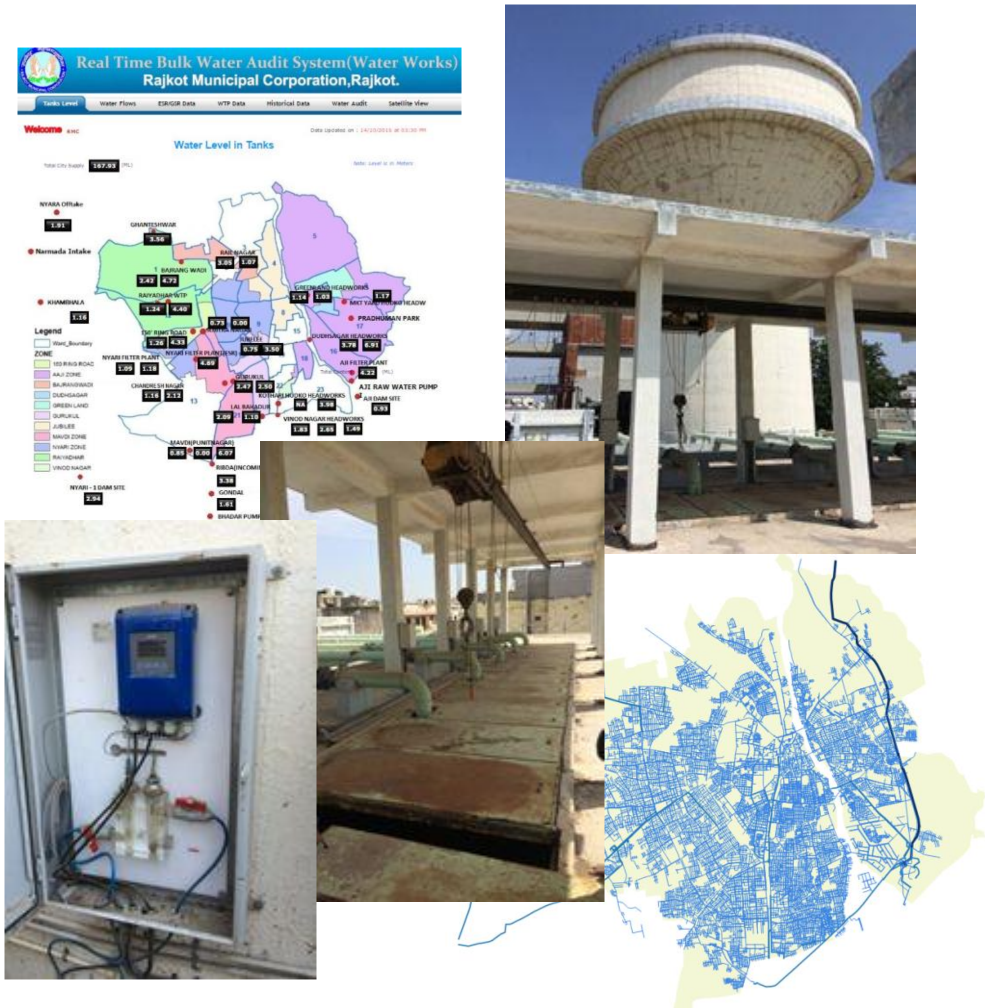
Integrated Resource Management in Asian Cities: *The Urban Nexus*



Water Demand Management in Rajkot – Gujarat, India

MISSION REPORT

October 2016

Contents

Glossary

DMA	District Metering Area
GIS	Geographic Information System
HR	Human resources
IBNET	International Benchmarking Network for Water and Sanitation Utilities
IWA	International Water Association
IT	Information Technology
lcd	litres per capita per day
MNF	Minimum Night Flow
MLD	Mega litres per day = 1,000 m³/day or 1 Million litres/day
NRW	Non-Revenue-Water
RMC	Rajkot Municipal Corporation
RW	Revenue Water
SCADA	Supervisory Control and Data Acquisition
SI	System Input
SFD	Excreta Flow Diagram
SSP	Sardar Sarovar Project
WB	Water Balance
WD	Water Department
WTP	Water Treatment Plant

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0 EXECUTIVE SUMMARY

This report summarizes the findings of a 14 day mission conducted to Rajkot Municipality, in Gujarat State in the Northwest of India in September/October 2016. The objective of the mission was to assess the options of water demand management, and, to a lesser extent, assess waste water management. The results were presented to the Commissioner of Rajkot and the Chief Engineers on 30th September 2016.

Gujarat is one of the most water scarce regions in India, with nearly 80% of its geographical area having a renewable water resource endowment of less than 1,0 ML (or 1.000 m3) per capita per year. Water use in three out of the four regions, namely north Gujarat, Saurashtra with the city of Rajkot and Kachchh, is considered unsustainable.

The Analysing the water sources of RMC reveals that local water resources provide approximately one third of the current urban demand (refer to Figure 9 on page 17). Most of the water comes from the Narmada river system hundreds of kilometres away through the Sardar Sarovar Project (SSP). Every litre of water is charged with estimated 6 Watt of energy to make it to Rajkot. Too much to be wasted!

Tackling Non-Revenue-Water and physical network losses is therefore highly relevant for sustainable resources management.

The recommendations of the mission address primarily improved water demand management in Rajkot in the fields of water supply and wastewater treatment. Specifically the following measures are proposed:

- The new SCADA is primarily used for Data Acquisition. Data however is recommended to be processed into performance indicators. This allows the comparison of the different supply systems and the identification of efficiency gains (refer to chapter 5.1 on page 31 for more details).
- The on-going project in Chandresh-Nagar-Zone reveals the challenges of "transiting" from intermittent supply to continuous supply. In order to facilitate Scaling-Up into other parts of Rajkot it is recommended to dedicate all needed support to this important exercise. Not only is a major technical effort undertaken, but also significant social efforts are needed to support customers accepting water meters as the most efficient means of water demand management in the world (more details are found in chapter 5.2 on page 32).
- It is recommended also to introduce the Water Balances as a tool to describe each supply system under RMC and to identify areas with high Non-Revenue-Water. A water balance was developed with the ward engineers towards the end of the mission while adopting the information provided by them (Chapter 3.1 introduces the tool and chapter 5.3 on page 34 explains the necessary requirements to use this tool efficiently).
- In order to manage customers and assets professionally a modern data platform is essential. Rather than having a small ineffective GIS group in each department it is recommendable to join forces and set-up a professional, multi-sectorial GIS task force (Chapter 5.4 explains more on page 37).
- The reuse of treated Wastewater Effluent is a valuable source of water. A reliable and efficient wastewater treatment will allow the reuse of 170 MLD which will alleviate the hydrological water balance of Rajkot significantly. Precautions are imperative and require vigilance to avoid any undesired exposure of farmers and users to germs and contaminants (refer to chapter 5.2 on page 38 for more details).

1 INTRODUCTION

1.1 Background

Rajkot Municipality is located in the centre of the Saurashtra region at a distance of 210 km from Ghandinagar, the capital of Gujarat and 950 from Delhi, the national capital. With appr. 1.5 million inhabitants the city is the 4th-largest in Gujarat and ranks 35 in India. The topography is marked by a generally flat relief and two rivers, Aji and Nyeri, which drain Monsoon water in the months June to September.

The city is governed by an elected mayor and administered by a commissioner nominated by the state government. The commissioner heads the Rajkot Municipal Corporation (RMC), which provides, among others, water and sanitation services to the residents.

The urban area was recently extended into southern direction to cover 170 km² which are divided into 18 administrative areas (wards). These are combined into three larger zones as shown in **Figure 1**.

Figure 1: Rajkot Administrative Map displaying the new ward numbering

Rajkot ranks 147 among the fastest growing cities in the world. The rapid growth exposes the water supply in a generally semi arid environment to particular challenges. All discussion partners within RMC were very much aware of this challenge.

1.2 Water Supply in the Saurashtra Region

Considering current water demand the Saurashtra Region must be described as water scarce. Historically the nearby shallow surface water bodies have secured water to the city. The annual average 630 mm of rain was sufficient to sustain urban areas and agricultural demand.

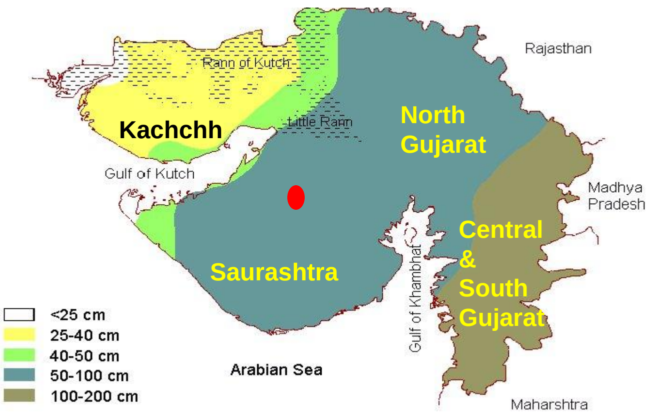

Figure 2: Precipitation in the Saurashtra Region

Today, after the population of Rajkot has doubled in the past two decades, surface water is no longer a reliable option for the water supply of Rajkot. Also groundwater as a sustainable water source can be ruled out due to the required effort of pumping from great depth and advanced treatment. Critical constituents, such as Fluoride and Nitrate in higher concentrations hamper the use of groundwater for urban water supply.

Among the 185 rivers in Gujarat state there are only 8 perennial rivers which carry water all year through. All of them are located in the south of the state at a considerable distance.

In response to the dire water resources situation a major national effort was undertaken to secure water for the Saurashtra Region and beyond. The Sardar Sarovar Project (SSP) is channelling Narmada water through the Narmada Channel, the largest of its kind in the world into Gujarat and Rajasthan. A system of open channels and transmission pipes is taking the water into Saurashtra as shown in **Figure 3** below[1].

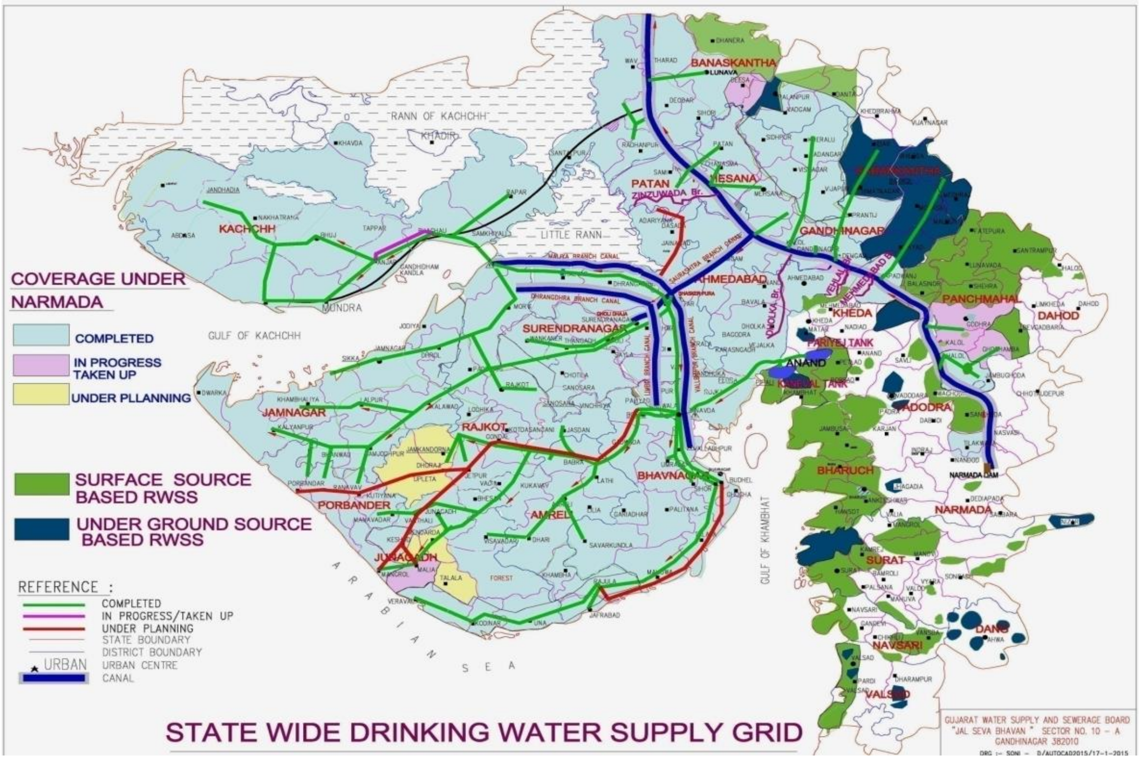

Figure 3: Sardar Sarovar / Narmada Supply Scheme

2 WATER MANAGEMENT IN RAJKOT

2.1 Service Levels

The residents of Rajkot had seen serious water supply problems in previous years. Inequity in water distribution has lead to unrest and a strong dependency on water tankers with their poor water quality and high cost.

