018530 - SWITCH

Sustainable Water Management in the City of the Future

Integrated Project
Global Change and Ecosystems

Deliverable D1.1.6

Strategic Planning for the Urban Water Systems of Tel-Aviv-Yafo

Due date of deliverable: M63
Actual submission date: M63

Start date of project: 1 February 2006 Duration: 63 months

Revision [final]

Project co-funded by the European Commission within the Sixth Framework Programme		
Dissemination Level		
PU	Public	X
PP	Restricted to other programme participants (including the Commission Services)	
RE	Restricted to a group specified by the consortium (including the Commission Services)	
CO	Confidential, only for members of the consortium (including the Commission Services)	

Strategic Planning for the Urban Water Systems of Tel-Aviv-Yafo

Audience

This document is of interest to medium level and higher management of municipal water departments and utilities, urban water researchers and all those interested in strategic planning for urban water systems.

Purpose

To report on the outcomes of the strategic planning process undertaken in Tel Aviv, as part of the SWITCH project, in the period 2006-2011.

Background

A number of SWITCH demonstration cities, including Tel Aviv have implemented a strategic planning process. The end-product of this process is a new strategic plan or a new strategic direction for the city. These plans are based on scenario analyis and the development of new strategies, based on scientific innovations.

Potential Impact

City managers that would adopt the approach described in this document, would rationalise the planning and implementation of measures in the urban water system. The suggested indicators, after adaptation to the local context, could be used as a tool to measure the sustainability of urban water systems.

Recommendations

Also visit: www.switchurbanwater.eu for Strategic Planning documents for Accra, Alexandria, Cali, Hamburg and Lodz.

Strategic Planning for the Urban Water Systems of Tel-Aviv-Yafo



Final Report

Steering Committee and Tel Aviv Water Club

April 2011

Abstract

The rapid urban development occurs all around the globe is leading to negative and significant impacts on the ecological system, conditions of the city infrastructure and city life. This emphasis the need for strategic planning for sustainable development of the cities. This work presents the strategic planning process for the urban water system of Tel-Aviv-Yafo.

In the first phase of the process the profile of Tel-Aviv-Yafo urban water system was described. The expected future trends, the system limitations and the energy and waste that produced by Tel-Aviv-Yafo urban water system were presented. In addition, the natural and the artificial components of the urban water system, their inter relationships, and the urban–national systems relationships, were discussed. The results of the phase were summarized according to SWOT methodology which emphasis the strength, weakness, opportunities and threats of Tel-Aviv urban water system.

Based on the results of the first phase, the following city vision for its urban water system process was proposed in the second phase:

“The water, sewage and drainage systems of Tel-Aviv-Yafo are reliable, efficient and sustainable, and advance values of service, fairness and equality and aspects of public health and the environment"

From this vision derived 4 types of goals:

A. Common to all the systems
B. Goals of the Water Supply System
C. Goals of the Sewage System
D. Goals of the Drainage System

The next step was to decide about the Actions and Means to implement the Vision and the Goals and to choose indicators to make a follow-up of this implementation.

There are 13 goals, 37 actions and means and 49 indicators that divided to – Disiered, Current and 5 year target.

This report was presented to the high administration of Tel Aviv Yafo Municipality which decided to adopt it and to incorporate it in its annual working program.

Acknowledgments

This study has been carried out within the framework of the European research project SWITCH (Sustainable Urban Water Management Improves Tomorrow's City's Health). SWITCH is supported by the European Commission under the 6th Framework Programme and contributes to the thematic priority area of "Global Change and Ecosystems" [1.1.6.3] Contract n° 018530-2.
The study team was supported by Dr. Peter van der Steen of UNESCO-IHE Institute for Water Education, the Netherlands .
The authors of this work wish to thanks the following people for their willingness to help us during this work: Michael Milner, Klod Piyotro, Lina Wishnivski, Michael Levi, Yehudit West, Yonathan Raz, Dr. Erez Sverldov, Shaul Gvirtzman, Daniel Solomon.

Avi Aharoni
Mekorot- National Water Co.
Co-Chair

Prof. Avner Adin
Hebrew University of Jerusalem
Co-Chair

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

1. Introduction

SWITCH is the name of a research program, implemented and co-funded by the European Union and a cross-disciplinary team of 33 partners from 15 countries around the world. The team includes groups from universities, industrial companies, research organizations, urban planners, water utilities and consultants.

The research project, subtitled "Managing Water for the City of the Future", commenced in 2006 and is managed by UNESCO-IHE of Delft, Holland (Dr. Peter van der Steen). Its Israeli partners are Mekorot Water Company, the national water utility, (Project Manager - Avi Aharoni) and the Hebrew University of Jerusalem (Project Manager – Prof. Avner Adin).

The project aims at developing and promoting a new approach to managing urban water resources and systems, an approach that accentuates integrated planning and sustainability. Its program includes bringing together researchers and practitioners from 11 cities from throughout the world in order to develop, on the basis of this approach, new water management strategies for each of these cities.

The program's Israeli partners proposed the city of Tel-Aviv-Yafo as one of the 11 demonstration cities, with the intention to utilize the project as a tool for developing with the municipality's experts a new strategic water plan for the city.

The Tel-Aviv-Yafo municipality embraced this initiative and decided to join the project as part of the overall city's master planning. The Israeli SWITCH project partners, together with the Strategic Planning Unit of the municipal Engineering Administration and the new municipal water corporation, "Mei-Avivim", prepared, subsequently, a work plan ("the Work Plan") that included three phases:

- **Phase I:** Prepare a profile of Tel-Aviv-Yafo's urban water systems;
- **Phase II:** Formulate Tel-Aviv-Yafo's urban water systems' vision and goals;
- **Phase III:** Formulate the actions and means for realizing Tel-Aviv-Yafo's urban water systems' vision and goals and the indicators for monitoring the progress and extent of their realization.

To oversee the execution of this Work Plan, a steering committee was formed ("the Steering Committee"). The Steering Committee included Prof. Avner Adin of the Hebrew University of Jerusalem, Avi Aharoni of Mekorot Water Company, Tami Gavrieli and Guido Segal of the Strategic Planning Unit of the municipal Engineering Administration and David Jackman, the former manager of the municipalities Water, Sewage and Drainage Department and, until recently the CEO of the new municipal water corporation, "Mei Avivim" (the new water corporation undertook all the municipality's water and sewage activities, leaving only a Drainage Department).

In line with the SWITCH program's declared policy that "researchers and practitioners work directly with civil society through 'learning alliances'", which will "serve as platforms for bringing together the researchers and the cities' stakeholders", the Steering Committee's specifically required that the Work Plan's execution should be coordinated with all the municipal urban water systems' stakeholders.

For this purpose, a "Water Club", which included members from all the relevant stakeholders (the Municipality, Government Ministries, the Israel Water and Sewage Authority, the Government's Municipalities' Water Administration, Universities, NGOs, the media, Mekorot Water Company and others) was formed.

The Water Club met several times over the past few years and discussed new methods and means for managing the city's water resources and systems. These meetings were well-participated and generated a variety of ideas and suggestions for improving the management of the municipal water systems.

The first phase of the Work Plan (preparing a profile of the city's water systems) was carried out by a team that included researchers from the Hebrew University of Jerusalem, Mekorot Water Company, the Strategic Planning Unit of the municipal Engineering Administration (Tami Gavriely, Guido Segal,Einat Amoyal, Gal Lederer and the municipal water corporation, "Mei Avivim" (David Jackman). The profile, completed in February 2010, relied, partially, on a Masters in Science Degree thesis which was written about a year earlier under the auspices of the SWITCH project and reviewed, inter alia, the issues facing the Tel-Aviv-Yafo water systems.

The second phase of the Work Plan (formulating the city's water systems' vision and goals) was supposed to use, as a starting point, the city's water systems' master plan (drawn as part of the city's overall master plan), but only two background studies related to the preparation of the city's Outline Plan (and not its Master Plan) were completed to this date: "Municipal Water Systems Planning – Goals Analysis" and "Municipal Water Systems Planning – Status Report, Analysis of Shortcomings and Planning Considerations".

Dr. Daniel Hoffman, ADAN Technical & Economic Services Ltd ("ADAN"), a consulting company specializing in desalination, water and wastewater treatment, energy (including renewable energy), power stations and the environment, was assigned the execution of the second and third phases of the Work Plan, utilizing, where applicable, the above background studies, as well as its own ideas and the ideas raised by the Water Club.

ADAN's intermediate reports and proposals were presented initially to the members of the Steering Committee and the Water Club, who contributed useful comments and proposed additions and changes. Many of these were assimilated in the final version of ADAN's work, the outcome of which is presented in this Report, together with its underlying background, methodology, approach and considerations.

2 Phase I. The Urban water system profile

2.1 Sustainable urban water system

In 1800 only 3% of the world populations were living in the cities while today more than 40% are living there. The number of giant cities in the world (more than 10 millions residences) grew up dramatically in the past 30 years and also in Israel, the same trends of cities expansion is occurring during these days. This rapid development occurred sometimes without any control, planning and design, leading to poverty and to insufficient infrastructures developments in the present which will surly have effects in the future. Therefore, it is very important to make sure that the urban development will happen according to the tripartite nature (economic, social-

cultural and environmental) of sustainability principles by considering also the expected future city needs in the present development.

