet, Moinbagh and Serilingampally areas for the period November 2006 to October 2007 was reviewed and the incidence of these diseases was calculated. The attack rates of these diseases were compared among the three areas.

5.3.3 Observations

During 2006 to 2007, Adikmet reported 290 cases of acute diarrhea with annual attack rate of 6.5/1,000. The corresponding figures for Moinbagh and Serilingampally were 637 and 760 cases with attack rates of 10.8 and 29.2 respectively **(Figure 5.3)**.

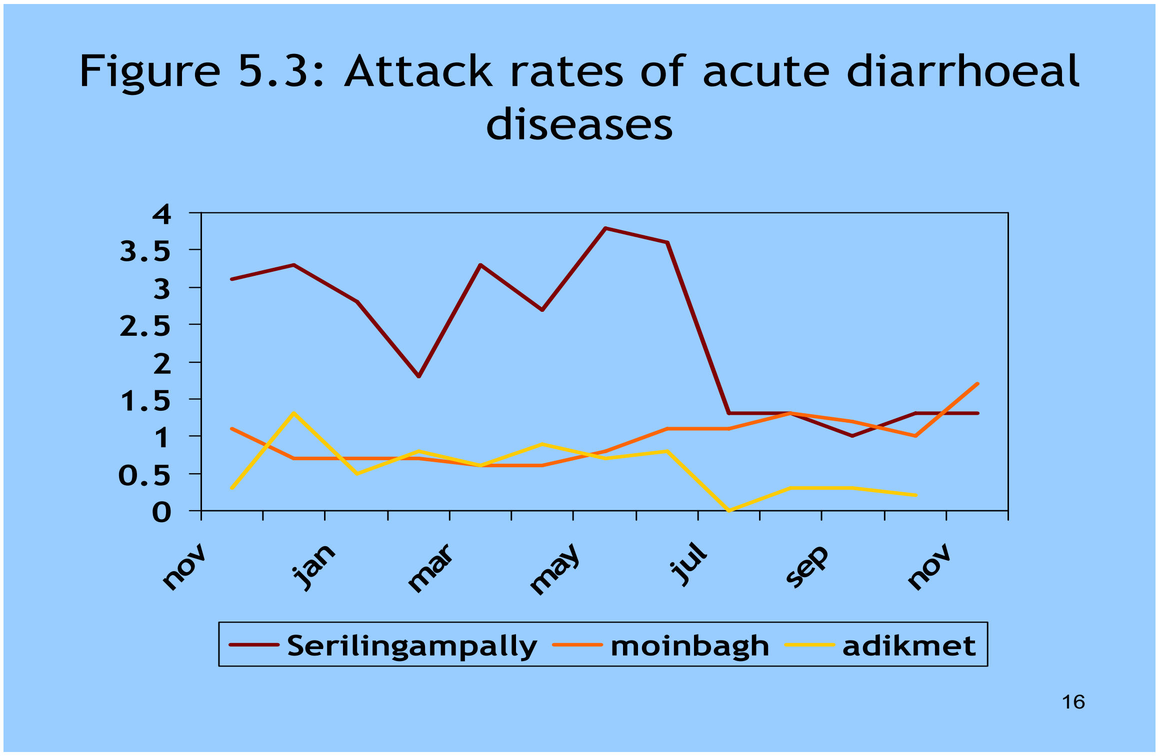
The attack rates among less than five years of age were 25, 44 and 113 per 1,000 at Adikmet, Moinbagh and Serilingampally respectively **(Table 5.2)**, which were significantly higher when compared to those above five years of age. There was no difference in attack rates among either of sex (Table 5.2).

5.3.4 Constraints faced while interpreting the data

The study has several limitations. First, the baseline data for the incidence of diarrhoeal disease in the selected areas prior to the implementation of safety plan was not available. Second, the areas selected for comparison had different sources of health providers. Third, the socio-economic characteristics of all the three areas are not similar (prevalence of water borne diseases and back ground information survey done by IHS). The observed lower incidence of acute diarrhoeal diseases in Adikmet might thus be due to confounding effect of socio-economic status.

5.3.5 Conclusions

We conclude that the incidence of acute diarrhoeal disease incidence is significantly lower in the area where water safety plan has been implemented. Considering the limitations of the study, we cannot convincingly say t hat the low



Source: Department of Health, Hyderabad

Table 5.2: Distribution of acute diarrhoeal cases related to Age and Sex (November 2006 to October 2007)

Attack rates per 1,000 population

Age	**Adikmet**	**Moinbagh**	**Serilingampally**
< 5years	24	44	113
> 5years	4	5	16
Sex			
Female	6	10	29
Male	7	11	30

Source: Department of Health, Hyderabad

incidence of diarrhoeal disease in the target area is due to the impact of implementation of Water Safety Plan. Hence, we recommend continuation of the study and sharing of information between the health and water supply department. We also recommend that the addresses of the patients may also be shared with the water board so that the status of the pipe lines may be matched with the findings of the GIS maps.