The 20 min supply scheme was introduced as of 1st October 2013 and required dissecting the distribution network into small areas which are opened following a specific scheme, thus ensuring that all households receive a fair share of water. Since water metering is not done on

[1] Narmada, Water Resources, Water Supply and Kalpsar Department (Water Resources Division), 2015

household level an average daily volume of 500 litres per household is adopted. Depending on the hydraulic features of the network and the specific location of each household and its storing capacity a wider range of water must be actually assumed.

Table 1: Number of service connections in September 2016 by type (source: RMC IT Dept. 9/16)

Type	non-metered	metered
Residential	276.108	779
Non-Residential	7.049	130
Schools	-	16
Total:	**283.157**	**925**

In total some 284.082 water subscribers are registered at RMC. Domestic customers account for 97.5% of the subscribers. A small number of 0.2% of the subscribers is being metered. The tariff however is in either case a flat lump sum tariff. Details are presented in Annex 2.

Table 2: Number of service connections by diameter and share of revenue in fiscal year 2015/16 (source: RMC IT Dept. 9/16)

diameter (inch)	number	number of meters (%)	revenue (%)
3/8"	303	0,1%	0,1%
1/2"	282.139	99,3%	81,5%
3/4"	722	0,3%	0,4%
1"	232	0,1%	2,0%
1 1/4"	2	0,0%	0,0%
1 1/2"	153	0,1%	1,7%
2"	318	0,1%	6,5%
2 1/2"	35	0,0%	0,5%
3"	89	0,0%	2,5%
4"	76	0,0%	2,6%
6"	10	0,0%	1,6%
8"	3	0,0%	0,2%
Total number of subscribers	**284.082**	**100%**	**100%**

The overwhelming majority of subscribers are equipped with ½" inch service connections with an annual fee of 840 Rs/year. A wide spectrum of connections is offered by RMC. Many of the larger diameters serve high rises, residential communities (societies), industries and commercial businesses as well as public institutions.

The regular daily supply pattern constitutes an improvement. Although this may be common practise in all major cities of India it must be stated though that intermittent supply has serious disadvantages. The average daily supply time in the major cities in India is 4.5 hours[2].

2.1.1 Water Quality

Low water quality with some occurrence of microbiological contamination must be assumed because temporarily pressurized networks ex-filtrate fresh water, which flows back contaminated into the pipe once the pressure seizes. Defective and leaking sewer pipes in the underground aggravate the problem. This issue frequently remains unnoticed because the water is stored in the customer's storage facilities.

Chlorine dosing seems to be high, with residual chlorine levels above 1 mg/l indicating that the operators have concerns of germ contamination in the system.

No analysis results are available on tap water quality. The wide spread tendency of households to use some kind of treatment of tap water suggests that a certain level of contamination in the water quality is expected by the consumers. A clean cloth, or to those who can afford it, a Reverse-Osmosis (RO) treatment is used to produce drinking water.

In addition to the different "coping techniques" of households to acquire drinking water they have a significant burden of maintaining in-house facilities for storage and pumping as can be seen in **Figure 4** below.

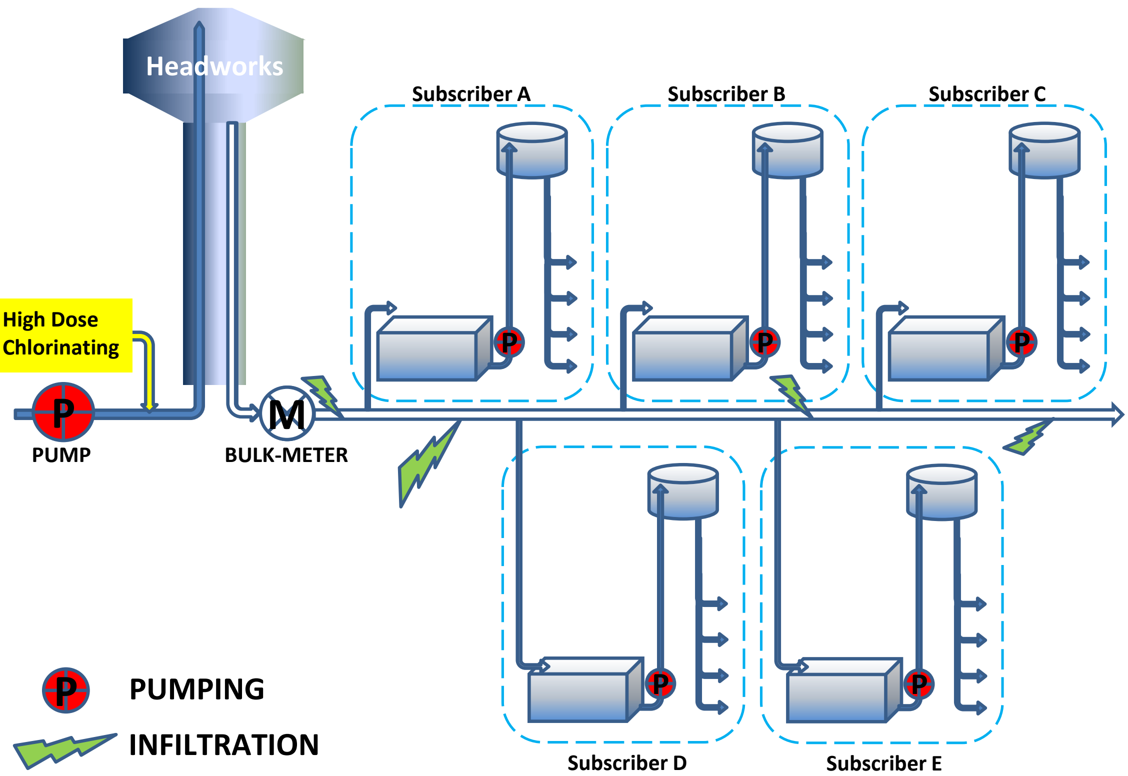

Figure 4: Intermittent Supply and corresponding in-house plumbing

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[2] *Source: Professor Srinivas Chary, Director, centre for Energy, Environment, Urban Governance and Infrastructure Development, Administrative Staff College of India*

The households are required to provide for storage capacities to store the maximum volume of water possible and add to the supply security. This however reduces water quality again; Solids flushed into the storage facility settle. The water that eventually is used in the dwelling is no longer fresh, which leads to spilling this water if found necessary by the dweller. Those who store water in buckets etc. dispose the water once the water service is due.

2.1.2 Increased water demand in intermittently served systems

The intermittent water demand and the inherent sense of unreliability lead the water consumers to store all the water they receive. Investments are made on household level to extend storage capacity. Since there is no incentive to save water a clear tendency is observed to store more water than actually needed during an average day.

In-house plumbing (see **Figure 4**) is a major source of water leakage; e.g. un-tight or overflowing storage facilities or defective floater valves, especially in roof tanks. These water losses have to be added on top of the actual network losses.

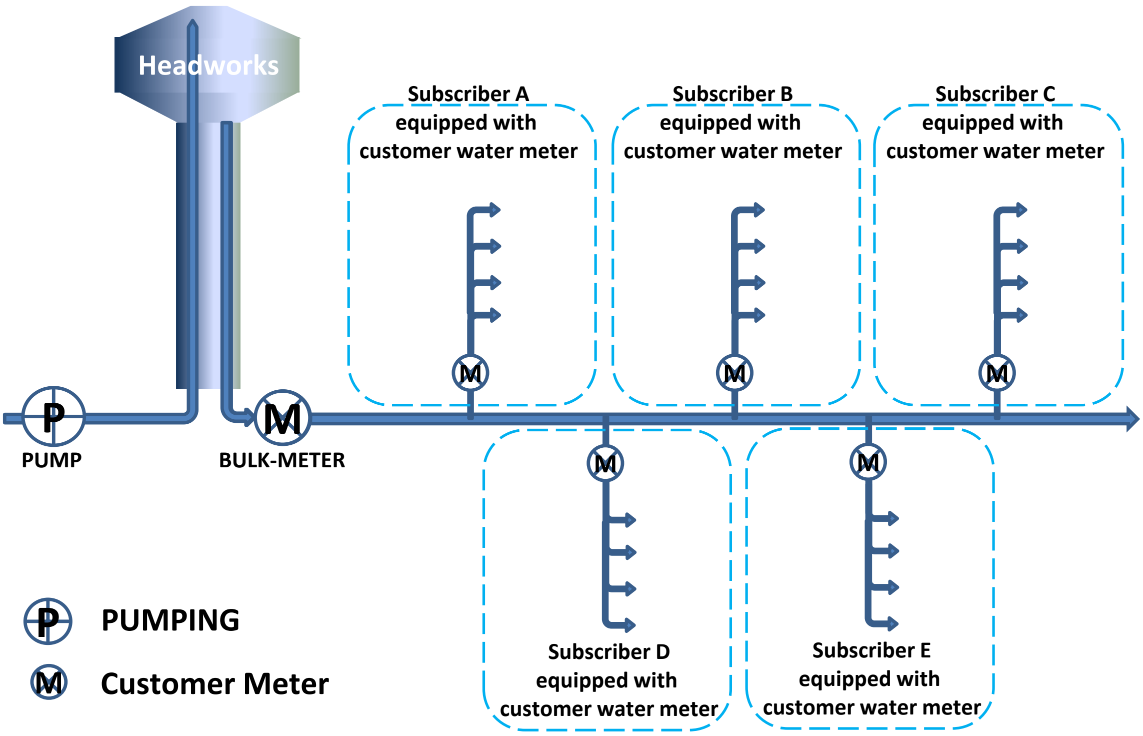

Figure 5: In-house plumbing in a continuously supplied network

Introducing a volumetric tariff along with a water meter will encourage the subscribers to keep their in-house plumbing neatly in order as shown in **Figure 5**. A reliable water supply that comes with appropriate pressure may lead the subscriber to dismantle some of the in-house facilities to use the available network pressure and reduce the energy bill.

2.1.3 Energy demand to secure water

Analysing the O&M cost for 2015/16 provided by RMC reveals that some 28 Crore Rs annually (280 Mio. Rs) or 45% of the O&M cost (Narmada Water import not included) are spent on Energy. The major part is used to transport the water into the headwork facilities and maintain a pressure that allows gravity service.

This pressure however does not benefit the subscribers. Instead, the hydraulic pressure is broken at the storage facilities which are mostly on ground or below ground. The subscriber needs to operate own pumps to lift the water to his premises or the roof storage (see **Figure 4**).

Accordingly, more pumping is needed in Rajkot with the current supply scheme than in a network that is continuously pressurized.

2.1.4 Complaint Management

RMC maintains a complaint management system which is operational on a continuous 24/7 basis. Complaints are addressed on the different levels and escalated within two weeks to the highest administrative levels if not handled to the satisfaction of the citizens. Complaints concern primarily water leakages, water wastage, lacking water, illegal connections and illegal use by private suction pumps.

2.2 Network Documentation

Documenting the assets is common practice in water supply and sewerage management. Usually, large paper documents are used in detailed planning and for asset management. No such maps were seen in use and indication whether or not network maps are saved in archives was not evident.