One of the most important urban infrastructures is the urban water system. A very good definition was given by White and Turner (2003) for sustainable urban water system: "A sustainable urban water system is a system that satisfied the water related needs of the community at the lowest cost to society whilst minimizing environmental and social impact". This system includes both artificial and natural components which have inter-relationships and the sustainability must act on each one of them:

The artificial components are the one who continuously constructed and maintained according to city needs. They can be divided to three main systems: (1) supply system, (2) sewage system, (3) drainage system (also called: storm water system). During the operation of these components energy is consumed and waste is produced and these are very important factors in keeping the system sustainability.

The natural water bodies (rivers, lakes, seas, aquifers) are key factors in the city life and environment. They are commonly used as source for potable water. They and the area around them are widely used as the city's green lunges and also for vacation, tourism and more. The natural bodies may be dramatically affected by the city life and the city development. In sustainable urban water management approach, both reversible and irreversible damages of the natural water bodies must be prevented during the city development.

In order to reorientate urban water area toward sustainability, the different components of the system should be viewed in relation to each other, which require the adoption of an integrated approach to urban water system planning, provision and management. Mitchell (2006) summarized the main principles of integrated urban water management approach:

- Consider all parts of water cycle, natural and constructed, surface and sub-surface, recognizing them as an integrated system.
- Consider all requirements for water, both anthropogenic and ecological.

- Consider the local context, accounting for environmental, social-cultural and economic perspectives.
- Include all stakeholders in the process.
- Strive for sustainability, balancing for environmental, social and economic needs in the short, medium and long term.

As was mentioned before it is very hard to forecast what will be the future needs, but the first step for doing that is to understand the expected future trends. The most relevant trends that may affect urban water systems in the future are:

- Climate change – might leads to change in the amount of precipitation, sea level rise and more.
- Population growth – leads to increase of the water consumption in the city.
- Increasing life quality standards - leads to increase of the water consumption in the city.
- Urbanization – increase the water run-off and floods as results of asphalt covering.
- Stress on the water systems – continuation of the current stress on a water resource may leads to ecological irreversible damage and to water loss.
- Energy costs – According to the forecasts, the energy prices are expected to rise in the forthcoming years.

Summarizing all the above it can be state that a city that wishes to achieve sustainability for its urban water system should set itself the following objectives (Duong, 2009):

- Educate citizens to be aware of "water and sustainability" and where the authorities will involve the public in decision making.
- Manage its urban water system in an integrated way; integrating aspects of water supply, storm water management, wastewater collection, wastewater treatment and wastewater reuse.

- Use a set of sustainability indicators for decision making and planning.
- Have strong scientific basis for decision making concerning the management of its urban water system. To ensure equity in assess to water, as well as to irrigated green areas.
- Minimized the energy consumption in the urban water system.
- Supply water in good quality to its citizens in sufficient qualities at the lowest possible costs.
- Provide all its citizens with proper sanitation, at the lowest possible costs.
- Give priority to water demand management over development of new resources.
- Give priority to pollution prevention over end-pipe treatment.
- Reduce the net waste output from the city to the environment to below carrying capacity of the receiving environment.
- Enhance the self waste purification capacity of the receiving environment by eco-hydrology.
- Reduce the risk of flooding in vulnerable areas to levels acceptable to all stakeholders, even under future climate change scenarios.
- Protect and enhance the water quality and ecological status of urban receiving waters, both surface and groundwater.
- Apply source control techniques to enable storm water to contribution to the quality of life in the urban environment.
- Harvest rainwater and storm water for non-potable reuse purpose.
- Utilize storm water to re-establish a balanced natural water cycle in conjunction with landscape development.

A very good example for **un**sustainable development is found in the history of Tel Aviv. Tel-Aviv was established in 1909 and in those early days its water supply system relied on pumping from local wells. In the middle of the 40's of the last century there were evidences for salination processes in the local wells but the pumping continued on. Due to the over

pumping and intrusion of the sea water, currently more than 30 wells (Figure 1) were closed due to high concentrations of chloride. The over pumping led to irreversible damage and these water are no longer available for the city needs. This example emphasis the vulnerability of Tel-Aviv Yafo water system and it demonstrates that Tel-Aviv Yafo urban water system development must followed sustainable principles. The following work presents the process of strategic planning for the urban water system of Tel-Aviv-Yafo aimed to achieve and to illuminate the sustainable management of the city urban water system.

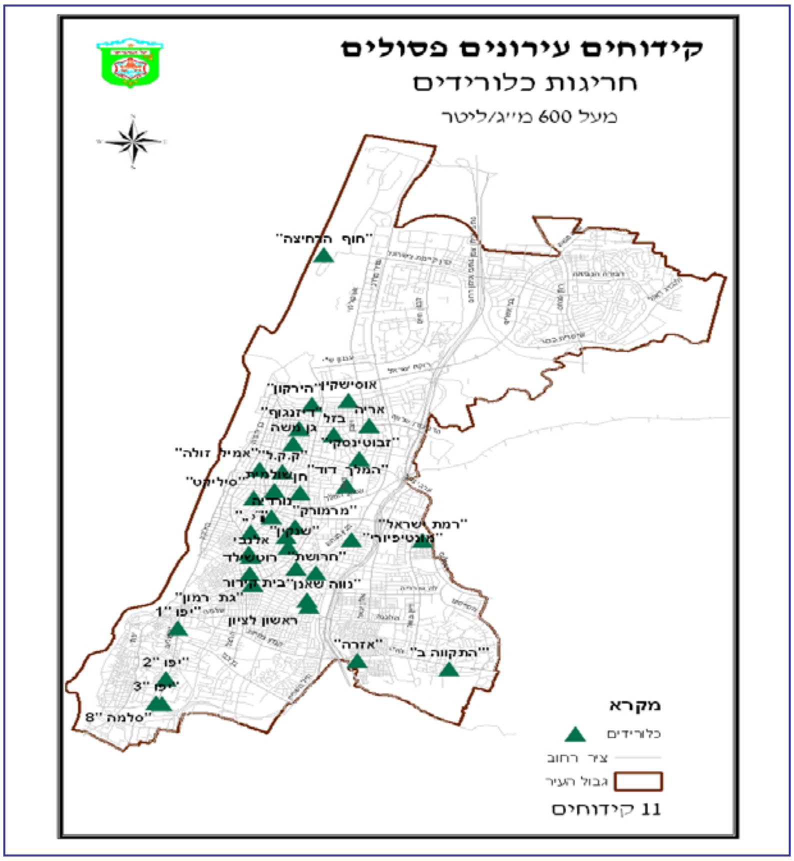

Fig. 1. The 33 Tel Aviv Yafo wells forbidden for use as result of high concentrations of chloride found in their water.

2.2 Indicators for sustainable urban water system

In few discussions of the "Water Club" raised a long list of proposed indicators for how to make the follow-up of the implementation of the vision and goals.

Due to lack of time, the list for actions and means were shortened only through the assessment of a team that included the Steering Committee members and the top technical and administrative personnel of the municipal water corporation "Mei Avivim"

This team pared down the list by deciding, according to their experience, which actions are feasible and practical, and, more importantly, the results of which actions can be monitored and measured by the criteria set

The approach to choose the indicators was to prepare an initial comprehensive list, which included also some useful suggestions from the Water Club, and to pare this list through tests, comparisons and prioritization.

The report includes 13 goals, 37 actions and means and 49 indicators.

The full list of the indicators is presented later on in this report.

2.3 Background, objectives and plans of the process

Background

Tel Aviv metropolitan (also called Gush-Dan) is the largest metropolitan in Israel with about 35% of Israel population. Tel-Aviv Yafo city is the biggest city in the metropolitan but its influence is beyond its relative population weight (about 5% of Israel population), it is the business, culture, fashion capital of Israel and it seems that every new idea or innovative technology that coming to Israel start its journey in Tel-Aviv Yafo. During the years 2001-2006 the department of Strategic Planning in Tel-Aviv Yafo municipality led and prepared a very comprehensive and long process for Strategic planning of the city in order to define the city vision (Municipality of Tel-Aviv Yafo, 2006). Also a list of indicators was developed in order to examine the gap between the actual state of the city and the vision.

Although the work was very wide and many issues of Tel Aviv Yafo city life were discussed, the urban water system was not considered and therefore its vision and its indicators are still missing.