6.0 Introduction

Concurrently with identifying the hazards and evaluating the risks, the WSP team document existing and potential control measures. The team considers whether the controls are effective. Depending on the type of control this could be done by site inspection, validation or monitoring data. The risks should be in terms of likelihood and consequence, taking into account all existing control measures. The reduction in risk achieved by each control measure will be an indication of its effectiveness. If the effectiveness of the control is not known at the time of the initial risk assessment, the risk should be calculated as though the control was not working. Any remaining risks after all the control measures have been taken into account, and which the WSP team consider unacceptable, may be investigated in terms of additional corrective actions. Control measures are steps in the drinking water supply that directly affect drinking water quality and ensure the water consistently meets water quality targets.

Existing control measures should be determined for each of the identified hazards and hazardous events. The risks should be recalculated in terms of likelihood and consequences taking into account the effectiveness of each control. Control measures must be considered not only for their longer term average performance but also, in light of their potential to 'fail' or be ineffective over a short space of time.

Risks should be prioritised in terms of their likely impact on the safety of the system. Through the risk assessment process the WSP team can decide whether the system needs to be modified to achieve the relevant water quality targets.

6.1 Typical Control Measures associated with Hazards at Catchment Area

- Catchment controls and mitigation
- Restricted access to catchments
- Water utility ownership and control of catchment land
- Codes of practice on agricultural chemical use and slurry spreading
- Communication and education of catchment stakeholders
- Raw water storage
- River biology –point source contamination
- Intake and river continuous monitoring
- Site inspections

6.2 Typical Control Measures associated with Hazards at Treatment Plant

- Water treatment process optimization
    - Chemical dosing
    - Filter backwashing
    - Flow rate
    - Minor infrastructure modification
- Treatment controls and mitigation
- Validated treatment processes
- Alarmed operating limits
- Stand-by generator
- Automatic shut-down
- Continuous monitoring with alarms
- Trained staff (Operator competency)
- Communications back up

6.3 Typical Control Measures associated with Hazards at a Distribution Network

- Regular reservoir inspections (external and internal)
- Cover open service reservoirs
- Up to date network maps
- Known valve status
- Mains repair procedures
- Trained staff (Operator competency)
- Hygiene procedures
- Hydrant security
- Non-return valves
- Pressure monitoring and recording
- Protected pipes

6.4 Typical Control Measures associated with Hazards at Consumers Premises

- Property inspections
- Consumer education
- Non-return valves
- Advice to boil/not use the water

Typical hazards and control measures identified for disinfection are presented in **Table 6.1.**Control measures identified for each hazard in distribution network of 3 pilot areas viz., Adikmet, Moinbagh and Serilingampally are presented in **Tables 6.2 through 6.4** respectively.

6.5 Risk Assessment and Prioritization

Because a number of hazards/events may occur at any one step, it is important to decide whether any of these present a significant risk and need to be evaluated for action. The controls should be initially validated by intensive monitoring. Only then can the risks be prioritised and reassessed. If it is clear that the system needs to be modified to achieve the relevant water quality objectives an upgrade/improvement plan may be developed and implemented. The risk assessment process can involve a quantitative or semi-quantitative approach (estimation of consequence/likelihood and frequency/severity) as detailed in chapter 4, section 4.3, or a simple team decision to rule hazardous events in or out.

Table 6.1: Control Measures Identified for each Hazard with respect to Disinfection

Hazard	Hazardous event, source of Hazard/ cause	Likelihood	Severity	Score	Risk rating (See Table 4.5)	Control measures
Microbial	Inadequate disinfection method	3	4	12	High	• Improve disinfection method • Minimising ingress of contamination to system and long reservoir detention times
Chemical	Formation of disinfection by-products at levels that exceed guideline levels	3	3	9	Medium	• Reducing water age through tanks downstream where possible in periods of low water demand
Microbial	Less effective disinfection due to elevated turbidity	4	4	16	Very high	• Improve clarification and filtration processes • Quantify effect of increased turbidity on disinfection effectiveness
Microbial	Major malfunction/ failure of disinfection plant (no dosing)	2	5	10	High	• Chlorination plants refitted for equipment and process reliability
Microbial	Reliability of disinfection plant less than target level	3	4	12	High	• Defined band widths for chlorine dosing
Microbial	Low chlorine residual in distribution	4	4	16	Very high	• Set point designed to achieve microbial standards at consumer
Microbial	Power failure to disinfection plant	2	5	10	High	• Dual power source
Physical, chemical, microbial	Contamination of dosing chemicals or wrong chemical supplied and dosed.	2	4	8	Medium	• On-line monitoring controls • Lab certificate from supplier