Both, the water distribution network and the sewerage system in Rajkot are documented on GIS data files. The data however seems to be outdated and shows, more so in the case of the sewerage system, major data gaps:

Data Item	Observation / comment
- Service areas	The documentations do not show any delimitation of Water services provided by the municipality but reach beyond the actual limits of the municipality. Occasionally patches of undocumented areas indicate that network documentation for dense urban areas has not taken place. All 18 head works serve individual supply zones. These are certainly further divided into sub-zones. This information should ideally be contained in the GIS database.
- Roads and Building	Are not included, but are definitively available with RMC (Housing Dept.). This data must be included for orientation and require continuous update. This could be achieved by cooperating with the other concerned departments of the municipality: - The finance department, as they collect the water subscription fee. - The housing and roads departments.
- Transmission Pipes	The documentation contains 423.5 km of pipes with diameters from 175 mm up to 1500 mm diameter. All levels of pipes: Transmission, Primary, Secondary and Tertiary pipes are contained in the same data-set.
- Distribution	1,334 km of distribution pipes with diameters ranging from 15 mm to 160

Pipes	mm are documented. Those pipes, described as distribution and lateral pipes are in fact considered to be distribution pipes. Apart from being outdated it seems that secondary and certainly tertiary networks are not documented which is a data gap that needs some attention (further discussion on that topic later). Assuming that the property of the water utility ends at the subscriber water meter it must be stated that most of the lateral pipes are also missing. This is indeed relevant information for a systematic loss reduction strategy, but also for asset management and asset valuation that will be needed at some point of time. The pipes are not consistently connected with each other and are not connected to valves. This is essential in case the network documentation shall be used for purposes of hydraulic calculation. More details on the GIS later in the following chapter.
- Subscriber Connections	Since subscriber connections are not included in the GIS database also the location of the water meters can not be retrieved from the GIS data. Unless it is part of a *Customer Information Management System* it is considered not necessary to maintain the subscriber connections in the database. The main reason is that customer data changes on a daily basis and requires additional data processing effort with only limited added value to network management. For improved water balancing however, consumption data from the customer department is highly relevant. It is recommended to communicate aggregated consumption by “headwork” zone on a regular basis.
- Valves	Network valves are extremely important for smooth network management. The current demand management of Rajkot is based on daily using the valves. However, no data set with valves was seen to be in use. The documentation is helpful for repair/maintenance purposes. Regularly operating (fully close/fully open) the valves is necessary to make sure the valves remain functional. Valves are indispensable to establish *District Metering Areas* (DMA’s) or to conduct *step-testing* to pinpoint areas within the DMA which are specifically affected by losses.

2.3 Network Features

Knowledge of the network is generally limited. Network data that was available dates back to 2004, accordingly the information presented in the following is indicative only and by no means complete. The correctness of the data could not be verified.

The total length of documented assets is 1,757 kilometres of different diameters. The breakdown is shown in Table 3 below. The database distinguishes 3 categories.

Table 3: Breakdown of documented pipe assets

Diameter (mm)	Distribution	Lateral	Main
<= DN 50	12.201 m	0 m	0 m
>DN50; <=DN100	1.072.951 m	0 m	5.228 m

Diameter (mm)	Distribution	Lateral	Main
>DN100; <=DN150	11.866 m	236.071 m	0 m
>DN150; <=DN200	0 m	793 m	125.488 m
>DN200; <=DN400	0 m	0 m	166.428 m
>DN400; <=DN1000	0 m	0 m	114.615 m
>DN1000	0 m	0 m	11.708 m

The material composition of the network is given in the database. It shows that the predominant material in use is Asbestos Cement (AC) with 85% followed by Mild Steel (MS) with 14%. In recent years AC-pipes were no longer utilised and more appropriate material was employed. The network of Chandresh Nagar Headwork[3] for example has been largely replaced. Ductile Iron (DI) pipes for the larger diameters and Poly-Vinyl-Chloride (PVC) pipes for the service pipes have been utilised.

Table 4: Pipe materials

Pipe Material	Length (km)
Ductile Iron (DI)	2,2
Asbestos Cement (AC)	1.495,9
Mild Steel (MS)	251,7
Reinforced Concrete (RCC)	2,7
(Material unknown)	4,7
Total	**1.757,3**

2.3.1 Analysis

The relevant minimum data that shall be contained in network documentation, possibly passed on a georeferenced GIS system, is the following:

- Diameter (contained in Rajkot data set)
- Length (contained, can be easily retrieved if GIS based)
- Material (contained with occasional blanks)
- Pipe Age (not contained).

The total network length as presented in Table 3 and Table 4 above indicates that the specific length is 6.2 metres of pipe length per subscriber, which is clearly lower than expected[4]*.* Indicators are described as *Network Density (connections/km of pipe length)* commonly ranges for a similar urban arrangement in the order above 15 metres per subscription.

The following remarks have to be made with regard to the level of network documentation.

(i) Above indicator reveals that the network is not completely documented and additional effort has to be made to locate all network assets. This is especially important to make sure those Headwork-Systems or *District Metering Areas (DMAs)* are consistently isolated.

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[3] Chandresh Nagar Zone is generally referred to as Ward No.8 zone. In fact it is located primarily in ward No.8 and contains also parts of wards No.11 and No.13.

[4] The *International Benchmarking Network for Water and Sanitation Utilities (IBNET)* is a good reference for globally used indicators

(ii) Data has to be continuously updated based on feedback from:
   a. the repair teams who collect valuable data from the field that should be used to complement to the documentation efforts and verify existing information.
   b. On-going replacement projects.

(iii) Pipe breaks are recommended to be documented systematically. Nowadays this is made as part of the repair routine: georeferenced data is reported back to the GIS department, which, as data density increases helps identifying pipe sections which are particularly vulnerable. In many instances repair frequency can be related to material and age of the concerned pipes. The prevalence of pipe breaks usually indicates that material condition is critical or pressure condition is unusual.

Eventually the GIS system will support decision makers in the process of prioritising pipe repair measures.

2.4 Water Network Management Practices

The distribution network is managed by three City Engineers which supervise 18 Ward-Engineers. These operate the head-works and the corresponding distribution networks with the support of contractors. The contractors are in charge of network operation and maintenance. More than 100 valve operators (petrolars) make sure the sub-distribution zones receive water for precisely 20 minutes per day.

It is assumed that the daily demand of each subscriber is provided within these 20 minutes. Detailed information is not available because water consumption is neither metered on household level nor on ´sub-zone´ level (please refer to the following section for definitions).

2.4.1 Definitions

In develop a common understanding of the water distribution infrastructure a number of definitions are required as shown in the Figure 6.

2.4.2 Pipe repairs

Pipe repairs are one main activity that is sub-contracted to private sector operators. Pipe repairs take place upon reporting a leakage, usually by subscribers. In fact, leakages are the first reason of subscriber complaints.

Accordingly, only visual leaks are identified and this is no surprise because the water operators have no possibility to proceed systematically with leak detection and repair. The main reasons are:

- Due to the intermittent supply pattern leakage are observed during the 20 minutes supply period only. During this short period of time the network doesn't show a normal hydraulic behaviour: flow velocities are extremely high, which results in large friction losses and pressure drop. Many leaks can remain unnoticed because the leakage water doesn't surface and percolates into the underground instead.
- Exact volumes of distributed water are largely unknown. Despite the bulk meter on the level of the Secondary Distribution network after the headwork reservoirs, the internal distribution on the level of the Tertiary Distribution Network (Sub-Zone) is not known. The main reason is that subscribers are not metered and there consumption is unknown. Also, the actual number of subscribers is not known and therefore no estimate of water volume can be made. A bulk meter at the entrance to every Tertiary Distribution Network would provide this information however.

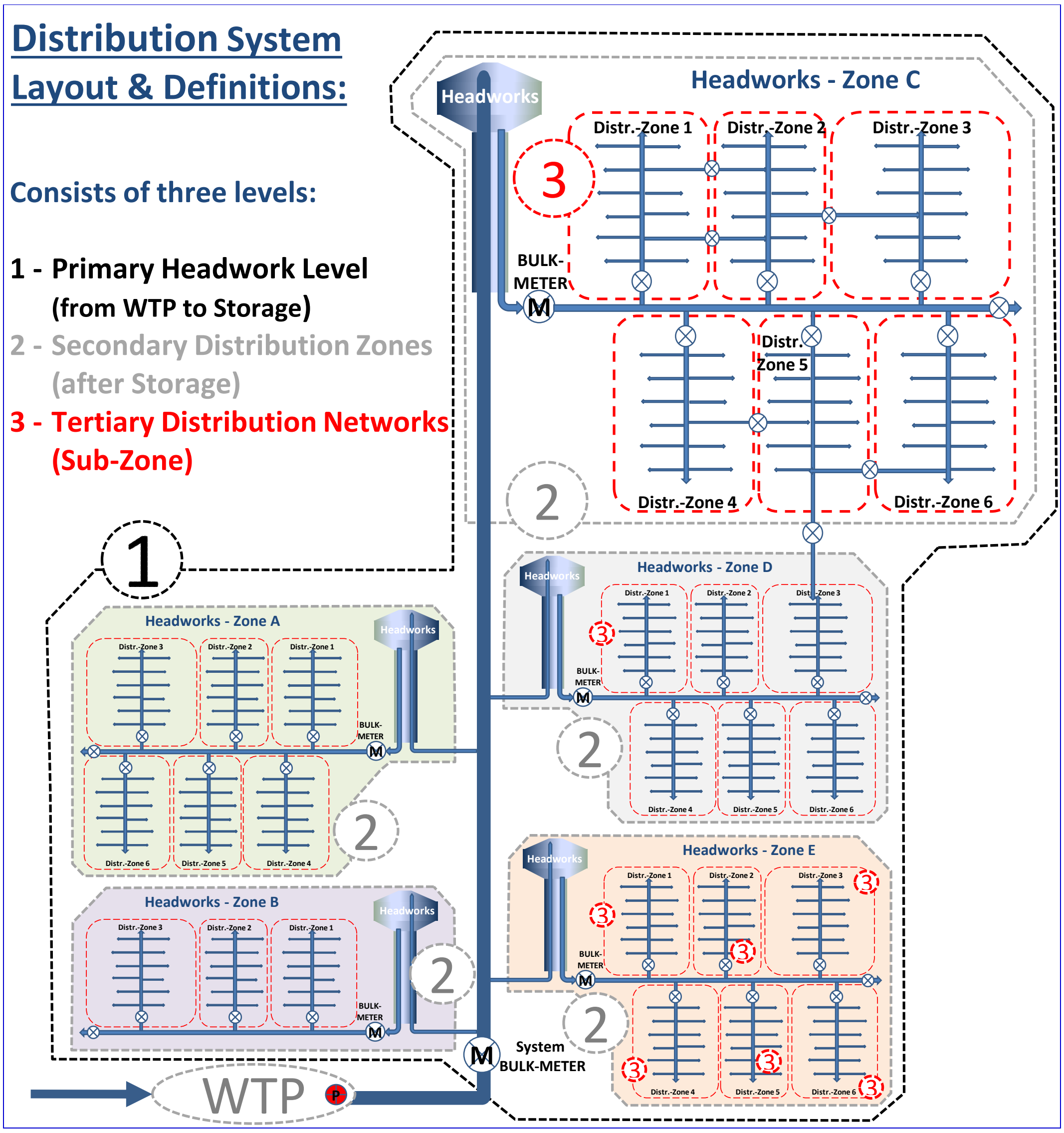


Figure 6: Structure of Distribution Network – Layout & Definitions

WTP	*Water Treatment Plant, generally referred to as filter plant. Water from the different sources is treated here*
M	*Bulk Water Meters at various locations*
⊗	*Valves at various locations*

2.4.3 Subscriber Connections

In October 2016 some 284,082 subscribers have been registered as water consumers. These numbers are available to the IT-section of RMC under the Financial Department. The overwhelming majority of service connections are of 1/2-inch type. This category contributes with more than 80% to the income as shown in Table 2 above. The typically assumed consumption per day is 400 to 500 litres per connection and day. Subscriber connections could be much larger though. A more detailed breakdown of service pipes is included in Annex 1.

Despite the fact that more than 900 water meters of different diameters are installed in the network there is only little experience with water meters as tools in demand management. The main reason is that water meters are not read at all and that there is no volumetric water tariff in place. Annex 1 indicates a tariff for house connections with water meters, but the actual tariff remains a flat (lump-sum) tariff regardless of the volumes consumed. As described earlier in chapter 2.3 there is an on-going replacement project of the Distribution Network in the Chandresh-Nagar Secondary Distribution Zone. The ring-shaped DI-500 mm Secondary Distribution has been successfully replaced. The replacement of the Tertiary Distribution Network is 80% completed.

Tender documents for the installation of 12,000 Multi-jet Class-B water meters with optional automatic meter reading (AMR) functionality are under preparation and shall be installed in Chandresh-Nagar Zone.

Figure 7: Typical Multi-Jet water meter

The transition process from lump-sum (flat) tariff to volumetric consumption based must be regarded as a challenge that requires good preparation of the subscribers and the administration. It must be stated that this decision constitutes the most relevant step towards intelligent water demand management. It clearly shows the way forward towards sustainable urban water management. Please refer also to chapter 3 for more specific recommendations.