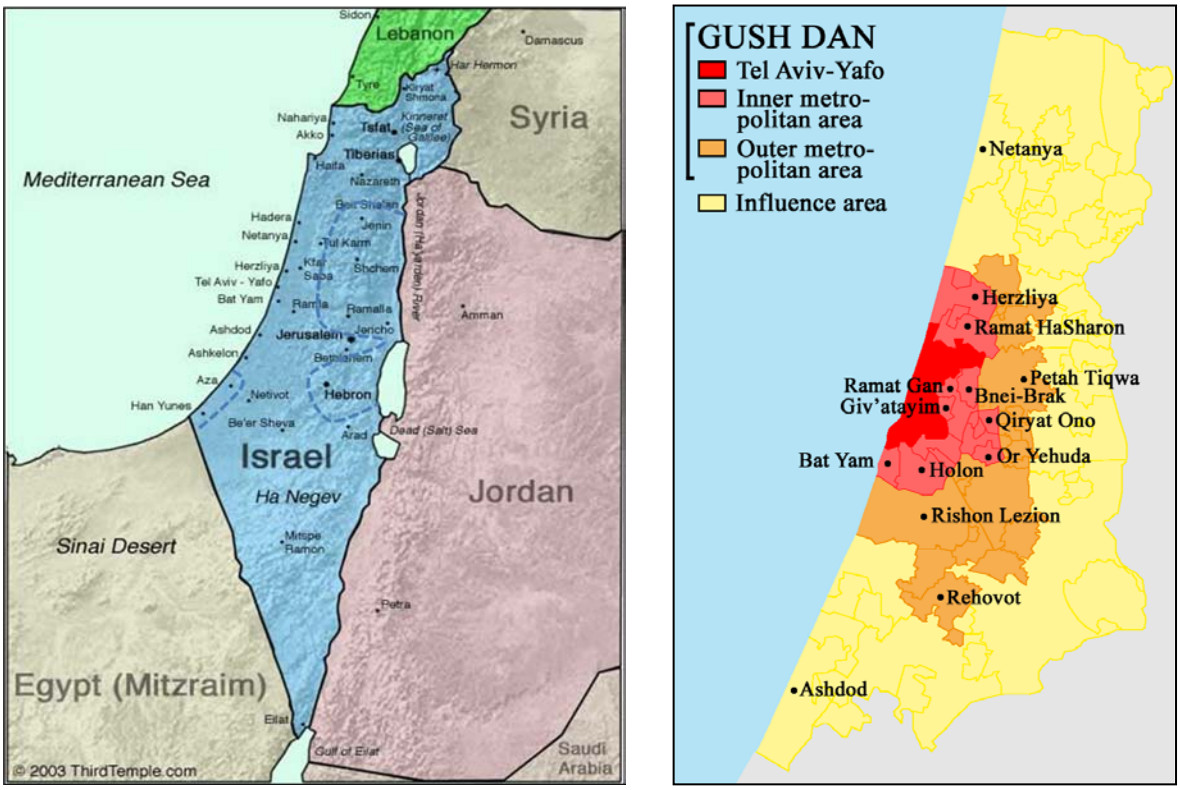

Fig.2. Maps of (left) Israel and (right) Tel-Aviv metropolitan (Gush-Dan).

The SWITCH project (http://www.switchurbanwater.eu/) is an EU funded action research program being implemented and co-funded by a cross-disciplinary team of 33 partners from across the globe. The "consortium" is from the field of academic, urban planning, water utility and consulting interests. This network of researches and practitioners are working directly with stockholders in 11 cities around the globe. The overall goal behind this global consortium is to catalyze change towards more sustainable urban water management in the "City of the future (in 2035)". Demonstrating research and sharing knowledge across a range of different geographical, climatic and socio-cultural settings is expected to lead to global adoption and acceleration of more sustainable solution.

Tel-Aviv Yafo has been chosen as one of the demonstration cities included in the SWITCH project. The two Israeli partners in the project, namely the Hebrew University of Jerusalem and Mekorot National Water Company, together with SWITCH, have discussed the possibility to prepare a Water Strategy for Tel Aviv Yafo with the city experts namely, Mei-Avivim and the department of Strategic Planning in Tel-Aviv municipality. A "Water Club" was established with members from a number of organizations (Tel Aviv Municipality, Water Authority, various ministries, Yarqon river authority, Hebrew University, Mekorot and others). This "Water Club" has met several times during the last

two years and has discussed new ways of managing water in Tel Aviv Yafo. This club decided that the framework for developing the proposed project of strategic planning for the urban water system, will be Tel-Aviv Yafo City Strategic Planning that was prepared in the years 2001-2006.

The process objective

To formulate a vision for sustainable urban water system, and developing monitoring tools, made of indicators and associated measures, to benchmark the city's progress towards the vision.

The process plan

The process was divided to three phases:

Phase I: The urban water system profile of Tel-Aviv-Yafo

This phase includes the analysis of the present state of the urban water system – its characteristics, challenges and opportunities. The results of the research study are summarized by the **SWOT** (**S**trength, **W**eaknesses, **O**pportunities, **T**hreats) methodology.

Phase II: Formulation of the urban sustainable water system vision

This phase is based on the profile phase findings and it is concentrated on creating the desired vision, of the sustainable urban water system.

Phase III: Action plans and Indicators

Action plans are derived from the strategic plan, in order to achieve the vision for the urban water system. In parallel, a monitoring tool, made up of indicators, will be developed to benchmark the city's progress – whether it is moving towards achieving the objectives of the strategic plan for the urban system.

2.4 The urban water system profile of Tel-Aviv-Yafo

The expected future trends in Tel-Aviv urban water system

The national water system is expected to be in condition of water shortage due to population growth and maybe climate change which expected to cause higher frequency of droughts. This water shortage may be balanced by construction of desalination plats, but the need for water saving and efficient management of the water system will remain. Regarding Tel-Aviv water system, the most certain future trends is population growth. There are offered several scenarios for population growth. According to the strictest one, the population will grow from 390,000 citizens today to about 450,000 in 2025 which mean 15% population growth (Center for Economic and Social research, 2008). If the current water consumption modes will continue as today, this will lead to at least 15% increase in the water demand and in the sewage discharge, in the future.

General limitation of Tel-Aviv urban water system

The land prices in Tel-Aviv are one of highest in Israel. This leads to dense and high construction which characterizes the city. The high land prices are very important factor that limits the development of the urban water system. It is one of the reasons for the preference of national over local water plant, although in the national plant there are additional significant costs of water transportation to the city from the plant. The high land price limits the development of local desalination and wastewater plants and limits the free area for water reservoir such as for rain water harvesting and percolation.

One of the ideas that were offered in order to challenge this limitation is to build artificial island like the one which were build for infrastructure all over the world. Such an offer for local desalination plant was examined by Tel-Aviv municipality and it was found to be more expensive as compared to inland alternatives. Moreover, an artificial island will have effect on the Mediterranean Sea by changing the flow of the sand and more.

Energy and Waste produced by Tel-Aviv urban water system

Energy - Tel-Aviv is lying near the Mediterranean coast with very flat landscape (average elevation: 30 m). This resulted in almost totally gravitational flow and consumption by the water system of only 0.8% of the total electric consumption in Tel-Aviv. This minimal energy consumption is necessary and thus, there is no opportunity for significant energy saving.

Waste - A very important question that appeared during the work was: what are the borders of Tel-Aviv-Yafo urban water system? Is the waste water treatment plant – "Shafdan", is part of Tel Aviv water system? The Shafdan treats Tel-Aviv-Yafo effluents but also the effluents from the other cities in Gush-Dan (It is almost impossible to define the part of Tel-Aviv-Yafo sewage in the Shafdan). Also, The Shafdan is located about 10 km south of Tel-Aviv-Yafo and it affects its surrounding area and therefore it has no effect on Tel-Aviv-Yafo. Also Tel-Aviv-Yafo municipality is only one of the partners in Igudan Union which operates the Shafdan.

The current authors chose the lenient approach by defining that the Tel-Aviv water system include all the water system components that are found in the municipal area of Tel-Aviv. According to this approach all the sewage of the city is discharge out of the city borders to the Shafdan, and there is no treatment of waste inside the city. Exceptions are the wastes from local factories that heavily contaminated with heavy metal and salts. These wastes are treated locally in the factories and their sludge is transfer to Ramat-Hovav which is the national center for toxic waste (Igudan Union reports).

The components of Tel-Aviv-Yafo urban water system

As was mentioned before one of the main principles of sustainable urban water system development is the integrated approach which based on comprehensive understanding of system components and their inter relationships.

Urban–National water systems relationship – Tel-Aviv-Yafo water system is highly influences, affects and depends on the Israeli national water system. About 95% of Tel-Aviv potable water are supplied by the national water system (The national water carrier of Israel or the Yarqon-Negev western line waters) and Tel-Aviv-Yafo consumes about 2.5% of the national water consumption. The city sewage is discharge and flow with the rest of Gush-

Dan cities- sewage toward the Shafdan, where they are treated and purified and taken for irrigation in the northern Negev fields. Therefore, construction of local grey water plants in the future will reduce the amount of water that flow to the Shafdan and therefore it will affect the amount of water available for the northern Negev agriculture.

Inter-relationships between the water system components –Tel-Aviv-Yafo water system can be divided to two types of components:

The artificial water system components: (1) the water supply system, (2) the sewage system, (3) the drainage system.

The natural water bodies: (4) the coastal aquifer, (5) the Ayalon River, (6) the Yarqon River and (7) the Mediterranean Sea.

The inter-relationships between the system components are presented in Fig 3.

As was mentioned before, the water of the supply system are coming mostly (95%) for external source (The national water system) but 5% are pumped in local wells from the coastal aquifer. Therefore the quality of the supplied water system may be influenced by the coastal aquifer. About 9% of the water that consumed in Tel-Aviv are tacking to irrigate the city gardens (Fig. 4), part of these water are percolating to the coastal aquifer and affecting its water quality.

Regarding the supply-sewage systems relationships, it is approximated that between 60-70% of the supply water are flowing in the sewage system out of the city borders as sewage. Currently there are no systematic gauges measurements which clarified exactly what is the amount of sewage that flows from Tel-Aviv to the Shafdan.

In times of local sealing in the sewage system, the sewage may flow in the drainage system, and also in rainy days when the drainage system can not contain and transport the high quantity of rain water, the flows of the drainage and the sewage systems are getting mixed.

The drainage system is ending and flowing into the Yarqon and Ayalon Rivers or into the Mediterranean Sea. The Ayalon River is flowing into the Yarqon River and the Yarqon River is flowing into the Mediterranean Sea. The Yarqon River waters are originate in the tertiary effluents and spring water in the upper stream parts of the river, out side the city borders.