Note: Risk rated at high and very high are considered significant

Table 6.2 : Control Measures Identified for each Hazard in distribution network for Adikmet

S. No.	Hazard event/Source/Cause	Likelihood Score	Severity Score	Risk Score	Risk Classification	Control Measures
1	Contamination due to crossing of water supply line with sewer	3	3	9	Moderate	Provide Good Design. Control sewer and mains leakage
2	Back-siphoning of contaminated water	3	3	9	Moderate	Ensure backflow Preventers are in place
3	Sewer connected to storm water drains	4	2	8	Moderate	Protect storm water drain connection from sewer line
4	Dumping of Solid Waste into open drains	4	2	8	Moderate	Educate people for solid waste disposal practices
5	Contamination introduced during repairs	4	3	12	Moderate	Provide Hygienic Codes for work on distribution mains
6	Tampering due to unrestricted access & illegal connection to treated water pipes	4	3	12	Moderate	Control Illegal Connections

6.5

Table 6.3 : Control Measures Identified for each Hazard in distribution network for Moinbagh

S. No.	Hazard event/Source/Cause	Likelihood Score	Severity Score	Risk Score	Risk Classification	Control Measures
1	Residential Settlement without sewage treatment & disposal system	5	3	15	High	Provide infrastructure to prevent waste from reaching open drains /canals
2	Open drains (unlined) carrying sewage & sullage	5	4	20	Very High	Provide lining to the drain
3	Contamination due to crossing of water supply line with sewer	4	2	8	Moderate	Provide Good Design. Control sewer and mains leakage
4	Dumping of Solid Waste into open drains	4	2	8	Moderate	Educate people for solid waste disposal practices
5	Contamination introduced during repairs	4	3	12	Moderate	Provide Hygienic Codes for work on distribution mains
6	Tampering due to unrestricted access & illegal connection to treated water pipes	4	3	12	Moderate	Control illegal Connections

Table 6.4 : Control Measures Identified for each Hazard in distribution network for Serilingampally

S. No.	Hazard event/Source/Cause	Likelihood Score	Severity Score	Risk Score	Risk Classification	Control Measures
1	Contamination due to crossing of water supply line with sewer	3	3	9	Moderate	Provide Good Design. Control sewer and mains leakage
2	Residential Settlement without sewage treatment & disposal system	5	3	15	High	Provide infrastructure to prevent waste from reaching open drains /canals
3	Sewer connected to storm water drains	4	2	8	Moderate	Protect storm water drain connection from sewer line
4	Open drains (lined) carrying sewage & sullage	5	4	20	Very High	Provide collection and treatment system
5	Contamination introduced during repairs	4	3	12	Moderate	Provide Hygienic Codes for work on distribution mains
6	Tampering due to unrestricted access & illegal connection to treated water pipes	4	3	12	Moderate	Control Illegal Connections

6.7

7.0 Introduction

Implementation of improvement/upgrade plans should be monitored to confirm improvements have been made and are effective and that the WSP has been updated accordingly.

Operational monitoring includes defining or validating monitoring of the control measures and establishing procedures to demonstrate that the controls continue to work. These actions should be documented in the management procedures. Defining the monitoring of the control measures requires inclusion of the corrective actions necessary when operations targets are not met.

The number and type of control measure will vary for each system and will be determined by the type and frequency of hazards and hazardous events associated with the system. Monitoring of control points is essential for supporting risk management by demonstrating that the control measure is effective and that if a deviation is detected, that actions can be taken in a timely manner to prevent water quality targets from being compromised.

7.1 Operational Monitoring Parameters

Measurable: *E. coli,* Residual Chlorine, pH and Turbidity.

Routine monitoring is usually based on simple observations and tests, such as turbidity, rather than complex microbial or chemical tests. For some control measures, it may be necessary to define 'critical limits' outside of which confidence in water safety would diminish. Deviations from these critical limits usually require urgent action and may involve immediate notification of the local health authority and/or the application of a contingency plan for an alternative supply of water. Monitoring and corrective actions form the control loop to ensure that unsafe drinking-water is not consumed. Corrective actions should be specific and predetermined where possible to enable their rapid implementation. Monitoring data provide important feedback on how the water supply system is working and should be frequently assessed.