2.4.4 Supervisory Control and Data Acquisition (SCADA)

A Supervisory Control and Data Acquisition (SCADA) system consists of two parts; the Data Acquisition part including monitoring and processing in addition to the Supervisory Control part that allows remote steering.

In July 2015 State water resources minister Vijay Rupani launched the Real Time Bulk Water Audit System which in essence is a SCADA system. For the first time in Gujarat State a Municipal Corporation was able to monitor real time inflow and outflow of water and its distribution from various sources and head-works into the city.

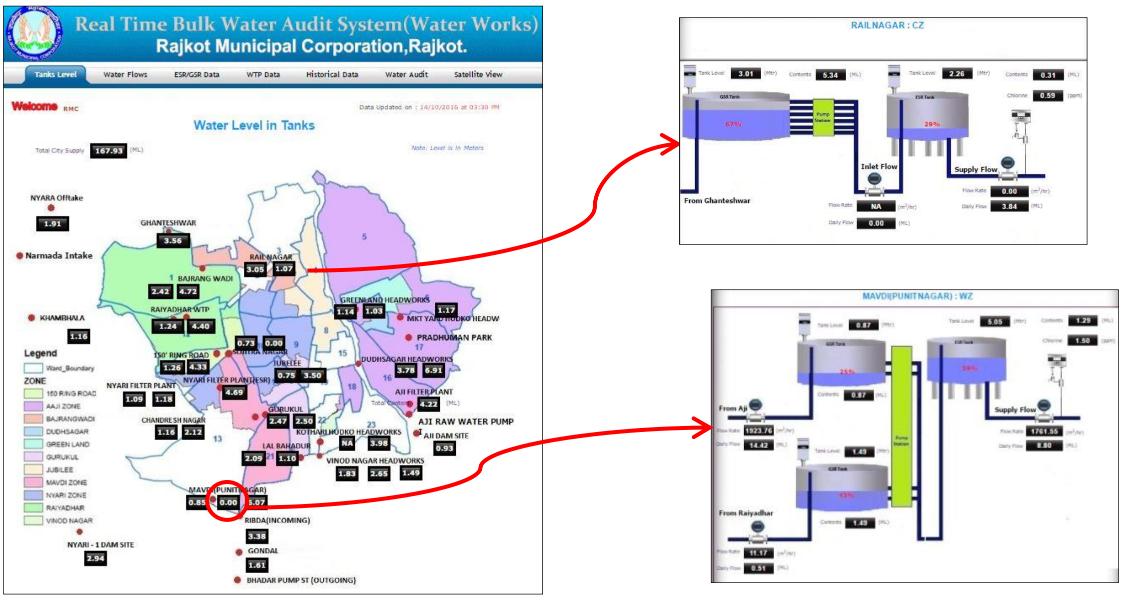


Figure 8: Website of RMC Real Time Bulk Meter Audit System (left), Railnagar (right top) and Mavdi Headwork (right bottom)

RMC is currently generating a solid data base to monitor the performance of the Primary Headwork Level (see Figure 6 above). The data is then deployed for decision making and development of Performance Indicators (PI).

The system provides access to the data from any given point through a desktop computer or a mobile (Android-) application provided the user has access to the internet. Real-time data can be checked or historic data may be aggregated. In terms of water quality the residual chlorine is indicated for each entrance into the secondary distribution network (after headwork-storage).

Table 5: Water Sources

Water Source	Type of source	Distance (km)	Capacity (MLD)
Aji-1 + Narmada at Aji	Dam+Canal	0	110
Lalpari-Randarda	Lake	0	6
Bhadar-1	Dam	65	50
Nyari-1	Dam	18	35 (58)
Nyari-2	Dam	24	7.5
Narmada at Raiyadhar WTP	Canal	6	35
Total			**243.5 (266.5)**

The collected data reveals important information concerning the varying water sources as well as water distribution and water quality on the level of the Primary Distribution Network, the Headwork level.

The cost of water provision is essential for RMC. Rajkot water supply depends in the first months after the monsoon to a certain degree on nearby lakes and dams. This water is considered less expensive because transport distances are shorter, but treatment effort is high. Narmada water complements to the overall production. The share of the Narmada source increases over the course of the year and reaches more than 90% as can be seen from the historic SCADA records provided by RMC (refer to **Figure 9** below).

Another observation is that the water production is relatively constant over the year. Seasonal variation, e.g. with a slight peak in summer and a drop during the monsoon months would be an expected behaviour but does not show in the data. The explanation might be that water is conveyed according to a constant arrangement that has proven to be acceptable by all participants. This, conversely, not necessarily represents the actual demand of the subscribers. It almost certainly deviates from the actual demand of the subscribers because they are not in charge of managing their demand.

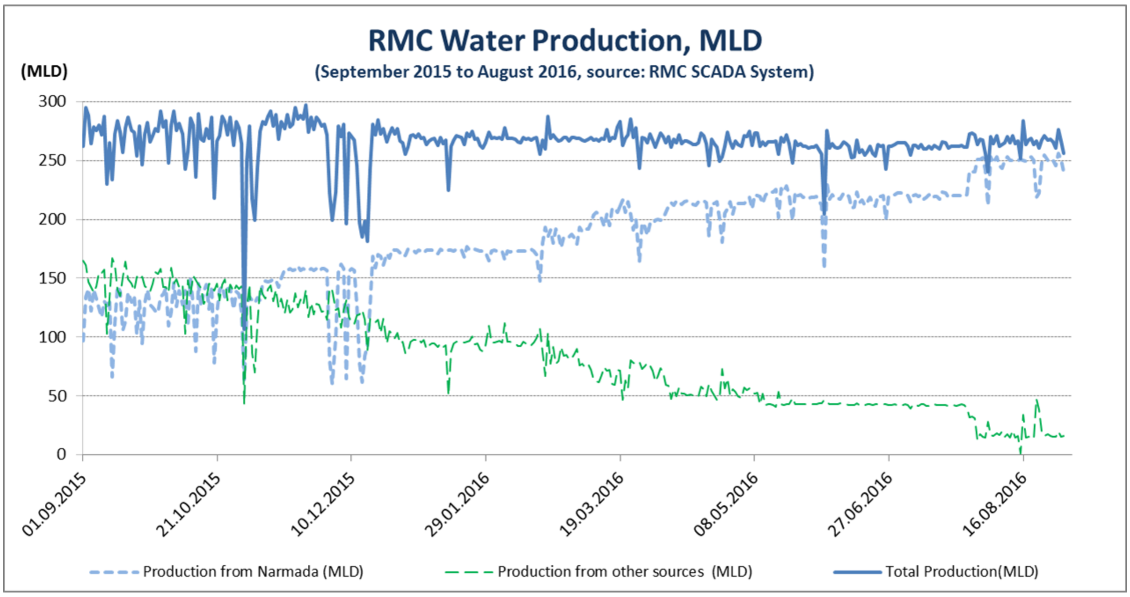


Figure 9: RMC Water Production in MLD (Mega litres per day; 1 MLD = 1,000 m³/d)

The water demand management concept of Rajkot is based on two principles:

- Equity of water availability, i.e. all subscribers receive the same level of services.
- Strict water rationing by providing water for a limited period of time.

Translating these principles into technical measures involve the division of the urban distribution networks through the headwork arrangement into the Secondary Distribution Network and, with countless valves into the Tertiary Distribution Networks (Sub-zones) mentioned earlier.

Here, the SCADA also proves to be extremely important to better understand the operations on the level of the Secondary Distribution Network.

The Supply into each Headwork Zone (Secondary Network) is determined on the basis of a calculated demand. Assuming a certain number of served subscribers constitutes the basis for the volume of water that is reserved for a specific Headwork Zone as shown in Table 6 below. The numbers reflect the zone demand on the 20th of September 2016. It is evident that there is a good match between `Demand` and `Supply`.

The main observation however is that the number of subscribers and their presumed consumption is not known. The water distribution on the primary level into the Headwork-Zones may, as a consequence, be rigged.

Table 6: Calculated Demand and effective Supply on 20.09.2016

Sr. No.	Zone	Headwork Zone - Secondary Distribution Network	Demand (MLD)	Supply (MLD)
1	West Zone	Nyari	33.00	33.27
2	WZ	Mavdi	26.00	25.82
3	**WZ**	**Chandresh Nagar**	**9.00**	**9.49**
4	WZ	Bajarang Wadi	5.00	4.88
5	WZ	Sojitra Nagar	3.00	3.20
6	WZ	Raiyadhar	29.00	33.15
7	WZ	Ring Road	6.00	6.67
8	Central Zone	Jubilee	23.00	22.68
9	CZ	Gurukul	22.00	21.74

Sr. No.	Zone	Headwork Zone - Secondary Distribution Network	Demand (MLD)	Supply (MLD)
10	CZ	L.B.P.S.	5.00	4.64
11	CZ	Popatpara	4.00	3.90
12	East Zone	Greenland P.S.	16.50	16.56
13	EZ	Dudhsagar P.S.	7.50	7.85
14	EZ	Vinod Nagar P.S.	9.00	10.27
15	EZ	Kothariya Hudco	1.50	1.10
16	EZ	Aji-30	21.00	23.86
17	EZ	Aji-18	14.00	15.72
18	EZ	Manda	1.00	1.27
Total Flow in MLD			**235.50**	**246.07**

To better understand the water distribution within a Headwork-Zone (Secondary Network) the Chandresh Nagar Zone was picked. 9 MLD is the benchmark volume and 9.49 MLD were actually delivered on that day.

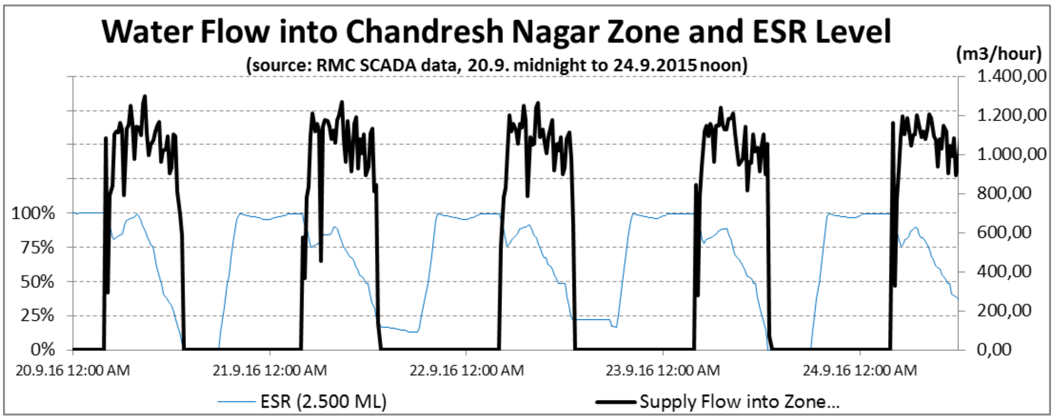


Figure 10: Flow into Chandresh Nagar Zone (kL/hour = m³/hour) and ESR water level (%)

The supply usually starts with a 100% filled Elevated Storage Reservoir (ESR). The first water is provided at 3:45 in the morning of each day and stops in the early afternoon, leaving the ESR between 0% and 25% filled.

Considering the daily demand of 9 ML the sizing of the ESR with 2.5 ML is perfectly sufficient. Because of the intermittent operation of the tertiary distribution networks the ESR has to be backed by lifting large volumes of water from the GSR. This requires large pumps which can handle large volumes in short periods of time.

The SCADA system allows taking an even closer look into the actual distribution into the tertiary distribution networks. **Figure 11** shows the daily flow that is taking place. Reportedly some 23 sub-zones are served following the 20 minutes supply pattern.

Box 1: Water Storage

Water storage capacity in the Rajkot reportedly adds up to 240 ML. This volume corresponds with 98% of the daily supply (246 ML).

A common rule of thumb requires storage capacity to meet 25% of the daily demand if the primary, secondary and tertiary networks are continuously pressurized.