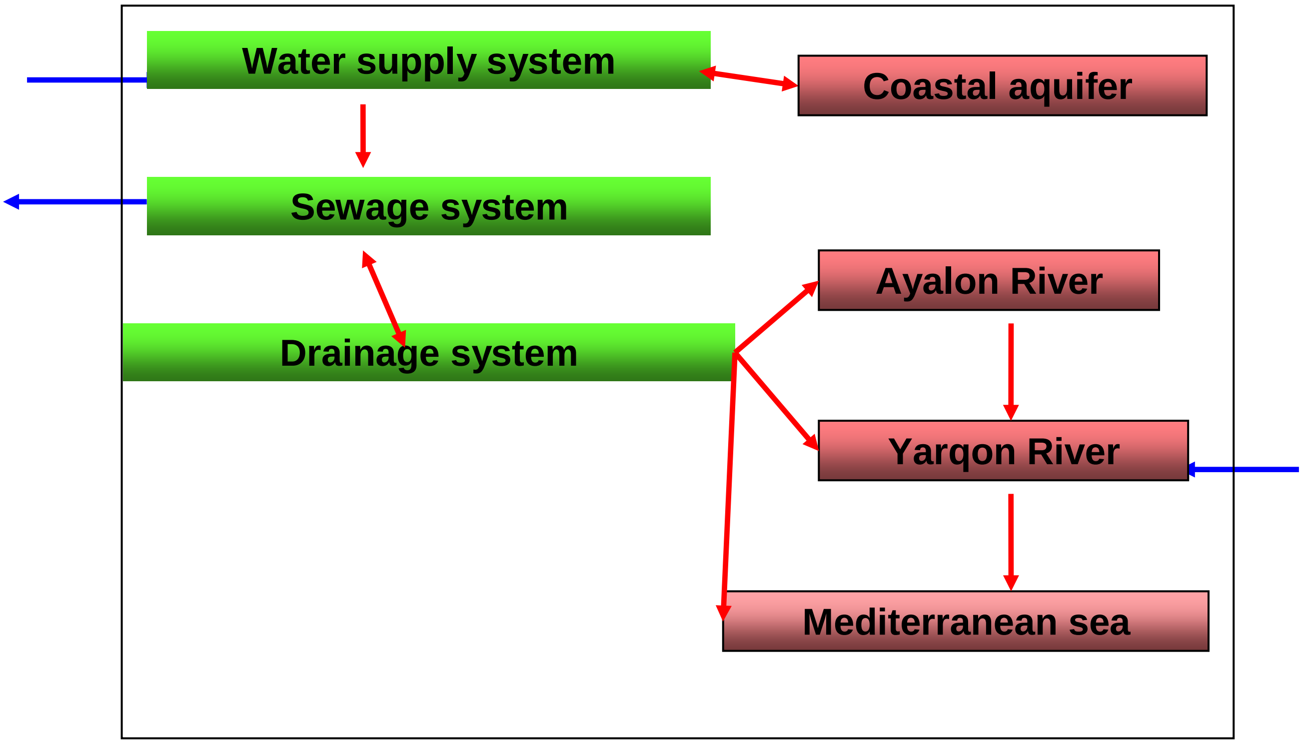

Fig.3. The inter-relationships between the components of Tel-Aviv Yafo water system.

<u>The water supply system</u> – As was mentioned before, the urban water supply system is relaying mostly on the national water system. The last 5 years were years of drought which led to acute national water crisis in Israel. The country's main water sources dropped to almost below the safe minimum levels which threatens the water quality and availability. The Water Authority of Israel started aggressive campaign to encourage the citizens to save water and also it reduced dramatically the water allocations for the different sectors. The construction and operation of the big national desalination plants in the forthcoming years will not change the basic reality of water shortage in Israel. Tel-Aviv as a leading city in Israel must be an example by developing its water system according to the national water sustainability needs, and it must put all affords for water saving and to reduce its external water consumption.

The residential consumptions per capita in different cities in Israel are compared in table 1 for the year 2006. In Tel-Aviv, the residential consumption is about 15% more than the national average residential consumption while its water lost are low (4.4%) relative to the average national value (8.6%). Part of the large consumption in Tel-Aviv residential sector

may be an artificial bias due to the presence of thousands of foreigners that living mostly in southern Tel-Aviv and use water but were not registered as city residences. But the overall trends in Israel indicate that the higher income of the population, the higher the water consumption and Tel-Aviv has one of the highest costs of living in Israel. The residential sector consumes about 60% of the total water consumption of Tel-Aviv (Fig. 4). Therefore, the large consumption in this sector pointing at large saving opportunity; 10% saving in the residential sector will lead to 6% saving in the total water consumption of the city.

Table 1. Water consumption and water loss in several cities in Israel (in the year 2006)

	Water loss (%)	**Specific residential water consumption (m3/year)**
Eilat	20.6	87.9
Ashdod	7.9	55.8
Beer -Shava	9.1	73.3
Haifa	5.6	63.3
Herzelia	6.4	94.7
Jerusalem	12.3	44
Tel-Aviv Yafo	**4.4**	**68.5**
Israel - average	**8.6**	**60**

A very impressive educational work is done by the department of environmental quality of Tel-Aviv municipality. All the city's children in the age of junior school are getting this year (2009-2010) at least one and half weekly hours of water education. A new educational book was written and published this year in order to teach the children how and where to save water. It is believed that the children are a key factor in moving the public toward more water saving awareness.

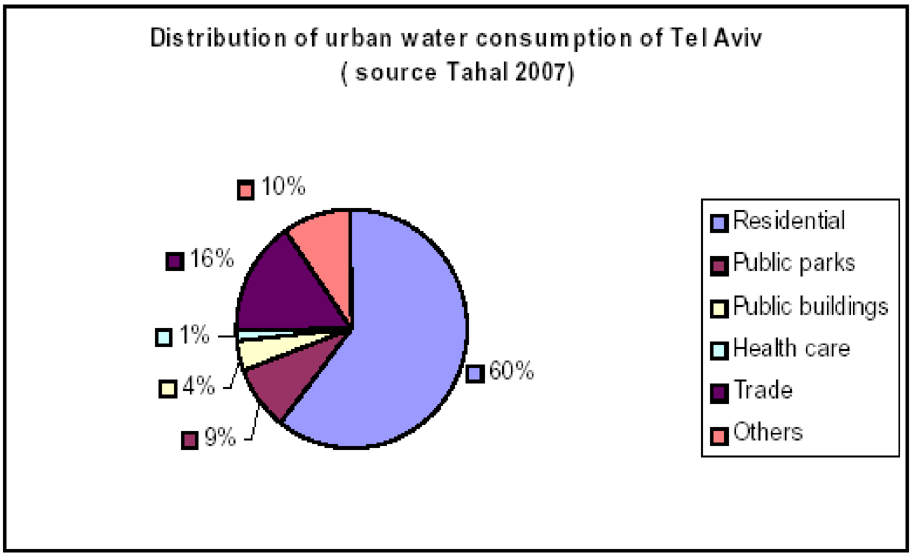

Fig.4. Distribution of urban water consumption of Tel-Aviv-Yafo.

The volume of Tel-Aviv water reservoir is 45,000 m^3 which is only 1/3 the amount of daily consumption in the city. In case of emergency such as war, water terror etc., this will not be enough if the external supply of water will stop for more than one day. Only few local wells (about 11) are still operating for supply of drinking water (Fig. 5). It is common in the world to force security radius around the wells and to forbid any activity in this radius in order to protect the wells. This security radius is missing in Tel-Aviv wells due to the dense structure of the city and the high price of land. Due to these facts Sevrldov and Gvirtzman (2009) offered to purify the coastal aquifer contaminated wells by stopping the pumping, and to use the local wells only as water reservoir for a case of emergency.