Regularly assessed monitoring records are a necessary element of the WSP as they can be reviewed, through external and internal audit, to identify whether the controls are adequate and also, to demonstrate adherence of the water system to the water quality targets.

7.2 Operational Monitoring Parameters to Monitor Control Measures

Often verification monitoring will be the compliance monitoring required by regulatory or government bodies in which case parameters and monitoring frequencies will be specified as part of compliance. The operational monitoring parameters to monitor control measures are presented in **Table 7.1.**

7.3 Identification of corrective measures

A corrective measure should be identified for each control measure that will prevent contaminated water being supplied if monitoring shows that the critical limit has been exceeded. Such events may be non-compliance with operational monitoring criteria, inadequate performance of a sewage treatment plant discharging to source water, extreme rainfall in a catchment.

Table 7.1: Operational Monitoring Parameters to Monitor Control Measures

Operational parameter	Raw water	Stilling Chamber	Coagu-lation	Sedime-ntation	Filtration	Disin-fection	Distribution system
pH	✓	✓	✓	✓	-	✓	✓
Turbidity	✓	-	✓	✓	✓	✓	✓
Dissolved oxygen	✓	-	-	-	-	-	-
Plant inflow	✓	-	-	-	-	-	-
Conductivity (TDS)	✓	-	-	-	-	-	-
Algae, algal toxins and metabolites	✓	-	-	-	-	-	-
Chemical dosage	-	✓	✓	-	-	✓	-
Flow rate	-	-	✓	-	-	✓	-
Headloss	-	-	-	-	✓	-	-
Disinfectant residual	-	✓	-	-	-	✓	✓
Hydraulic pressure	-	-	-	-	-	-	✓

8.0 Introduction

Having a formal process for verification and auditing of the WSP ensures that it is working properly. Verification involves three activities which are undertaken together to provide evidence that the WSP is working effectively. These are:

- Compliance monitoring
- Internal and external auditing of operational activities
- Consumer satisfaction

Verification should provide the evidence that the overall system design and operation is capable of consistently delivering water of the specified quality to meet the health-based targets. If not, improvement plan be revised and implemented.

8.1 Compliance Monitoring

All the control measures should have a clearly defined monitoring regime validating effectiveness and monitoring performance against set limits. The water supply organization expects to find results from verification monitoring that are consistent with the water quality targets. Corrective action plans need to be developed to respond, and understand the reasons for, any unexpected results. Monitoring frequencies will depend on the level of confidence required by the water supply organization and its regulatory authorities. The monitoring regime includes a review at intervals and at times of planned or unplanned changes in the supply system.

8.2 Internal and External Auditing of Operational Activities

Rigorous audits help to maintain the practical implementation of a WSP, ensuring that water quality and risks are controlled. Audits may involve internal and external review, regulatory and independent external auditors. Auditing can have both an assessment and a compliance checking role. The frequency of audits for verification will depend on the level of confidence required by the water supply organization and its regulatory authorities. Audits should be undertaken regularly.

8.3 Consumer Satisfaction

Verification includes checking that consumers are satisfied with the water supplied. If they are not, there is a risk that they will use less safe alternatives.

8.4 Parameters for Routine Verification Monitoring Programmes

For microbial water quality verification, indicator organisms are generally monitored. The most widely used verification system is to use the faecal indicator bacteria *E. coli* at representative points in the water distribution system. Chemicals are monitored directly for verification. Most chemical hazards are unlikely to occur at acutely hazardous concentrations and verification frequencies might be less frequent than for microorganisms.

8.5 Operational monitoring and Verification Plan

Unit process	**Operational Monitoring**		**Verification Monitoring**	
	What	**When**	**What**	**When**
Treatment works	On-line measurement --pH --Chlorine Turbidity Dosing records	Daily Daily Monthly	E. coli Faecal streptococci Record audit	Weekly Weekly Monthly
Distribution system	pH Turbidity Cl_2	Weekly Weekly Weekly	E. coli Turbidity Faecal streptococci	Monthly Monthly Monthly

8.6 Prepare management procedures

Actions to be undertaken in normal operation of the system (Standard Operating Procedures; SOPs) and corrective actions where necessary, according to the WSP need to be presented in the form of accessible management procedures. The procedures should be written by experienced staff and should be updated as necessary, particularly in light of implementation of the improvement plan and reviews of incidents, emergencies. It is preferable to interview staff and ensure their activities are captured in the documentation. This also helps to foster ownership and eventual implementation of the procedures.