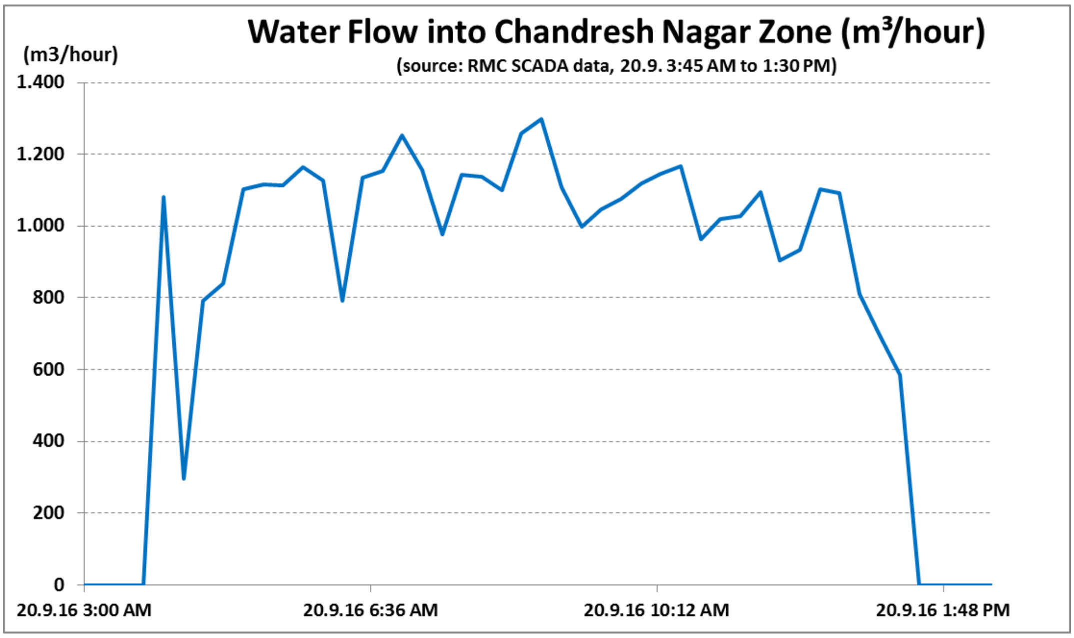


Figure 11: Water Flow into Chandresh Nagar Zone (kL/hour = m³/hour) on 20.9.2016

Knowing that the network has been largely replaced and that the backbone of the secondary structure is a new 500 mm DI ring pipe from which the tertiary systems are branched the following observations can be made:

1. The 15 minutes bulk meter reading interval is too short. It is recommendable to go for a 1 minute interval, because:
   a. it will allow RMC to monitor whether or not the 20 minute supply mode is respected by the ´petrolars´
   b. Details of the 23 tertiary networks (sub-zones) will become visible.
2. It is recommended to convert each tertiary networks into a District Metering Area (DMA) by installing a bulk meter and a pressure gauge and integrating both into the SCADA system:
   a. This will allow monitoring each area and improving its management.
   b. This helps identifying problems with installed private pumps on the service pipes.
   c. Correlating the water demand with the number of subscribers allows benchmarking the specific consumption.

2.4.5 District Metering Areas

Currently RMC is not applying the concept of District Metering Areas (DMA) in a demand management sense. Very good preconditions are available at RMC however and can be easily mobilized:

The objective of introducing DMA's is to improve water demand management. A sequence of steps has to be undertaken as follows:

- dissect the water distribution system into similar network units,
- regularly develop Water Balances (WB) to calculate the Non-Revenue-Water (NRW),
- compare the Performance Indicators (PI) of the different DMA's in Rajkot,
- develop reasonable and realistic benchmarks for RMC,

- identify priorities, and
- take decisions and translate them into action.

The following section will focus on the individual steps.

3 WATER MANAGEMENT IN RAJKOT

The objective of the mission to Rajkot under the urban Nexus programme was to identify the potential for saving natural resources, particularly energy and water. The starting point is that all water used in an urban context has been abstracted, transported, treated and distributed. A significant effort, both financially (investments) and operationally (staff, energy and chemicals) is required to reach the objective mentioned above. In addition to that the environmental impact has to be kept in mind: water is removed from its natural hydrological system and polluted. Polluted water is being collected to a large degree and constitutes a major source of health and environmental risk if not handled adequately. After treatment to recent Indian standards it may as well be a valuable source of irrigation water, thus alleviating the water stress. The Excreta Flow Diagram presented later in this section attempts to provide an overview of the current sanitary situation in Rajkot.

3.1 Water Demand Management and Water Balance Concept

The major challenge facing Water Utilities worldwide entails managing water demand and take control over its water losses.

The International Water Association (IWA) introduced the concept of the Water Balance two decades ago to describe the relationship between water production and water consumption.

The principle of the water balance is fairly simple:

> ***The difference between both, Production and Consumption, is generally associated with different categories of water losses.***

Box 2: IWA-Water Balance

A workshop was held on October 3rd together with RMC Ward Engineers to develop a water balance according to IWA standards (see Annex 2). Advantage was taken of an Excel-Tool developed by Liemberger et al. who shared this very versatile tool for download. Different languages can be chosen, Gujarati however is currently not yet available. http://www.liemberger.cc/).

A Water Balance (WB) details how much of each type of loss is occurring and how much it is costing the water utility. The key concept behind this approach is that water should always generate income. In conducting a water balance audit, a quantity is determined for the major components of water consumption and water loss, and a price is placed on each component in order to assess its financial impact on the water utility. A detailed and accurate water balance forms the basis for an effective loss reduction strategy.

Therefore, the purpose of a Water Balance is to better understand the performance of a service area with the objective of improving decision making processes on the level of water network management.

The following section will introduce the different contributors to water balance of RMC. The components are shown in the following figure:

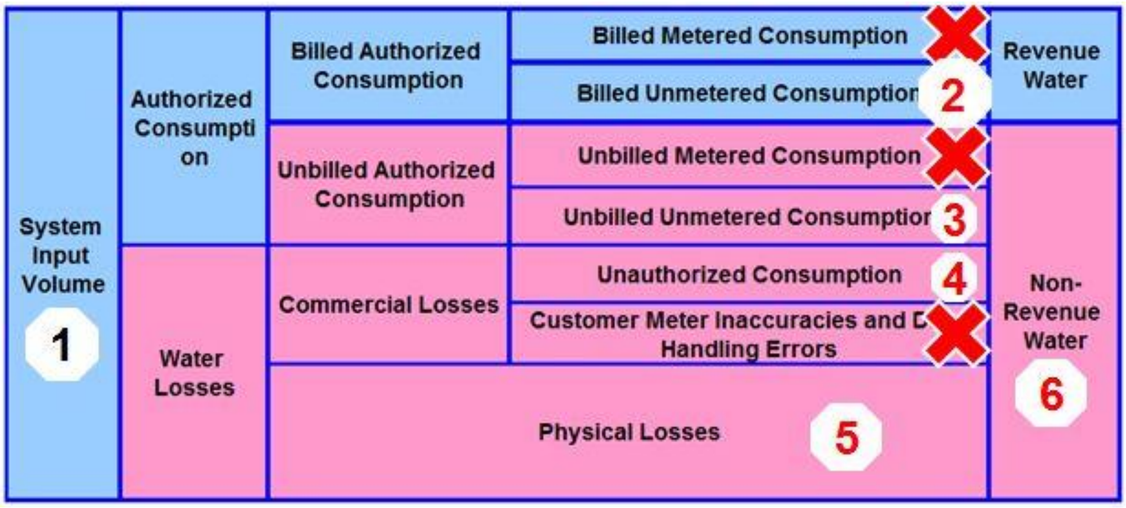


Figure 12: Components of the IWA Water Balance

The light blue components signify water volumes which generate profit. The red components are related to losses. Components are filled in the order of numbers shown in Figure 7. The black colour signifies water volumes which are metered by the RMC. The red volumes are either based on information estimated by the operators (2) or based on estimates (3) and (4). Water meters are not in use and therefore Billed Metered Consumption and Unbilled Metered Consumption as well as Metering Inaccuracies are not relevant in Rajkot (marked with an X). Because the consumption is not metered a justifiable distinctions can not be made between Commercial Losses (4) and the Physical Losses (5). Accordingly, the Non-Revenue-Water (NRW) (6) is determined by deducing the Revenue Water (2) from the System Input Volume (1).

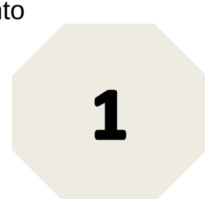
Water Balances can be established in RMC on two different levels:

- For the entire water supply system, that is the Primary Distribution Network or the entirety of RMC water supply, and
- For each Headwork-Zone (Secondary Distribution Network).

In the following a water balance will be presented that is based on the data retrieved from the SCADA and the information provided during the workshop (3.10.2016). Another water balance will be established in parallel for the Chandresh-Nagar-Zone (Ward No.8). It is obvious that the latter WB is part of the large WB. It describes one of 18 secondary distribution networks within RMC.

3.1.1 System Input

The System Input is the volume of water that is measures at the sources. Because water losses at the production stage are comparatively high it was decided to take them into account as quantity of water that is not generating revenue.



Bulk Meters are required to determine the System Input. Fortunately all Transmission Mains are metered in addition to the Entrance Mains into the Secondary Distribution Network. Data logging is taking place within the operation of the SCADA system and historic data is available since the commissioning of the SCADA in May 2015[5].

The total system input is given as follows:

(September 2015-August 2016)	**RMC**	**Chandresh-Nagar**
System Input (ML)	97,192	3,574

3.1.2 Billed Metered Consumption

Close to 1000 water meters are installed in the network but they are neither read nor used for billing. This category is therefore not applicable in RMC.

3.1.3 Billed Unmetered Consumption

2

The IT section within the financial department has provided the number of subscribers used here for RMC. The volume of water is subsequently derived from the number of subscriber. The consumption was assumed per subscriber (e.g. 450 litres per ½" domestic subscription and day) and the overall annual demand was calculated.

The number for Chandresh Nagar Zone is based on the information that 12,000 subscribers are served in this secondary zone. Again, the water volume was calculated assuming a certain mix of subscribers with their specific consumption. Please refer to Annex 2 for more details.

The Billed Unmetered Consumption was derived from given assumptions, primarily the specific water demand per subscription as follows:

(September 2015-August 2016)	**RMC**	**Chandresh-Nagar**
Billed Unmetered Consumption (ML)	60,301	2,514

3.1.4 Revenue Water (RW)

Because the Billed Metered Consumption is irrelevant and the Billed Unmetered Consumption is the sole source of income for the water operations[6] the revenue water for the duration from September 2015 until August 2016 is identical with the Billed Unmetered Consumption:

(September 2015-August 2016)	**RMC**	**Chandresh-Nagar**
Revenue Water (ML)	60,301	2,514

3.1.5 Unbilled Metered Consumption

A significant amount of water is used as process water and lost. This volume of water is neither used to serve the citizens of Rajkot nor is it used to generate revenue. Aggregating the volume

[5] No data is available for the month 07/2015 due to a computer virus.

[6] Water operations are not self-sustaining in RMC. Depending on the share of Narmada water source approximately one third of cost are covered through water tariffs.

of water registered by the SCADA system, results in the volumes shown in the table below. A proportional amount was adopted for Chandresh Nagar.

(September 2015-August 2016)	**RMC**	**Chandresh-Nagar**
Unbilled Unmetered Consumption (ML)	9,371	345

3.1.6 Unbilled Unmetered Consumption

No tangible information is available about authorized water consumers which fall under the category Unbilled Unmetered. It could be assumed however that a few public users may not be charged, such as:

1. The fire department, or
2. Public fountains.

The volume of water used for these purposes is in the order of 400,000 m³/year.

The categories introduced earlier represent the **authorized water consumption**. Even though that water may not be completely billed, it is all authorized by RMC.

(September 2015-August 2016)	**RMC**	**Chandresh-Nagar**
Unbilled Unmetered Consumption (ML)	400	0

3.1.7 Unauthorized Consumption

4

Water theft is generally referred to as *Unauthorized Consumption*. For obvious reasons it is difficult to estimate the concerned volume of water.

Due to the absence of water meters a simple method of fraud consists of sharing a service connection among two households. RMC is undertaking a serious effort to eliminate these types of theft. It was assumed that the total number of illegal domestic water users is 10,000. In addition it was assumed that the number of illegal consumers was estimated at 200.

(September 2015-August 2016)	**RMC**	**Chandresh-Nagar**
Unauthorized Consumption (ML)	1,839	0

3.1.8 Customer Meter Inaccuracies and Data Handling Errors

This category is not applicable in RMC.

3.1.9 Physical Water Losses

5

In an old water distribution network the main contributor to NRW are the *Physical Losses* or *Real Losses*. They are neither measured nor estimated but, being the last component of the water balance determined by subtraction.