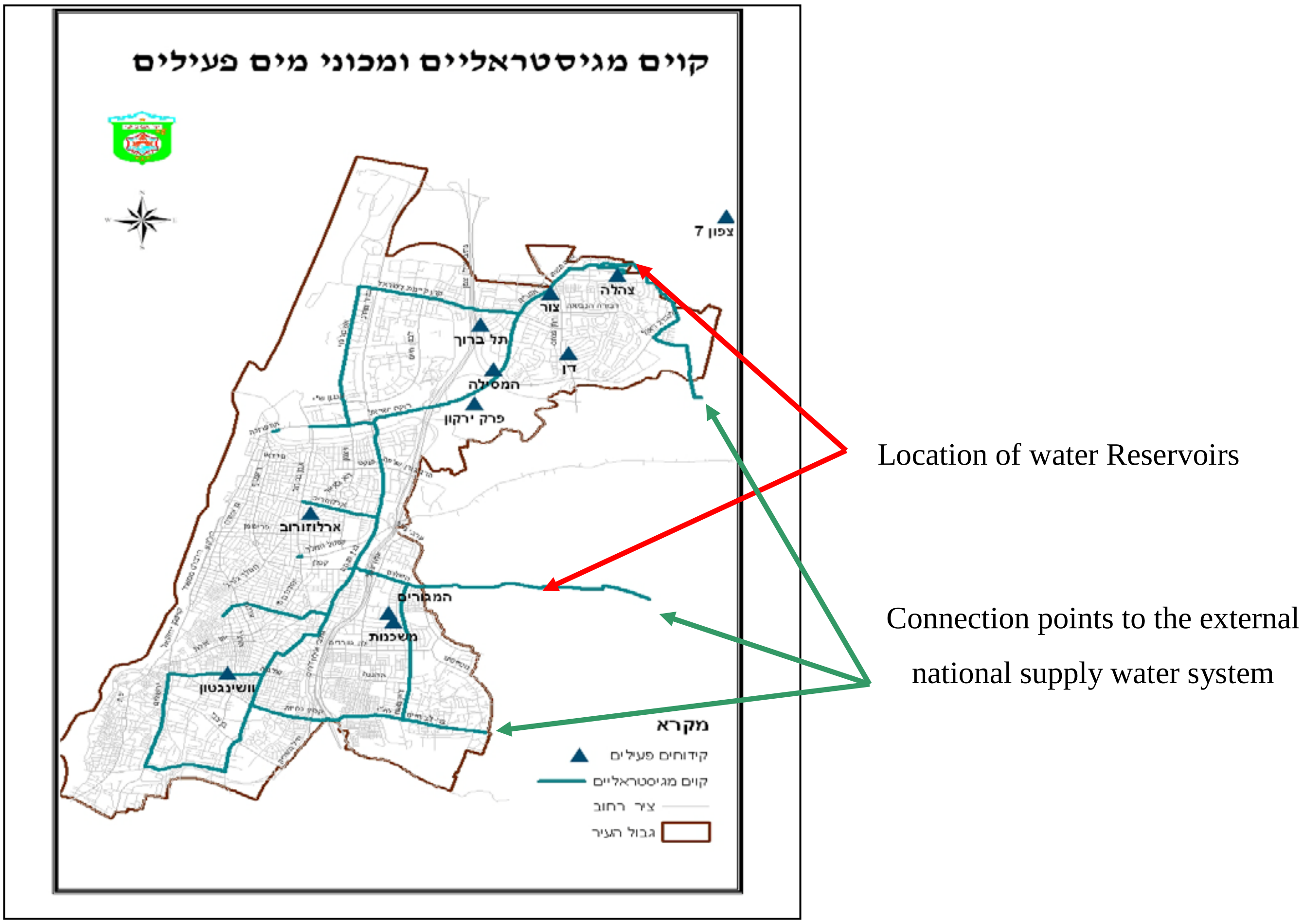

Fig. 5. Active local wells (blue triangles), location of the water reservoir and the main supply water pipe system.

In order to evaluate the condition of the supply water pipes the **PVA** – **P**ipe **V**ulnerability **A**ssessment indicator was offered by the people of Mei-Avivim. This indicator takes into account both the material and the age of the pipe. The good grade of 82 from 100 and the low water lost (Table 1) indicate that the water supply pipes are in reasonable state but a good maintenance of the system must continue in the future in order to upgrade and to prevent degradation of the system.

The supply water quality in Tel-Aviv is strictly controlled. Quality tests are done all over the year in 64 points around the city, in the local wells, in the reservoirs and in the connecting points to the external national water system. All the tests are done according to the instructions of the Ministry of Health. Almost 1800 quality tests are done each year and as can be seen in Table 2, at the last years the number of irregular samples was less than 1%. All these irregular samples were found to be intact in revalidation tests.

Table 2. Number of irregular samples that were found during the years 2004-2008 (source: Mei-Avivim)

	N° of samples	**N° of irregular samples**	**Percents of irregular samples (%)**
2004	1581	13	0.8
2005	1731	16	0.9
2006	1768	13	0.7
2007	1793	8	0.4
2008	1816	15	0.8

Table 3. Number of calls to the municipal telephone service center between the years 2006-2009 due to drainage and sewage problems and floods.

Month	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**Sum**
Sum Sewage	4059	3463	3403	2839	3011	2602	2944	2889	2867	3346	3649	3998	39070
Sum Drainage	412	269	50	32	2		1	2	5	328	341	758	2200
Sum	4471	3732	3453	2871	3013	2602	2945	2891	2872	3674	3990	4756	41270

The sewage system – Surprisingly and in contrast to the strict quality control of the supply water system, still today there are more than 480 cesspits which scattered all around the city (Fig. 6). These primitive cesspits may lead to nitrate contamination of the coastal aquifers and to water loss. Also the condition of the sewage pipes is bad, they get PVA grade of 43

from 100. The bad condition of the pipes may explain the high number of calls to the municipal telephone service center due to sewage flooding in the city (Table 3). This condition is not acceptable especially when the forecasts predict significant higher loads in the future due to 15% population growth.

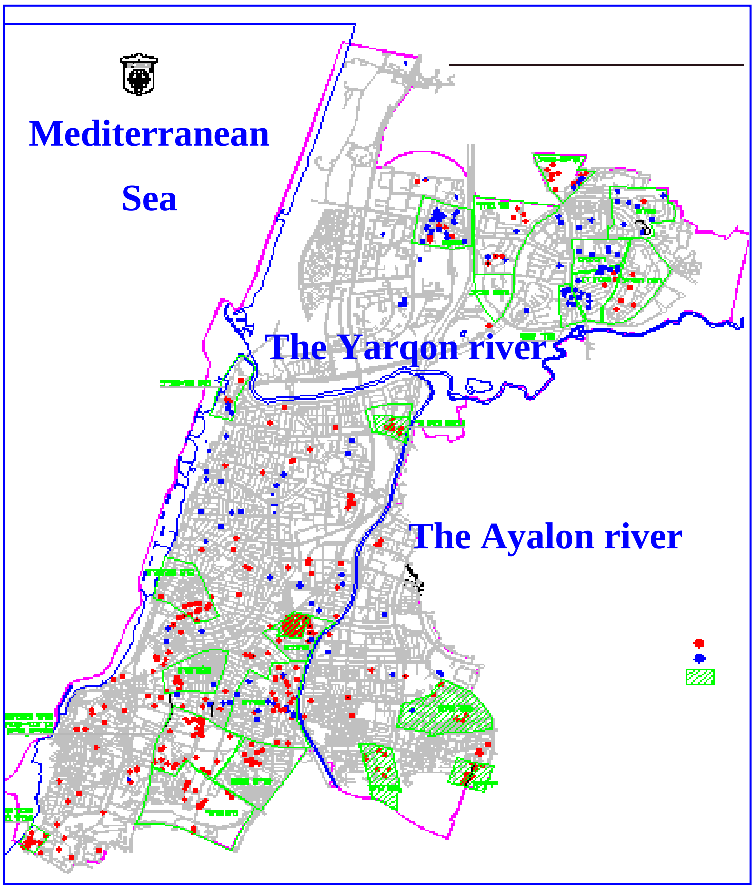

Fig. 6. Active cesspits in Tel-Aviv (the blue and red points).

Drainage water system – The annual precipitations in Tel-Aviv (530 mm) are a little bit lower than London (580 mm) but it concentrated in very short and singles events which lead to high run off. According to a simple calculation the amount of water that falls in the area of Tel-Aviv is 25 millions m^3 which is about 50% of Tel-Aviv yearly consumption. While the last regulations state that 20% of the area in new building must be exposed in order to increase the water percolation to the ground, it seems that not enough is done in order to fulfill that large potential of rain harvesting in Tel-Aviv.

It is common in the world to design the urban water drainage system for 50 years events. In Tel-Aviv the drainage system have been design for only 2 years events and almost every winter Tel-Aviv citizens are suffering from event of floods as can be seen from the high number of calls to the municipal telephonic service center (table 3). It must be emphasis that most of Tel-Aviv citizens got used to the flooding events in winter and therefore they do not call to the telephonic center, meaning that the number of calls represent only extraordinary events of flooding.

The coastal aquifer **–** The unsustainable development of Tel-Aviv regarding its urban water system, the unawareness for environmental quality issues and the lack of control on contaminators, led to severe pollution of the coastal aquifer in the area under Tel-Aviv city. Although today the environmental regulations are strictly control and many afford are done in order to prevent the spreading of the contaminated area, it is needed large investment and plenty of time until the contaminated wells will be again appropriate for use.

Today, only 11 local wells are active while about 50 local wells are inactive due to high concentration of contaminants. The source of these contaminants is either non-point type such as salty sea water intrusions that led to high chloride concentrations (Fig. 7B), or point type such as trichloroethylene pollution from an old and inactive weapon factory (Fig 7A) and chrome pollution from the southern industrial area (Fig. 7C).

The Ayalon River **–** only small part of Ayalon River is found in Tel-Aviv area. It drainage basin cover large part of central Israel (Fig. 8) and Tel-Aviv has minority effect on the quality and the quantity of the flow. Still this river has influence on the city life and also on the Yarqon River water.

In summer time, sewage and effluents form several sources (such Ben-Gurion airport and Ayalon waste water plants) are flowing in the upper part of the river. In the entrance to Tel-Aviv municipal area they are stopped by a very basic and simple dam made of ground which called "Shetoolim dam". From this dam they are pumped to the Shafdan sewage system. Therefore, the part of Ayalon River in the area of Tel-Aviv is dry during the summer unless exceptional events such as sewage flowing

from Tel-Aviv drainage system or sewage over flow in the upper part of the river that Shetoolim dam is not capable to stop.