8.7 Planned periodic review

The WSP must be regularly reviewed through analysis of the data collected as part of the monitoring process but periodically, the WSP team should meet and review the plan and learn from experiences and new procedures. The review process is essential in the overall implementation and provides the basis from which future assessments can be made. Following an emergency/incident/near miss risk should be reassessed and may need to be fed into the improvement plan.

Any change made to the WSP as a result of a review should be documented.

9.0 References

1. Howard G (2002). Urban water supply surveillance — a reference manual. Water, Engineering and Development Centre/Department for International Development, Loughborough University, UK.

2. WHO (World Health Organization) (2004). Guidelines for Drinking-Water Quality. Third Edition.

3. Sam Godfrey and Guy Howard, (2004): Water Safety Plans (WSP) for urban piped water supplies in developing countries, WEDC, Loughborough University, UK

4. Davison, A, Howard, G, Stevens, M, Callan, P, Fewtrell, L, Deere, D and Bartram, J (2005) Water Safety Plans: Managing drinking-water quality from catchment to consumer. Geneva: World Health Organisation. WHO/SDE/WSH/05.06

5. Godfrey S. and Howard G., 2005, Water Safety Plans – Planning water safety management for urban piped water supplies in developing countries (Book 1), WEDC, Loughborough University, UK

6. Godfrey S. and Howard G., 2005, Water Safety Plans – Supporting water safety management for urban piped water supplies in developing countries (Book 2), WEDC, Loughborough University, UK

7. WHO Water Safety Plan portal – includes case studies, tools and other information on developing water safety plans: http://www.who.int/wsportal/en/

8. Davison, A , Deere ,D ,Stevens, M, Howard, G and Bartram, J (2006) Water safety Plan Manual

9. Water Safety Plan: Spanish Town Water Supply. ST. Catherine, Jamaica (2007) Environmental & Engineering Managers Ltd. Kingston

10. Water Safety Plan Manual (Draft) Special pre-publication release for the Lisbon, Portugal May 12-14, 2008, Conference: Water Safety Plans: Global Experiences And Future Trends. WHO and IWA

11. Bartram J, Corrales L, Davison A, Deere D, Drury D, Gordon B, Howard G, Rinehold A, Stevens M. Water Safety Plan Manual: Step-by-Step Risk management for drinking water suppliers. WHO, Geneva, 2009.

12. Vairavamoorthy, K., Gorantiwar, S.D., Mohamed-Mansoor, M.A. and Mohan, S. (2006). Water safety Plan Book 3, “Risk Assessment of Contaminant Intrusion into Water Distribution Systems”, Water, Engineering and Development Centre, Loughborough University, Leicestershire, LE11 3TU, UK.

13. C.K.George, NS Reddy, Dhanraj, K Saritha. Assessing acute gastroenteritis risks associated with water quality and sanitation in Hyderabad city. The institute of health systems, Hyderabad (October 2007).

14. Dr.Shailaja, Water safety plan in the role of department of health, Govt. of Andhra Pradesh 2008

Table 1: Type of pollution source and its properties		
Properties of pollution source	**Unit**	**Value**
Underground sewer pipe		
Network map	*Shape file*	
For each pipe		
Length	*m*	
Bury depth	*m*	
Material		
Leakage rate	*cm/hr*	
Diameter	*cm*	
Lined open ditch/drain		
Network map	*Shape file*	
For each ditch/drain		
Length	*m*	
Material		
Leakage rate	*cm/hr*	
Depth	*cm*	
Unlined open ditch/drain		
Network map	*Shape file*	
For each ditch/drain		
Length	*m*	
Soil type		
Seepage rate	*cm/hr*	
Depth	*cm*	
Open surface foul water bodies		
Foul water body map	*Shape file*	
For each foul water body		
Area	m^2	
Soil type		
Seepage rate	*cm/hr*	
Depth	*cm*	

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Table 2: Soil properties		
Soil map (shape file) and for each soil type:		
Soil property	**Unit**	**Value**
Saturated volumetric water content	cm^3/cm^3	
Initial volumetric water content	cm^3/cm^3	
Saturated hydraulic conductivity	*cm/hr*	
Soil characteristic curve coefficient	-	
Soil porosity	cm^3/cm^3	
Air entry head	*cm*	
Pore size index	-	
Bulk density	*g/cc*	
Fraction organic content	*cc/g*	

Table 3: Contaminant properties		
Contaminant property	**Unit**	**Value**
Liquid phase decay	*/hour*	
Diffusion coefficient	cm^2/day	
Organic carbon partition coefficient of the pollutant		

Table 4: Properties of pipes of water distribution network		
Parameter	**Unit**	**Value**
Network map	*Shape file*	
For each pipe of network		
Length	*m*	
Bury depth	*m*	