There is however some indication for the magnitude of physical losses provided by the *Minimum Night Flow*. This option is unavailable in RMC because of intermittent service. Network documentation on age, occurrence of repair and replacement efforts gives some good indication.

The total volume of Physical Losses is determined by subtracting all the Revenue Water and the Commercial Losses from the System Input. This water is assumed to be effectively lost on the way from production to the consumer through malfunctioning infrastructure.

Box 3: Expressing NRW as a percentage

Using a percentage figure to express the Non-Revenue-Water is very common. The volume of NRW of 43,126 MLD represents some 47% of the System Input. As such it is an indication for the performance of the water distribution in RMC.

It is however recommended to use the absolute volumes of water in m^3 per time unit (day, week, month, year) rather than the percentage because it represents more accurately any future improvement in terms of resource savings. The percentage instead is a relative value that refers to the System Input, which is changing over the years and therefore is not appropriate as a reference value.

(September 2015-August 2016)	**RMC**	**Chandresh-Nagar**
Physical Losses (ML)	43,126	1,379

3.1.10 Non-Revenue-Water (NRW)

Because the Billed Metered Consumption is irrelevant and the Billed Unmetered Consumption is the sole source of income for the water operations[7] the revenue water for the duration from September 2015 until August 2016 is identical with the Billed Unmetered Consumption:

(September 2015-August 2016)	**RMC**	**Chandresh-Nagar**
Non-Revenue-Water (ML)	45,366	1,378
Non-Revenue-Water (%)	47%	39%

3.1.10.1 Analysis

Above calculations were made under the assumption that the specific domestic consumption per subscriber is 500 litres per day. Customers with different service pipe diameters are expected to receive different volumes of water (refer to Annex 2 for details).

The NRW, which is considered the most important indicator for water operations performance, is very sensitive to the specific subscriber demand.

Running the Excel-Tool (WB-EasyCalc) with specific demand ranging from 300 litres per subscriber and day (and the corresponding assumptions for other subscriber types as per Annex 2) to 800 l/subscriber/day shows that the NRW changes accordingly. (Refer to **Figure 13** below).

[7] Water operations are not self-sustaining in RMC. Depending on the share of Narmada water source approximately one third of cost are covered through water tariffs.

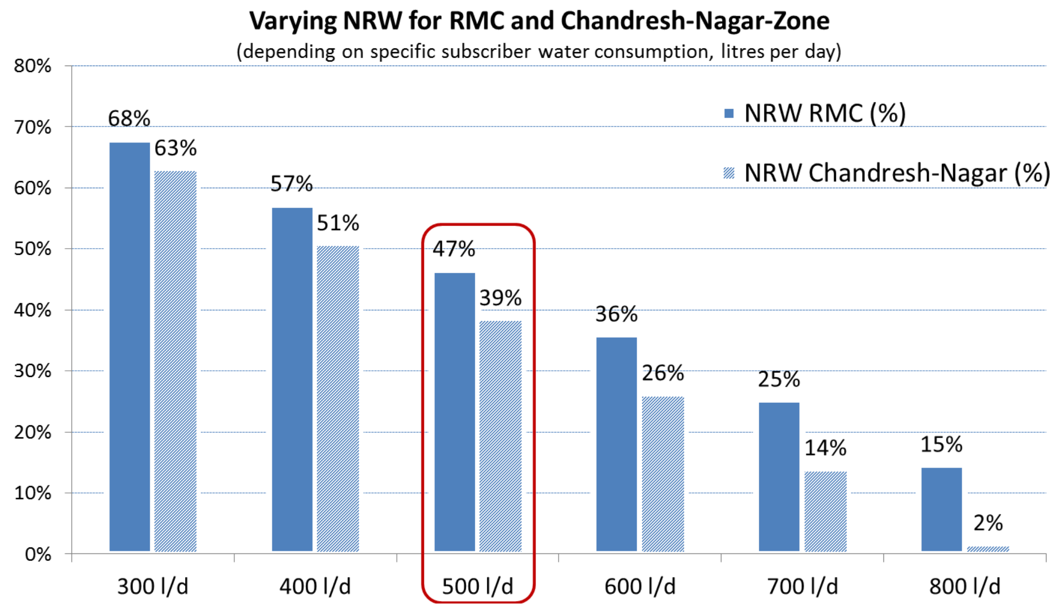


Figure 13: Varying NRW for RMC and Chandresh-Nagar-Zone

The graph shows that NRW is a function of the specific consumption. Since RMC relies on assumptions, no stable information can be provided on NRW, i.e. physical and commercial losses in the Water Supply.

➔ **Conclusively it must be stated that Water Demand Management is only possible if detailed information on consumption habits/patterns are available!**

3.2 Wastewater Reuse and Faecal Sludge Management in Rajkot

3.2.1 Overview

Rajkot, located Saurashtra is a water scarce city. Water is coming to a large extent from the distant Narmada Source. It serves both, urban and rural water supply.

Almost 100,000 ML (or 100,000,000 m³) are produced, consumed and polluted every year. The present section aims at describing the wastewater/sanitation situation on the level of RMC with the objective of pinpointing critical aspects along the sanitation chain. An Excreta Flow Diagram, or colloquially \`Shit Flow Diagram\` (SFD), is being developed along the sanitation chain to describe the current sanitary situation in Rajkot city.

3.2.2 The Sanitation Chain

The term "sanitation chain" which refers to the sequence according to which Faecal Sludge (FS) is "handled" along the way from production at the level of the households until its disposal is shown in **Figure 14** below.

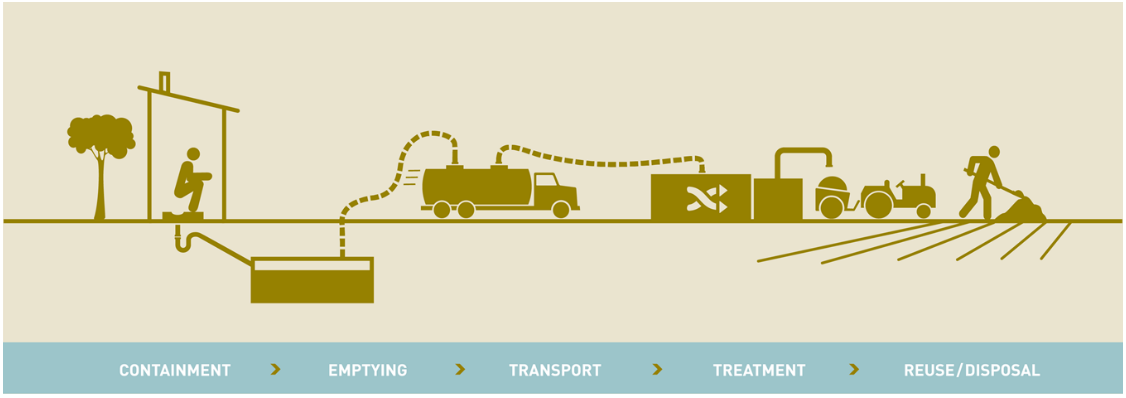


Figure 14: The Sanitation Chain (source: BMGF)

In many instances the sanitation chain is incomplete as it doesn't reach any point of safe disposal. The process usually ends at the point of containment or with the unregulated discharge.

The Sanitation Chain consists of the following elements:

3.2.2.1 Containment

The census 2011 had extensively included access to sanitation into the questionnaire. This data constitutes the departing point of national and other programs related to sanitation, first and foremost, the Swachh Bharat Mission and the aim to eradicate open defecation before the end of 2019. According to that census the situation in Rajkot was as shown in table below in 2011.

Table 7: Access and types of sanitation containment according to the Census of India 2011

	Population	Percentage
Total Population in the 23 wards of RMC (according to the ward numbering at the time)	**1,286,678**	**100%**
Number of households with latrine facility within the premises:	**1,180,542**	**92%**
Flush/pour flush latrine connected to:		
Piped sewer system	809,114	63%
Septic tank	342,497	27%
Other system	7,375	1%
Pit latrine:		
With slab/ventilated improved pit	8,235	1%
Without slab/ open pit	2,109	0%
Night soil disposed into open drain:	9,756	1%
Service Latrine:		
Night soil removed by human	1,066	0%
Night soil serviced by animal	228	0%
Number of households not having latrine facility within the premises:	**106,136**	**8%**
Alternative option:		
Public latrine	54,057	4%
Open defecation	52,118	4%

Above numbers indicate that some 92% of the population have access to in-house sanitation. 4% rely on public toilets and the remaining 4% have no access.

No exact population number is available for the fast growing urban agglomeration of Rajkot 5 years after the census. It is assumed that some 1.5 Million inhabitants live in the now 18 Wards.

According to discussions held in October 2016 the situation has improved further. Rajkot has declared itself `Open Defecation Free` in June 2016. This was achieved by building 12,000 in the course of the past two years. These measures encompass community toilets where individual toilets lacked space, as well as prefabricated toilets where sufficient space was available.

The containment situation in Rajkot is assumed to have developed as inquired during the mission in October 2016 and as shown in Table 8 below.

Table 8: Access and types of sanitation containment assumed for the SFD

	Population	Percentage
Total Population in the 23 wards of RMC (according to the ward numbering at the time)	**1,500,000**	**100%**
Number of households with latrine facility within the premises:	**1,440,000**	**96%**
Flush/pour flush latrine connected to:		
Piped sewer system	1,080,000	72%
Septic tank	345,000	27%
Other system	-	-
Pit latrine:		
With slab/ventilated improved pit	15,000	1%
Without slab/ open pit	-	-
Night soil disposed into open drain:	-	-
Service Latrine:		
Night soil removed by human	-	-
Night soil serviced by animal	-	-
Number of households not having latrine facility within the premises:	**60,000**	**4%**
Alternative option:		
Public latrine	60,000	4%
Open defecation	-	-

3.2.2.2 Emptying

The sewerage network is currently being extended. It is anticipated to reach 85% of the population in 2017. Today more than 1 Million residents are connected to the sewerage. The second largest group of citizens (345.000 inhabitants) relies on septic tanks and vacuum trucks for emptying. The 2 municipality trucks are free of charge. The service is covered by the drainage fee (400 INR per household per year) that applies to all users regardless the service they receive.

There are also 1-2 private vacuum trucks providing similar services. The low number of trucking capacity was explained with the little demand. Septic tanks are in fact percolating into the underground and need desludging only once in 10 to 15 years.

3.2.2.3 Transport

Sewage is transported to one of two wastewater treatment sites. While all collected wastewater directed towards Raiya WWTP is reportedly entirely conveyed to the treatment site some 110 MLD are collected in the catchment of Madhapar WWTP. Only 35 MLD are conveyed over a cascade of lifting stations to the treatment site. The remainder (75 MLD) are by-passing the Pumping Station and are eventually discharged into Aji River.

The vacuum trucks, both public and private, are reportedly discharging the septage into one of the two treatment sites.

3.2.2.4 Treatment

The current treatment capacity does not cope with the actual wastewater volume as shown in table below:

Table 9: Wastewater (WW) Treatment (Source: RMC, October 2016)

	WW in catchment	**Capacity**	**Treatment**
WWTP-name:	Volume generated in resp. catchment:	Design capacity to old national standards (30 mg BOD5/l):	Volume of WW receiving treatment today:
Madhapar	110.0 MLD	44.5 MLD	35.0 MLD
Raiya	40.0 MLD	51.0 MLD	40.0 MLD

Treatment efficiency is reportedly conforming to current Indian standards. RMC has launched the extension and new construction of additional WW-Treatment Plants which will be able to cope with the improved national Indian treatment standards (10 mg BOD5/l in effluent). The additional treatment capacity however is designed to deal with much larger volumes of wastewater. Volumes which are based on high specific water demand per capita (135 l/day) and a significant extension of the sewerage network. Additional volumes of collected septage are marginal.

3.2.2.5 Reuse / Disposal

Reuse of treated wastewater is one of the most important options for Integrated Water Management in a water scarce environment. Indian effluent standards were lifted recently indicating that reuse shall be encouraged. And reuse is being practiced today considering the large amount of wastewater that is being released into the environment, mostly the surface water bodies, Aji and Nyari Rivers. 75 MLD are treated and 75 MLD are not treated. In total 150 MLD find their way to farmers which abstract water from the rivers.

It is not clear whether the farmers are aware of the health risk they are exposed to and to which they expose the end users or their produce.