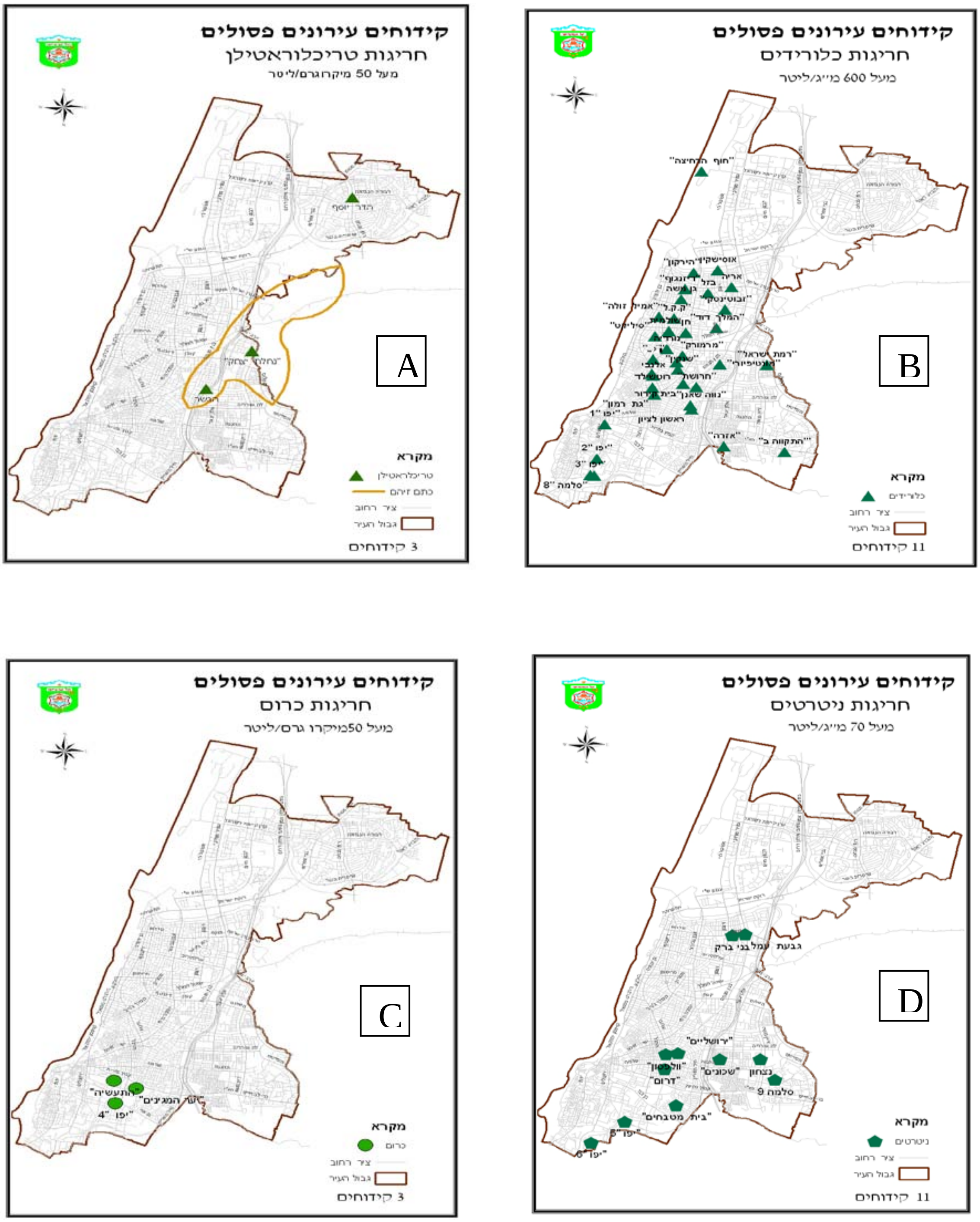

Fig. 7. Contaminated wells in the coastal aquifer in Tel-Aviv: (A) Due to Trichloroethylene (>50 μg /L), (B) Due to Chloride (> 600 mg/L), (C) Due to Chrome (>50 μg /L), (D) Due to Nitrate (>70 mg/L).

In winter times, Shetoolim dam can not stop the high quantity of water that flow in the river and the part of the river in Tel-Aviv is filled and flowing to the Yarqon River. The upper stream water are storm water and sewage mixed together which effect the quality of the Ayalon River water in Tel-Aviv area. Also the drainage system of Tel-Aviv is partially directed to the Ayalon, thus, also affecting its water quality. The Ayalon traffic routes are one of the main routs in Israel located along the river. In extreme rainy events the Ayalon River may flood and stop the traffic in Ayalon routes as happened in the famous rainy season of 1991-1992.

Fig. 8. The Yarqon and Ayalon rivers drainage basins.

<u>The Yarqon River</u> – The Yarqon River and its surrounding park – Ganei Yehoshua, have very important role in Tel-Aviv city life, it used for vacations, jogging, it is the green lunge of the city and more. Some will even compare it to central park in New-York. Some unique and endemics species are living in the Yarqon River ecosystem such as the famous fish *Acnthobrama telavivensis*, that large affords were invested in order to prevent its extinction.

Naturally, the Yarqon springs which feed the river have a flow of 25,000 m^3/hour and in the past it was the second largest river in Israel after the Yarden. In the early 60's

of the last century the Yarqon-Negev western and eastern lines were build in order to transfer the Yarqon springs water and the National water carrier to the Negev desert. Tel-Aviv water supply system was also connected to the western line. As a result, the water flow in the river decreased dramatically and it is now only 2% of the natural flow.

Today, the Yarqon is divided to three parts (Fig. 9): (a) The upper stream clean part (7 Km) – where small amount of about 200-400 m^3/day are fed from the Yarqon springs, (b) The polluted part (16 Km) – where about 1200 m^3/day of high quality tertiary effluent are flowing into the river, (c) The salty part (4 km) - which has estuarial ecological system and this is the part that found in Tel-Aviv municipal area.

Fig. 9. Yarqon River three parts: (blue) The clean part, (red) the contaminated part, (black) the salty part that found in Tel-Aviv municipal area**.**

A lot were done by the Yarqon River Authority and Tel-Aviv municipality in order to prevent pollution of the river by the city. Pumping stations were built along the river in order to prevent flow of the drainage system into the Yarqon River in summer time. This may happen when there is local sealing in the sewage system and the sewage are flowing in the drainage system. The pumping stations pump these sewage from the drainage system back into the sewage system that flow to the Shafdan. Still from time to time there are local events of pollution from Tel-Aviv and also pollution in the upper parts of the river. A very serious pollution event happened in 2008 when

large amounts of detergents flow from Sano factory to the upper part of the river. This led to almost complete extinction of the river ecosystem and currently the river ecosystem is in its first steps of recovery.

In winter, large part of the drainage system is directed to the Yarqon River. The pumping stations do not have the ability to pump the high quantities of water and this lead to pollution as can be seen in Fig. 10. It must be emphases that flood in the river are part of its natural ecosystem. These floods are cleaning the river, mixing the sediments and bringing nutrients. But the floods from the city are bringing large amount anthropogenic pollutants that contaminate and affect the water quality and the ecosystem of the river.

Fig. 10. Flood in the Yarqon River and the accompanied anthropogenic pollution.

<u>The Mediterranean Sea</u> **–** The Mediterranean Sea has an important role in the tourism and the city life. The sea volume is huge as compared to the volumes of the others Tel Aviv water system components. The Authorities in Israel and Tel-Aviv are acting according to Barcelona convention (1976) and therefore there is no delivered flow of sewage or other type of waste into the sea. From while to while there is event of sewage discharged into the sea resulted from accidences, but the large volume of the sea limits the damage and insures that the ecosystem of the sea is not threatened by the city in sustainable time scales.

2.5 Conclusions on Phase I

Tel-Aviv urban water system profile was prepared as background for phase II of the process – creating the city water system vision. For this purpose, the main points of the profile presented in the former chapter, are summaries here by using SWOT methodology. The SWOT methodology was successfully used during the process of Tel-Aviv City Strategic Planning during the years 2001-2006.

Strengths of Tel-Aviv urban water system

Developed system

Highly maintained (supply system)

Low energy consumption

Transportation of all the sewage out of city

Strict water quality control

Water education program

Yarqon protection action

Weaknesses of Tel-Aviv urban water system

High residential water consumption

Floods – inappropriate drainage system

Old sewage system (480 cesspits)

Expensive land

Yarqon and Ayalon rivers, Coastal aquifer pollutions

Small emergency reserves

National water shortage

***O*pportunities of Tel-Aviv urban water system**

New water resources:

Local desalination plants

Rain harvesting

- Water from Turkey

Water reuse

Waste water treatment plant?

Gray water reuse

Water consumption saving

Saving in the residential sector

Natural water bodies rehabilitation

Ayalon river

Yarqon river

Coastal aquifer

***T*hreats of Tel-Aviv urban water system**

15% population growth (in 2025)

Collapse of old parts in the system

National water shortage

Coastal aquifer pollution (gasoline stations, salty water)

Break of external water supply (war, terror, water pollution, earth quake)

3. Phase II: Vision and Goals

3.1 Methodology

The methodology adopted for executing Phases II and III of the Work Plan is based on the accepted procedure for developing indicators for sustainable urban water systems, as presented and applied in various papers published within the past few years. According to these studies, the procedure consists of the following four steps:

1. Defining and formulating the overall vision and the goals that it dictates.
2. Defining: a) the systems' boundaries, geographically and/or as relating to the systems' infrastructure and unit operations limits (the terminal points of each system upstream and downstream), and b) the planning horizon (usually 20-25 years, but some recommend to plan longer range – 50-100 years).
3. Defining the framework for the actions and/or means proposed to make the vision and its associated broken-down goals a reality. In the first stage all possible actions and means are listed. In the second stage this list is reduced, using among other tests a cost-benefit analysis, in order to concentrate on a limited list of those actions and means that will have the largest impact.

4. Selecting a limited number of indicators that will enable giving quantitative "dimensions" to the current, initial state and performance of the systems (identifying, by comparison to each indicator's desired and/or required value, existing problems, if and where such exist) and to the systems' state and performance at any future point in time, taking note of changes that have taken place in the external conditions (population size, nature and extent of economic activities, climate changes, etc.) and changes that are a result of applying the selected actions and means (enabling assessing the effectiveness and efficiency of each action and means), including identification of trends and future issues and problems.