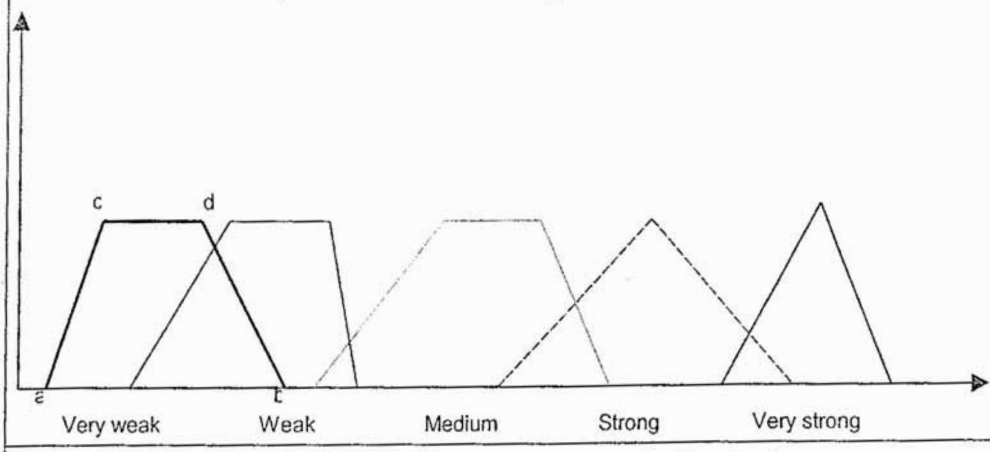
Table 5: Properties of water distribution network		
Parameter	**Unit**	**Value**
Network map ***For each pipe of network***	*Shape file*	
Length of pipe	*m*	
Joint method	Linguistic *(rubber, leadite...)*	
Material type	Linguistic *(CI,DI,RCC,PVC...)*	
Traffic load	Linguistic *(busy, medium, quiet...)*	
Surface type	Linguistic *(hard, grassed, water body...)*	
Internal protection	Linguistic *(good, medium, bad...)*	
External protection	Linguistic *(good, medium, bad...)*	
Bedding condition	Linguistic *(good, medium, bad...)*	
Workmanship	Linguistic *(good, medium, bad...)*	
Diameter of pipe	*mm*	
Installation year	*(year)*	
Bury depth of start node	*m*	
Bury depth of start node	*m*	
No. of connections	-	
No. of breaks per year	-	
Leakage rate	*lps*	
No. of valves	-	
Duration of water supply per day	*hrs*	
No. of times water supplied per day	-	

Table 6: Properties of different pipe materials

Property	**Unit**	**Value**	
*Pipe material:*________			
Corrosion index	Linguistic *(good, medium, bad .)*		
Maximum pressure	*kg/cm*^{2}		
Maximum load	*m-kg/m*		
Design life	*Years*		
Maximum diameter	*mm*		
Maximum diameter	*mm*		
		Age, years	Value
		0-10	
		11-20	
		21-30	
		31-40	
		41-50	
		51-60	
		61-70	
		71-80	
		81-90	
		91-100	

Table 7: Membership functions

Sample of membership functions



Corrosive Index (normalized values)

	a	b	c	d
Very weak				
Weak				
Medium				
Strong				
Very strong				

Internal Protection (normalized values)

	a	b	c	d
Very bad				
Bad				
Medium				
Good				
Very good				

External Protection (normalized values)

	a	b	c	d
Very bad				
Bad				
Medium				
Good				

Very good				

Soil Corrosivity (ohm-m)				
	a	b	c	d
Non-corrosive				
Mildly corrosive				
Corrosive				
Highly corrosive				
Extremely corrosive				
Surface Permeability (normalized values)				
	a	b	c	d
Very hard				
Hard				
Grassed				
Open land				
Water body				
Ground Fluctuations (normalized values)				
	a	b	c	d
Very bad				
Bad				
Medium				
Good				
Very good				
Joint Method (normalized values)				
	a	b	c	d
Very bad				
Bad				
Medium				
Good				
Very good				

Bedding condition (normalized values)				
	a	b	c	d
Very bad				
Bad				
Medium				
Good				
Very good				
Workmanship (normalized values)				
	a	b	c	d
Very bad				
Bad				
Medium				
Good				
Very good				
Traffic density (Vehicles/hr)				
	a	b	c	d
Very busy				
Busy				
Medium				
Quiet				
Very quiet				
Maximum pressure (m)				
	a	b	c	d
Very high				
High				
Medium				
Low				
Very low				

Table 8: Soil data		
Soil type:________		
Property	**Unit**	**Value**
Soil corrosivity	*m*	