The risk of environmental pollution by discharging wastewater through `Septic Tanks` is unclear but is considered moderate given the occasionally deep groundwater level. For the lack of better information 50% of the `Septic Tanks` are regarded in the SFD as affecting the groundwater negatively.

Results

Based on the discussion held in Rajkot and following available information on the sanitary situation in Rajkot as well as on the basis of the assumptions explained earlier, 50 % of the faecal matter is safely managed. Conversely, 50 % of the faecal matter is being managed unsafely.

The 36% of faecal matter which are diverted before the treatment stage at Madhapar WWTP must be regarded as particularly critical. →**The untreated raw wastewater entering the environment without any treatment is certainly one of the most pressing issues which call for alleviation.**

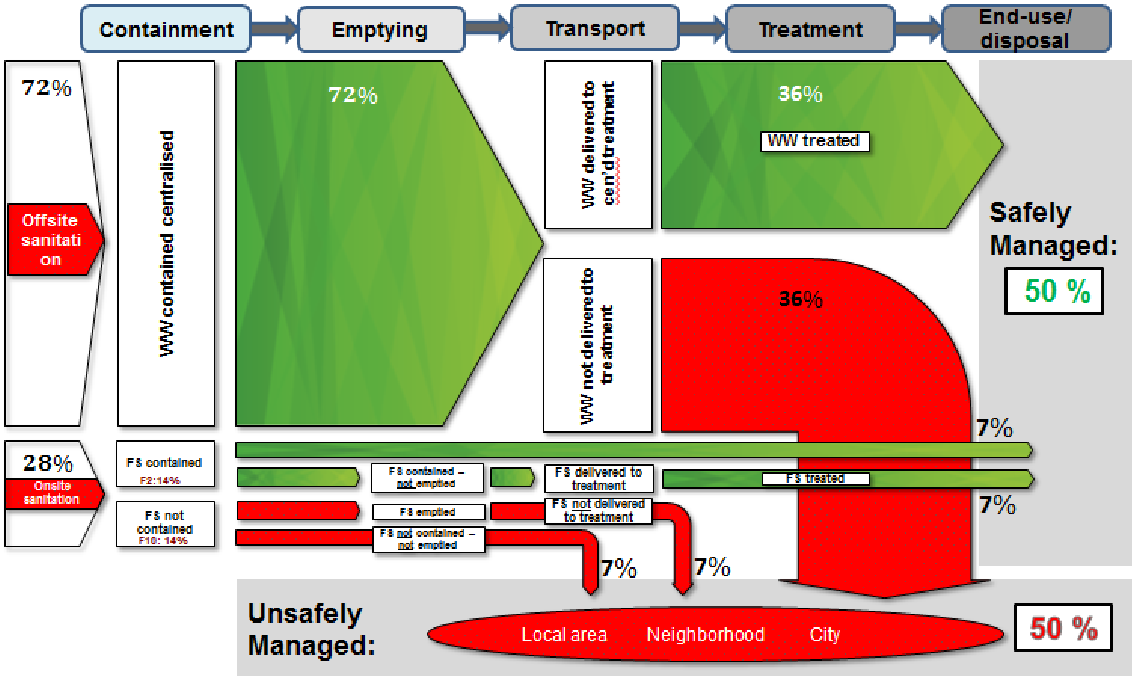


Figure 15: The Excreta Flow Diagram (SFD) for October 2016

4 RECOMMENDED MEASURES

The recommendations of the mission relate all to activities which directly or indirectly contribute to an improved water demand management in Rajkot.

The measures in below Table 10 were presented at RMC in the presence of the City Commissioner and the Chief Engineers. They are described in more detail in chapter 5.

Table 10: Recommended Measures

Improvement measure	Remark	Chapter
Utilize the SCADA system efficiently	The new SCADA is primarily used for Data Acquisition. An abundance of data is recommended to be processed into performance indicators. This way the different systems can be compared and efficiencies can be identified. Low performance is addressed and tackled systematically.	5.1 (page 31)
Learning from Chandresh Nagar Supply Zone	The on-going project in that supply area is an exercise that reveals the challenges of "transiting" from intermittent supply to continuous supply. Not only is a major technical effort undertaken but also a social effort needed when helping the customers to accept water meters.	5.2 (page 32)
Balancing the Systems	Develop water balances for each supply system under RMC and focus on areas with high Non-Revenue-Water	5.3 (page 34)
Digitize Data and Utilize the GIS System	In order to manage customers and assets professionally a modern data platform is essential. Rather than having a small ineffective GIS group in each department it is recommendable to join forces and set-up a professional, multi-sectorial GIS task force.	5.25.4 (page 37)
Wastewater Effluent Reuse	Constantly good wastewater treatment will allow the reuse of 170 MLD[8] which will alleviate the hydrological water balance of Rajkot significantly. Precautions are imperative and require vigilance to avoid undesired exposure to germs and contaminants	5.2 (page 38)

[8] Volume reported by RMC (Oct.2016)

5 INDICATIVE CONCEPT AND TIMELINE OF THE RECOMMENDED MEASURES

5.1 Utilize the SCADA system efficiently

5.1.1 Approach

The Real Time Bulk Water Audit System installed in RMC mid 2015 is in fact a Data Acquisition System as one component of a full fledged SCADA System. Currently all vital data is being recorded every 15 minutes. Data is stored and is available to all operators. This allows the remote verification of operational conditions.

Apart from aggregating some of the data, there is no processing and analysis taking place. It is recommended therefore to dedicate more attention to the data analysis in order to:

- Build a solid data base that allows the identification of exceptional operational conditions.
- Develop a knowledge base that allows city engineers and ward engineers to take informed decisions.
- Identify efficiencies and compare the performance of different systems.
- Support the network management process in order to optimize resources. E.g. low performance is addressed and tackled systematically.
- Allow more stable forecasts, e.g. the expected network behaviour if supply hours are extended.

5.1.2 Implementation

After the strengthening of the past years by further improving the superstructure of the water distribution in Rajkot it must be stated that the Headwork-Zones (the primary and secondary distribution networks) are under control. They are well integrated into the new SCADA infrastructure. It is essential to link this structure to the actual tertiary structure on the ground.

5.1.2.1 Establish District Metering Areas (DMA)

There are reportedly 18 Headwork Zones which are served with water by gravity from individual reservoirs. The extension of these distribution structures is not entirely clear. Accordingly it is recommendable to initiate a delimitation process. Based on available maps and network documentation a systematic procedure is required to dissect the city into Secondary Distribution Zones (all subscribers in this zone are connected to the same ESR or booster pump).

It is important to:

- Isolate secondary networks hydraulically from neighbouring systems (also to avoid some areas receiving water from different directions). The installation of border valves is required.
- Determine the number and types of subscribers of each secondary zone. This information is available with the IT section of the Financial Department.[9]
- Use the information delivered by the bulk meters. These sit at the outlet pipes of the ESR and at the entrance of the secondary zones. It is necessary to monitor closely flow and pressure.

(refer also to chapter 5.3.2.1 for more information on DMA's).

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[9] Currently (October 2016) the property owners of two wards have been incorporated into a GIS data base. This process is continuing at a pace of 1 ward per month. This information can be utilised by RMC Water Department to identify the number of subscribers by zone.

5.1.2.2 Reduce the metering interval

In order to improve the operation of the secondary and the tertiary distribution networks it is recommended to reduce the reading intervals of the distribution bulk meters at the outlet of the ESR from 15 min to 1 min. This will allow monitoring the petrolars (valve operators) more closely and will further allow correlating inflow and demand. Once the number of subscribers is known the predetermined flow into the networks (see Table 6 earlier) can be calculated more precisely and eventually excess water can be saved.

5.1.2.3 Install bulk meters at the entrance to the tertiary networks

The installation of smaller bulk meters at the level of the sub-zones (tertiary distribution network) will facilitate demand management within the zones. It is only required to provide daily readings, i.e. the aggregated volume of water supplied. This will serve as a control value to make sure the supplied water corresponds with the number of subscribers.

5.2 Learning from Chandresh Nagar Supply Zone

5.2.1 Approach

After improving the Headwork-Structure, RMC has decided to go forward by improving the secondary and tertiary structure. Chandresh-Nagar is the first of 18 distribution zones. 12,000 subscribers are targeted and 80% of the network has been replaced so far. The works are expected to be finalized in 2017.

Due to the elimination of leakages water savings have been achieved (reportedly 10-15% less water in needed). The service level has not improved however; the supply pattern has remained at 20 minutes a day.

The on-going project Chandresh-Nagar supply area reveals all the challenges of "transiting" from intermittent supply to continuous supply. Because every modern network management relies on customer water meters as the most important instrument to delegate demand management to the subscribers and because the public opinion is sensitive to the topic, it is of utmost importance to have a well designed process of social marketing and awareness measures to support the transition process.

Box 4: Subscriber Water Metering in intermittent supply scheme

Subscriber water meters are typically meant for continuous supply. The interior of water meters is made of replaceable plastic parts which have to be cooled by water. Air trapped in an empty supply pipe will set the plastic rotors in motion and cause them, in the absence of the cooling media, to wear. Meter reading precision will reduce to the disadvantage of the water service provider.

On the one hand, the water department of RMC will be able to test and learn from that pilot project. On the other hand there is some previous experience from India and around the world that is worthwhile consulting in order to avoid unnecessary difficulties. Not only is a major technical effort undertaken but also a significant communication effort is required to help the customers accept subscriber water meters.

5.2.2 Implementation

It must be clear to all the concerned decision makers that customer water meters and an improved 24/7 supply come as one package:

➔ **Continuous supply requires the use of subscriber water meters and, conversely water meters are designed for continuous supply!**

5.2.2.1 Installation of subscriber water meters

The subscriber water meters are a symbol of trust. The proposed Class-B[10] Multijet water meters are sufficiently precise if installed correctly in horizontal position. It is important to provide the subscribers access to the water meter at all times so they can monitor their consumption.

5.2.2.2 Sequence of steps on the way to 24/7 water supply

23 Sub-zones (tertiary distribution network) exist within Chandresh-Nagar-Zone (secondary). The average number of subscribers is in the order of 550 subscribers per sub-zone. It is recommendable to start with a continuous supply step by step, i.e. one sub-zone at the time.

The first sub-zone (the pilot zone) has to be well prepared:

- A bulk meter must be installed at the entrance of that sub-zone.
- 500 mm ring pipe from ESR must be pressurized at all time.
- All other sub-zones must be isolated by border valves and receive water only according to the usual 20 minutes per day.
- Both bulk meters at ESR and at the pilot-sub-zone must show same readings.
- The subscribers in the pilot sub-zone are well informed and aware that they will receive water on a 24/7 basis. Because the pressure conditions will be much better than during intermittent supply, they must be prepared by:
    - Fixing in-house piping and plumbing, siphons and taps, etc.
    - Make sure that floater valves on roof tanks or ground storage tanks are fully functional. Else they have to be by-passed.
- Subscribers which are absent or not responsive have to be disconnected temporarily until in-house plumbing is fixed.
- Subscribers are informed regularly about their consumption. Information concerning "normal" consumption and recommendations how and where in the house to save water is usually helpful. An information campaign for children at the local elementary school as well as other formats which prove effective may be considered.
- After achieving a stable consumption pattern subscriber data has to be analysed. At this stage it is useful to involve economists and/or socio-economist to prepare the development of a tariff.
- The development of a tariff is a challenging task, because:
    - it shall allow all water users of all social groups to use healthy water for a healthy live. Users who need little water (5 KL or 5,000 litres per subscriber and month) shall benefit from a tariff that is affordable by the poorest. Other users shall be encouraged to save water. Large users in an upper consumption bracket (more than 25 KL or 25,000 litres per subscriber per month) shall pay a tariff that subsidizes the lowest consumption bracket.
    - The tariff shall cover the cost of water provision. The minimum requirement is to cover operation & maintenance cost. Ideally, the tariff covers re-investment cost.

Box 5: Pre-paid water meters: an alternative to conventional subscriber water metering

Yet another alternative for subscriber metering is the pre-paid water meter. The advantage for users is the full cost control at all times. Based on a Token that is acquired from the utility or authorized vendors, it provides for a given volume of water. Generally, only a fixed price per m³ is adopted.

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[10] This description was in use until 2006. The 10 year transition period has ended. Class-B corresponds with the new Q3/Q1 80 according to the new system.

- Water tariffs are always prone to interference from various sides. It is therefore important to lead a moderated process in order to achieve good results through information and transparency.