3.2 Approach

Our approach for performing each of the four procedural steps, according to the ethodology described in Chapter 3.1 above, was:

Step 1 - Defining the municipal water systems' vision and goals

The approach taken for performing this step was to ensure that city's water systems' vision conforms to the city's overall vision, as defined by the municipality, while accentuating aspects of sustainability, as required by the SWITCH initiative, and health, environmental and social aspects, as demanded by many Water Club members. Chapter 3.3 below presents the vision as defined by a consensus of Steering Committee and Water Club members. As can be seen, the definition is short and general and includes all the goals common to water systems, whether national or municipal, such as water supply reliability, quality and efficiency, etc., as well as the above noted SWITCH and Water Club emphasized aspects.

The Tel-Aviv-Yafo municipal water systems' goals are derived not only from the vision, but also from the characteristics and boundaries specific to these systems. They are presented in Chapter 3.4 below. As can be seen, part of the goals common to comprehensive municipal water systems, such as goals that relate to water sources and production facilities, and to systems that treat the cities' sewage, their quality control and reuse, are not included within Chapter 3.4. We will see later that, likewise and correspondingly, the list of actions and means required for achieving these goals is also limited.

Step 2 – Defining the municipal water systems' boundaries

The approach to performing this step was to examine, as the point of departure, systems boundaries and sustainability issues and requirements as broad and comprehensive as possible, covering the full potential range of characteristics and conditions possible anywhere in the world for municipal water systems. These extreme-situation boundaries, issues and requirements will then provide a perspective and serve as a reference for comparison with the more limited boundaries, issues and requirements that correspond to the specific characteristics and conditions of the Tel-Aviv-Yafo municipal water systems.

Chapter 3.5 below presents the boundaries of such fully comprehensive urban water systems, and Chapter 3.6 below their sustainability issues and requirements.

The Tel-Aviv-Yafo municipal water sector consists of three systems: the water supply system, the sewage system and the drainage system. The description and characteristics of these systems is presented within Chapter 3.7 below. The differences between these systems

and the comprehensive municipal water systems described earlier are discussed in Chapter 3.8 below, as a background for and an explanation of the Tel-Aviv-Yafo municipal water systems' boundaries, which are defined in Chapter 3.9 below.

As will be shown in Chapter 3.8, the scope of services and activities of Tel-Aviv-Yafo's municipal water systems are significantly more limited than those of the comprehensive municipal water systems which served as a reference, due to the fact that they are part of an integrated national water supply system and part of a regional system that treats sewage and disposes its effluents (for agricultural reuse) and sludge. And since the scope of services and activities of the Tel-Aviv-Yafo municipal water sector are more limited, so are its boundaries.

Step 3 - Defining the actions and means for achieving the municipal water systems' vision and goals

The approach to performing this step was to prepare comprehensive lists of actions and means that are suited, specifically, to each of Tel-Aviv-Yafo's municipal water systems and reducing these lists through tests, comparisons and prioritization. The approach required that all actions and means on the list will be subjected to quantitative techno-economical analyses and, before they are adopted, prioritized and scheduled, they must meet the two tests that are normally used for preparing oerational action plans:

1. What is their absolute contribution to the Tel-Aviv-Yafo's municipal water systems' goals (according to the well-known "Pareto Law", about 20% of the proposed actions will generate 80% of the desired benefits) – or, in other words, they should be ranked first on the basis of their absolute contribution.
2. What are their cost-benefit ratios – they should be ranked also according to this criterion.

In fact, due to lack of time, the lists were shortened only through the assessment of a team that included the Steering Committee members and the top technical and administrative personnel of the municipal water corporation "Mei Avivim". This team pared down the list by deciding, according to their experience, which actions are feasible and practical, and, more importantly, the results of which actions can be monitored and measured by the criteria detailed in Step 4 below. Many actions and means originally on the list were rejected as not

feasible and/or too costly and/or not within the control of the municipal water corporation or the municipality's Drainage Department, as the case may be.

The list of means and actions that survived this elimination process is presented in the second column of the tables within Chapter 4 below (the first column shows the goals that were established for the Tel-Aviv-Yafo municipal water systems).

<u>Step 4 – Selecting and quantifying the indicators</u>

The criteria established by the Steering Committee for selecting the indicators were:

1. Simplicity
2. Relevance
3. Transparency
4. Cost-benefit ratio

The approach to performing this step was to prepare, similarly to Step 3, an initial comprehensive list, which included also some useful suggestions from the Water Club, and to pare this list through tests, comparisons and prioritization. The third column of the tables within Chapter 4 below exhibits the pared down lists of indicators that met the above criteria and passed the scrutiny of the Steering Committee members and the top Mei Avivim technical and administrative personnel.

3.3 Tel-Aviv-Yafo's Urban Water Systems' Vision

Tel-Aviv-Yafo's urban water systems' vision must conform to the overall, general vision of the city and serve its objectives. Beyond supporting these objectives, the water systems' vision and the strategies for its implementation must be based, where and as far as possible, on the principles of sustainability and economic, environmental and social aspects, as these have been defined in the literature:

> *"Sustainable development is development that satisfies the needsof the present without compromising the ability of the followinggenerations to satisfy their own needs"*

"Sustainable urban water systems are systems that meet the needs of the community that are dependent on the supply of water at minimal cost and minimal negative social and environmental effects"

The overall, general vision of the city was defined by the Strategic Planning Unit of the municipal Engineering Administration as:

"Tel-Aviv-Yafo will preserve itself as Israel's commercial and cultural center while raising the quality of life of its residents"

It is immediately seen that that in the last part of the city's general vision, which relates to the raising the quality of life of the city's residents, there is a built-in contradiction to the sustainability principle: raising the quality of life, as well as the standard of living of the city's residents, involves (like in any other place in the world) increasing per capita water consumption (as well as the consumption of other limited resources).

After lengthy debates, in which almost all members of the Steering Committee and the Water Club participated, the following formulation of the city's urban water systems' vision was agreed upon:

"The water, sewage and drainage systems of Tel-Aviv-Yafo are reliable, efficient and sustainable, and advance values of service, fairness and equality and aspects of public health and the environment"

3.4 Tel-Aviv-Yafo's Urban Water Systems' Goals

Following are the goals which result from Tel-Aviv-Yafo's Urban Water Systems' vision (Chapter 3.3 above):

Goals common to all the systems

- Development, operation and maintenance of the system at optimal costs
- Optimal service quality to all consumers
- Fairness and affirmative action to the southern and eastern sectors of the city

Goals of the Water Supply System

- A reliable supply of water to all municipal consumers
- A water supply quality, at the consumers' taps, that meets the requirements of the national Public Health Regulations
- Preventing the contamination of the water supply and the environment and advancing the removal of existing contaminations
- Preventing waste of water and energy in the system

Goals of the Sewage System

- Connecting, collecting and transporting the sewage efficiently from all its producers
- Avoiding sewage related sanitary and environmental hazards
- Preventing contamination of the municipal sewage by hazardous industrial and commercial effluents

Goals of the Drainage System

- Managing the run-offs within the city limits in a manner that maximizes its benefits and minimizes its damages
- Reducing flood damages, including environmental damages, as a result of abnormal rain events
- Advancing the integration of municipal storm water runoff within the management of drainage basin runoff.

3.5 Typical Boundaries for Comprehensive Urban Water Systems in the World

(Derived from papers that summarized studies of various
Sustainable urban water systems in the world)

Water Supply System

From the points of pumping the water from its natural sources (rivers, lakes, aquifers, etc.), sometimes by extending the system's boundaries geographically beyond the city's limits, even to the point of including the entire drainage basin which feeds these sources; **through** the municipal conveyance subsystems to the City, the water treatment facilities (particularly

where surface water is supplied) and the distribution networks to the consumers, **until** their connections to the domestic, industrial and commercial consumers pipe terminals.

Sewage System

From the terminals of the consumers sewage discharge pipes, **through** the sewage conveyance subsystem to the municipal sewage treatment plant and from these plants **until** the effluents disposal points, to nearby natural water bodies (rivers, lakes or sea) or to reuse applications sites (agricultural and industrial), including subsystems for treating or generating the by-products – sludge, bio-gas and heat – and the transport of the sludge **to** an approved disposal site or to agricultural reuse sites.

Drainage System

From the municipal collection points **to** the nearest natural water bodies or to reuse application sites.

3.6 Sustainability Issues and Requirements for Comprehensive Urban Water Systems in the World

Sustainability Issues

Below is a list of the main sustainability issues that have to be dealt with, which were identified through our literature survey:

- Water supply shortages, even in countries with abundant rainfall (due to climate changes, rainfall reductions, increased demand due to population growth, economic development and higher standards of living).
- Deteriorations in the quality of natural water supply sources (due to over-pumping, lowering of aquifer levels and seawater intrusion, anthropogenic, industrial, agricultural and even domestic pollution, increased usage of river water, with upstream users discharging the treated sewage back to the same river and affecting the downstream users).
- Deterioration of the entire ecological system surrounding natural water sources, including eutrification of water bodies and increased toxicity of both the water bodies and the soil above and along-side these bodies.

- Flooding due to extreme rainfall events (whose number and frequency are expected to increase as a result of the ongoing climate change).
- Sanitary and environmental hazards resulting from disposals of solid and liquid waste, treated effluents and sludge.
- Environmental hazards due to infrastructure work related to expanding the water supply, sewage and drainage systems themselves.