Table 9: Groundwater table		
Groundwater zone:________		
Property	**Unit**	**Value**
Average groundwater table depth	*m*	
Average groundwater fluctuation	*m*	

Table 10: Pressure		
Pressure zone:________		
Property	**Unit**	**Value**
Pressure	kg/cm^2	

Table 11: Balance factors for different groups of indicators	
Group	**Balance Factor**
Pipe	
Installation	
Corrosion	
Load/strength	
Intermittency	
Failure	
Physical	
Environmental	
Operational	
Pipe condition assessment	

Table 12: Weights for different indicators

Indicator	Weight	Indicator	Weight	Indicator	Weight
Level 3 indicators		*Level 2 Indicators*		*Level 1 Indicators*	
Physical		***Group 1***		***Group 1***	
Environmental		Pipe		Material decay	
Operational		Installation		Diameter	
		Group 2		Length	
		Corrosion		Int. protection	
		Load/strength		Ext. protection	
		Group 3		***Group 2***	
		Intermittency		Bedding condition	
		Failure		Workmanship	
				Joint method	
				No. of joints	
				Group 3	
				Year of install.	
				Soil corrosivity	
				Surface permeability	
				GW condition	
				Group 4	
				Buried depth	
				Traffic load	
				Hydraulic pressure	
				Group 5	
				No. of valves	
				No. of water supply/day	
				Duration of water supply/day	
				Group 6	
				Breakage history	

Table 13: Pipe Condition Assessment Indicators	
Level 1 Indicators	**Description**
Material decay	Hazen-William coefficient of friction (C) is considered to characterize this influence
Diameter	Larger diameter pipes are less prone to failure than smaller diameter pipes
Length	Larger length pipes are more prone to failure than smaller length pipes
Int. protection	The pipes having internal protection by lining and/or coating are less susceptible to corrosion
Ext. protection	The pipes having external protection by lining and/or coating are les susceptible to corrosion
Bedding condition	Improper bedding may result in premature pipe failure
Workmanship	Poor workmanship may deteriorate the pipes and cause more risk regardless of pipe age and other factors
Joint method	Some types of joints experience premature failure (e.g. leadite joints)
No. of joints	The more joints a pipe has, the greater the risk of the pipe getting structurally worse
Year of installation	The effects of pipe degradation become more apparent over time
Soil corrosivity	Pipe deteriorates quicker in more corrosive soil and the degree of deterioration depends on the pipe material
Surface permeability	The more permeable surface allows more moisture to percolate to the pipe. Surface salts will be carried to the pipe with the moisture
GW condition	The water pipes are deteriorated by the groundwater table
Buried depth	Pipes buried at a greater depths have more possibility of failure that those buried at shallower depths
Traffic load	Pipe failure rate increases with traffic loads on the surface
Maximum pressure	Changes to internal water pressure will change stresses acting on the pipe
No. of valves	The greater the number of valves, the greater the deterioration of the pipe
No. of water supply/day	The greater the number of water supplies the more the pipes will deteriorate
Duration of water supply/day	The longer the duration of water supply, the smaller the chances for pipe failure
Breakage history	The number of pipe breakage per year