- Develop a meter reading strategy. Reading and billing is a labour intensive occupation that will be a further burden on the tariff. It is useful to develop the right billing strategy in possible envisage longer reading intervals (covering more than a month). Modern handheld devices facilitate meter reading and billing and could be a reasonable option for Rajkot.
- Prepare the billing department to the new volumetric billing policy. On the spot billing may be combined with meter reading.
- Meter calibration/replacement is recommended before 10 years of operation. If the distribution system is operated intermittently water meter replacement is required earlier.

Box 6: Experience with 24/7 in India

Positive experience with the introduction of 24/7 supply pattern was made in Nagpur (pilot area with 10,000 subscribers) and in three cities in Karnataka State. In both cases performance based contracts were concluded.

A strong political willingness was described as being instrumental to achieving the envisaged objectives.

5.3 Develop Water Balances

5.3.1 Approach

The International Water Association (IWA) introduced the concept of the Water Balance (WB) two decades ago to describe the relationship between water production and water consumption.

The difference between both, production and consumption, is generally associated with water losses of different types as explained earlier. A WB is recommended to be prepared for all different levels: On the level of Rajkot (as presented in the Corporation on 29.9. and as introduced in the workshop on 3.10.2016) and on the inferior levels of the urban distribution network. Both WB are introduced earlier in 0. It is recommended to use the UK-English-language-Version[11] of the Excel-based Water Balance that was used during the mission.

It is recommended to establish WBs and calculate the NRW for all level of networks according to the following sequence. Because subscriber water meters are not used reasonable assumptions have to be made concerning the specific consumption. It was shown previously in this report that the NRW is sensitive to the assumptions made with regard to specific consumption.

Define area of the water balance

- The network must be well documented and has to be isolated from neighbouring areas (the latter being an imperative condition).
- There is no general rule, but a number between 1000 and 5000 subscribers has shown to be a practical size.
- Fully pressurized network is not mandatory but an advantage.

[11] Alternatively a team from RMC can develop a Gujarati Language Version within WB-EasyCalc.

Determine water volumes	- Bulk water meters at the entrance of the service area are mandatory to establish an IWA-WB. Data loggers are required only in case of a fully pressurize network to analyse the Minimum Night Flow - If subscriber water meters are not available only a reduced water balance can be established. A distinction between commercial and physical losses is not possible. Based on subscriber numbers the reduced water balance can be used to reflect the commercial situation of a service area.
Make reasonable assumptions if data is missing	- The exact volume of illegal- or unbilled consumption is generally not known. Therefore reasonable assumptions must be made to be able to fill the water balance. - The person developing the WB shall make qualified assumptions based on professional judgement.
Agree on adequate period of time	- The most common interval is one year in order to include seasonal variations. - Shorter intervals are possible and reveal seasonal particularities. - Monitoring the change over successive intervals allows comparing water system performance indicators over time.

Comparing different supply systems allows the operators to take informed decisions for an improved management.

5.3.2 Implementation

5.3.2.1 District Metering Areas (DMA's)

The objective of District Metering is to develop water balances and to identify priority DMA's which show high levels of water losses. Ultimately the DMA's are the most powerful instrument to improve water distribution network management.

Within RMC is possible to establish DMA's on different levels. In principle each of the many Sub-zones (Tertiary Distribution Networks) which receive water for 20 minutes every day and which are perfectly isolated from neighbouring areas can be used to develop a DMA. The main requirements are:

1. Knowledge about the subscribers and their subscription type,
2. A bulk meter that measures the flow into the area.

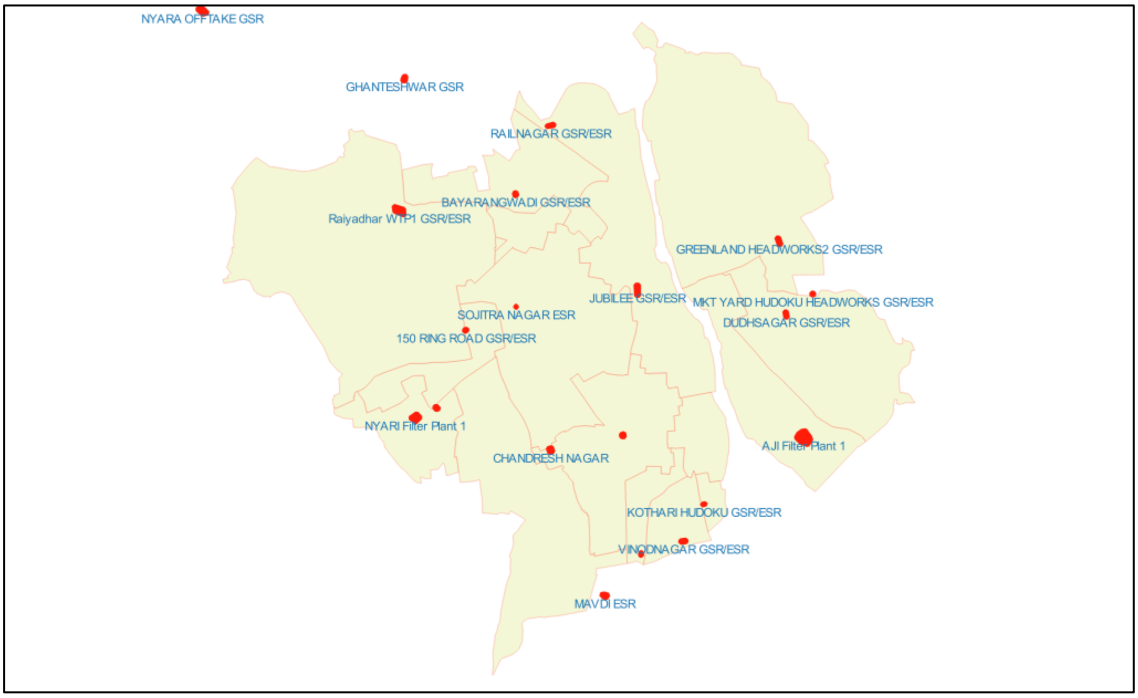

Figure 16: Rajkot urban area is divided into 18 Headwork-Zones with individual GSR/ESR (shown in red) which can be operated as DMA's and which can be dissected into even smaller DMA's.

5.3.2.2 Checking the Water Balance

Water balancing is recommended to be conducted on different levels for the same period of time:

1. On the level of the city as presented earlier. In this case the whole city will be considered as one DMA.
2. On the level of Secondary Distribution Networks, e.g. Chandresh-Nagar- Headwork-Zone.
3. On the level of Sub-Zones, the Tertiary Distribution System that is being operated by the valve operators for 20 minutes per day.

Efficiently dissecting a network can only take place with a closed valve or with a bulk water meter. It is therefore necessary to check all valves and to identify those which are needed to effectively operate the network. This measure consists of the following steps:

1. Improve network documentation of pipes and valves.
2. Check all valves for their functionality. However, this is considered a minor issue in Rajkot because valves are in operation on a daily basis.
3. Observe pressure changes within the concerned network area. A perfectly closed valve will result in a sharp pressure drop if no other pipe is serving the area.
4. Installation of valves in appropriate locations to isolate a DMA.
5. Installation of bulk water meters on pipes which need to remain open all the time to serve the subscribers.
6. Document all changes in the GIS system.

5.4 Digitize Data and Utilize the GIS System

5.4.1 Approach

In order to manage customers and assets professionally a modern data platform is essential. Rather than having a small ineffective GIS group in each department it is recommendable to join forces and set-up a professional, multi-sectorial GIS task force. However, GIS professionals are needed within the Water Department to contribute to the functionality and completeness of the whole GIS documentation.

The objective is to develop a professional GIS Database that:

- meets the varying requirements of the different departments,
- that facilitates communication among the departments and among the staff of RMC Water Department, and that
- enables efficient customer service and asset management.

Less than 1,800 km of pipes are documented in Rajkot where commonly accepted specific pipe length per subscription is in the range of 15 meters per subscription. This translates to 2.500 of network which are not documented. Closing this gap will improve network management, because a good documentation is essential for the following reasons:

- Improved asset management .Typically the minimum information are the diameter, material, construction date which need to be assigned to each documented pipe. Other attributes could be included (such as pipe repairs, see later this chapter). The pipe length can be determined automatically once the pipe is digitized.
- Better hydraulic understanding. With a hydraulic model any modification on the network can be anticipated. Before the hydraulic modelling however, a good documentation level has to be achieved. The following step would be a calibration, where pressure levels are modelled (pressure gauges will be helpful here).
- Identification of network limits and dissecting DMA's. DMA's can only be identified with a good level of documentation to make sure that DMA's are perfectly hydraulically isolated and to avoid unidentified pipes from serving two DMA's.
- Continuous mapping repair activities will show clusters of incidents where whole pipe sections need replacement rather than fixing visible leaks.

Typically most of the information handled on the level of a municipality has a geographic reference. The most important are:

- Properties and land type uses (such as commerce, industry)
- Services such as schools, health and public space.
- Distribution of population who are tax payers (and voters).
- Roads, traffic and accidents but also public security and crime.
- Utilities, such as communication, energy and gas in addition to course water and sanitation.

It is recommended to establish a section within RMC that is dedicated to geographic data processing. Water assets would be one of several sectors concerned.

5.4.2 Implementation

Because the networks are buried most of the times one of the typical challenges of water distribution network documentation is the need to verify existing data all the time. In many instances the real network is not correctly documented. Therefore it is suggested to incorporate all network repair activities into the GIS system to:

- Verify existing data,

- Show repair incidents,
- Indicate pipe replacement activities,
- Facilitate reporting of the activities on a regular basis.

The subcontracted network repair teams and all other staff which has access to excavated pipes will contribute to improving network documentation.

The requirements are the following:

- Provision of mobile devices with GPS functionality and a camera. Alternatively a cell phone (smart phone) may be used.
- Programming of a form that allows entering all data on the spot into the mobile application (e.g. Android based public domain from OpenDataKit.org).
- Enhancing back-office capabilities, especially training levels of GIS staff in processing field data.
- Develop web-based GIS application to allow all authorized staff to access data in the office and in the field.

5.5 Wastewater Effluent Reuse

5.5.1 Approach

Adequate wastewater treatment in Rajkot will allow the reuse of 170 MLD of wastewater which is generated on a daily basis in the city. In section 3.2 of this report the Excreta Flow Diagram (**Figure 15**) has shown that 50% of the wastewater produced in the city is not managed safely. Reuse, as the most appropriate method of discharging adequately treated effluent in water scare region is practiced. This however happens haphazardly where it should be a well monitored process for the sake of those exposed to irrigation water (farmers and consumers).

A number of options may be considered for future reuse of treated effluent:

Reuse in agriculture, horticulture, forestry, public urban green, etc.	- Limitations of effluent reuse need to be taken seriously to avoid adverse effects on farmers and consumers.
Groundwater recharge to build-up a strategic resource	- Gujarat state has some good experience with groundwater recharge that should be consulted.
Discharge into surface water bodies	- This most common disposal practice is hardly an option especially when receiving river holds little or no freshwater in the summer season.

5.5.2 Implementation

Significant extension measures of wastewater sewerage are underway, from currently 72% to 85% coverage upon finalisation of on-going measure. The same is true for treatment capacity extension. The new treatment facilities will treat the wastewater to more strict standards which allow for restricted irrigation. It is not clear whether or not the future facilities have anticipated the reuse option for treated affluent and stabilized sludge.

It is recommended therefore to conduct a wastewater reuse study that investigates on feasibility level potential irrigation areas and possible limitations.

It is likely that additional infrastructure is required, such as:

- Retention/polishing ponds to further improve effluent quality.
- Irrigation scheme including lifting stations and piping.

The proposed study shall therefore consider different technical options with the respective:

- Capital expenditures,
- Operational expenditures,
- Environmental requirements.

ANNEXES

Annex 1:	Water Supply Connections and Tariffs	Document provided by the Finance Section within RMC
Annex 2:	Revenue Water Volume Calculation	Only the consumption of ½" Domestic subscribers was assumed at 500 litres per day. This annex calculates the volumes for all other connections based on the applied water tariff
Annex 3:	Water Balance -RMC	Document prepared with support from the Ward engineers of RMC on 3.10.2016. The file was jointly prepared and shared. The WB was prepared with WB-Easy Excel application, which is available for free download.
Annex 4:	Water Balance – Chandresh-Nagar-Zone	Ditto
Annex 5:	Excreta Flow Diagram	Prepared following the methodology developed by the SFD platform (www.susana.sfd.org)