Table 14: Composite structure of different pipe condition assessment indicators

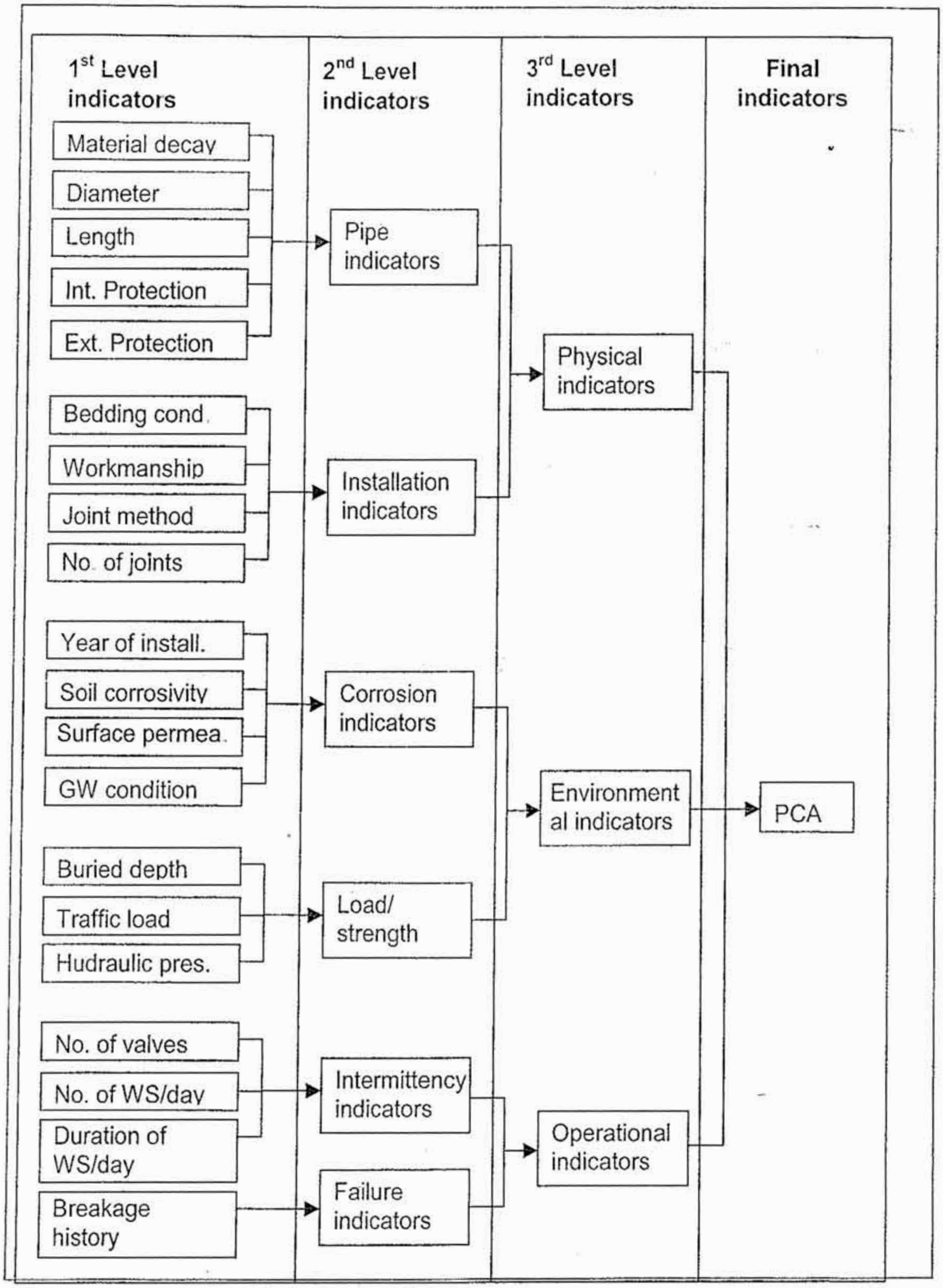


Table 15: Indicators that are influenced by the pipe material and the corresponding measure	
Indicator	**Measure**
Soil corrosivity	Pipe material corrosion resistance
Surface permeability	Pipe material corrosion resistance
GW condition	Pipe material corrosion resistance
Buried depth	Impact load
Traffic load	Impact load
Hydraulic pressure	Maximum pressure

Table 16: Typical values of pipe material corrosion resistance, impact strength and maximum pressure				
Pipe material	**Pipe material corrosion resistance**		**Impact Strength** *m-kg/m*	**Maximum pressure** *kg/cm^2*
	Internal	**External**		
DI	Highly corrodible	Corrodible	102 5	31 62-78 54
PVC	Non-corrodible	Non-corrodible	4 40	8 16-15 3
HDPE	Non-corrodible	Non-corrodible	20 5	10-20
AC	Mildly corrodible	Corrodible	23 5	5 1-35 7
PE	Non-corrodible	Corrodible	58 5	15-25
PC/RCC	Mildly corrodible	Corrodible	30	20 4-30
Steel/GI	Corrodible	Corrodible	150	14 28-97 92
CI	Highly corrodible	Extremely Corrodible	150	14 28-97 92

Table 17: Different criteria used for the normalization of the indicators	
Indicator	**Criterion**
Material decay	A
Diameter	A
Length	D
Int. protection	C
Ext. protection	C
Bedding condition	C
Workmanship	C
Joint method	C
No. of joints	D
Yea of installation	A
Soil corrosivity	B
Surface permeability	C
GW condition	C
Buried depth	D
Traffic load	B
Maximum pressure	B
No. of valves	D
No. of water supply/day	D
Duration of water supply/day	D
Breakage history	D

Table 18: Different criteria used for the normalization of the pipe material attributes/measures	
Measures	**Criterion**
Pipe material corrosion resistance	C
Impact load	B
Maximum pressure	B

Table 19: Weights for different indicators	
Indicator	**Weight**
Hazard agent (contaminant load)	
Vulnerability of water pipe (pipe condition)	