Sustainability Requirements

Following are some of the requirements that have been suggested for increasing the sustainability of urban water systems, according to the papers reviewed by us:

- Viewing the water supply, sewage and drainage systems as a single, integrated system.
- Viewing treated sewage and rain runoff as usable water resources.
- More efficient management of the water systems.
- Allocation and diversion of water to preserve nature and for landscaping.
- Reducing:

a) water demand (avoiding waste and economizing);

b) water losses due to pipe leakages;

c) land usage;

d) energy consumption;

e) chemicals usage;

f) sanitary and health hazards;

g) environmental hazards, including nutrient loads in discharges to water bodies, pollutants within disposed sludge (mainly heavy metals);

h) costs;

i) flood damages.

- Increasing water reuse.
- Reusing the nutrients in the sewage (through agricultural irrigation).
- Energy recovery (e.g. from bio-gas derived in sewage treatment plants)
- Infrastructure and equipment renewal and/or modernization.

3.7 Tel-Aviv-Yafo Urban Water Systems' Description and Characteristics

General

Tel-Aviv-Yafo, which is the business, cultural and shopping capital of Israel, occupies an area of about 5,000 hectares. It has about 400,000 residents, but during the week-days this number grows to about 1,000,000 people, due to the influx of workers, shoppers and entertainment seekers who are not city residents.

Phase I final report provides full details about the city and its water sector. The following is only an abbreviated summary of its main features and figures, particularly those that are relevant to and specifically impact the results of our study.

The City's Water Supply System

There are no formal restrictions on the quantities of water that the city can receive from the national water supply system. In 2008 the annual quantity received was about 44 million m^3. Self production of water by the city from the wells within its municipal boundaries (about 10 active wells) during this year was only about 4 million m^3, or about 9% of total municipal water supply (about 48 million m^3 or about 122 m^3/capita/year).

The system's storage capacity is 45,000 m^3 and the combined length of its distribution piping network or grid is about 950 km.

The Mekorot Water Company is responsible for ensuring the quality of the water delivered to the city from the national water system. The company relays the results of all water quality tests conducted by it to the Health Ministry's water quality control unit, which passes them on to the municipal water corporation, Mei Avivim. Water quality control within the municipal water supply system itself, beyond the interconnections to the national water supply grid, is the responsibility of Mei Avivim, which samples the water at the locations and frequencies mandated by the Ministry of Health, and delivers the samples to be analyzed by the Ministry's laboratories. The city's water treatment activities are limited to the chlorination of the water produced from its wells.

Municipal water usage and consumption is divided as follows:

- Domestic - about 27 million m^3/year or 58% of total municipal water supply;
- Industry and commerce - about 8.9 million m^3/year or 18.5% of total municipal water supply;
- Agriculture - about 2 million m^3/year or 4% of total municipal water supply;
- Public institutions (municipal parks, education, hospitals, etc.) - about 3.7 million m^3/year or 7.7% of total municipal water supply;
- Municipal parks - about 3.5 million m^3/year or 7.3% of total municipal water supply;
- Unaccounted water (difference between purchased and self-produced water quantities and the total quantity of water supplied to consumers) - about 2 million m^3/year or 4.4% of total municipal water supply.

The City's Sewage System

The city's sewage system is owned, operated and maintained by Mei Avivim. It does not include sewage treatment, effluent and sludge disposal and the generation and use and/or generation of energy as part of these activities, but only the collection of the sewage and their transport to the regional collection headers that transfer the sewage from all neighboring towns to the regional sewage treatment plant south of the city of Rishon Le-zion, the "Shafdan".

The regional sewage collection headers and the Shafdan sewage treatment plant are operated and maintained by the "Dan Cities Sewage Association", known by its Hebrew acronym as "Igudan". This is sewage corporation owned under partnership by the municipality of Tel-Aviv-Yafo (whose representative is the chairperson), 6 other nearby municipalities and 15 other local urban authorities. Altogether, about 2.5 million people receive sewage collection and treatment services from Igudan.

The regional sewage collection headers and the Shafdan are shown in Figure 1 below.

The combined length of Tel-Aviv-Yafo's inter-city sewage pipelines is about 595 km, and the volume of sewage transported by these lines is, on the average, about 114,000 m^3/day.

According to Igudan estimates, the city generates about 31.4 m^3/year of sewage. This amount corresponds to about 65% of the total annual municipal water supply or about 79 m^3/capita/year.

The City's Drainage System

The city's drainage system, which is operated and maintained by the municipal Drainage Department, can handle all storm-water flood events on a scale that occurs once a year, on the average.

The combined length of Tel-Aviv-Yafo's drainage pipes and channels is about 230 km.

These discharge the storm-water to the Ayalon Canal, the Yarkon River and the sea. The Ayalon Canal is capable of evacuating flows of up to 420 m^3/sec, which correspond to flooding events that occur, statistically, once every 25-30 years, and the Yarkon River can handle flows of up to 800 m^3/sec.

Fig. 11. The Igudan regional sewage collection headers and Shafdan treatment plant

3.8 The Differences Between Tel-Aviv-Yafo's Urban Water Systems and Typical Urban Water Systems in the World

- The Tel-Aviv-Yafo municipal water sector is more advanced and sophisticated than most of the corresponding municipal sectors that were analyzed, tested for sustainability and efficiency and reported in the literature we surveyed. It is part of the national water sector, which is well known for its high standard of planning and managing, and all its systems are already operated in an integrated and efficient manner (though, as demonstrated in this document, there is always room for improvements). In fact, as noted earlier, prior to the formation of the municipal water corporation, Mei Avivim, the city's water supply, sewage and drainage were all under the same municipal department. On the national level, the extent of sewage treatment (tertiary treatment is mandated by regulations) and the percentage of effluent reuse (over 75% today and over 85% within 5 years) are unmatched anywhere, storm runoff catchment and infiltration to the aquifers has been practiced for over 30 years, salinized and/or contaminated groundwater is being increasingly treated, and large-scale seawater desalination is employed to close the gap between increased demand and limited natural water sources and to improve, through blending, the quality of municipal water supplies.
- Since it is part of the national water system, the municipal water sector does not have to produce most of the water that it supplies to its consumers. Over 90% of this supply comes from the national grid, whose sources lie outside the municipal boundaries. Within the national water system, surface water treatment (filtration and disinfection of Sea of Galilee water delivered through the National Carrier) and quality control are performed by a highly professional and experienced Mekorot team, centrally, on a large scale, with clear economies of scale. The municipal wells, which provide the remaining 10% of demand, serve mostly as backup and a strategic reserve for emergency situations.
- The national water sector has a shortage of natural potable water, but, Israel being a coastal country, the availability of an indefinite amount of seawater, which can be readily desalinated, also on a large economical scale, assures that, in the long run (beyond the next three years when two large plants will go on stream), Tel-Aviv-Yafo will not suffer from water shortages.

- With desalinated seawater, whose quality is significantly higher than that of the natural water sources, becoming an ever larger component within the national water system, the forecast is for considerable improvements in the quality of the municipal water supplies (softer water, lower levels of chloride, sodium and nitrates), and, downstream, in the quality of the effluents produced in the Shafdan and reused for agricultural irrigation.
- Nevertheless, since seawater desalination plants are larger consumers of energy (though their use saves energy for pumping alternative natural water from the north and their soft product water reduces scaling of heat transfer surfaces which reduces the efficiency of water heating), energetic and environmental sustainability principles require that an effort be made to avoid water wastage and reduce consumption.
- The city has a serious problem with groundwater salinization due to seawater intrusion and contamination due to historic industrial effluent ground disposals and to gas stations and sewage line leaks. Without corrective action, the contamination plume, which is already a health hazard, will expand and disable use of additional city wells (twenty years ago there were 33 active wells and today only 10 are usable).
- The city has a well developed and efficient sewage system. As much as 65% of the water supplied to the consumers is collected and delivered to Shafdan (the balance is used mostly for gardening and is lost) and after Soil Aquifer Treatment (SAT) becomes an additional national resource. (Nevertheless, there are still about 700 cesspools within the city limits, and these should be eliminated completely.)
- The sewage treatment systems themselves (the Shafdan and the SAT system), however, unlike most other municipal sewage systems reviewed by us, do not lie within the city limits and are not part of the city's sewage system. The issues of conserving and reusing the sewage nutrients and of generating bio-gas are not relevant to the Tel-Aviv-Yafo sewage system.
- The Shafdan's effluents are exported to the south of the country and are thus unavailable for reuse within the city. However, it is possible to use effluents from the sewage treatment plants of municipalities northeast of the city for municipal parks irrigation and for the recreation around Yarkon River. Recently a Yarkon River Rehabilitation project is being completed, initiated by the Yarkon River Authority and Mekorot.

3.9 Tel-Aviv-Yafo's Urban Water Systems Boundaries

Tel-Aviv-Yafo's urban water systems' boundaries are therefore:

The City's Water Supply System

From the municipal pipeline connection points to the national water system and to each of the operating municipal wells **until** the connection points to the water pipes of each of the municipality's domestic, industrial, commercial, public institution and other water consumers.

The City's Sewage System

From the sewage discharge points of each of the municipality's domestic, industrial, commercial, public institution and other clients **until** the sewer lines' connections to Igudan's regional sewage collection headers, which relay the sewage to the Shafdan.

The City's Drainage System

From all points of collecting the rain runoff throughout the city **until** their discharge points to the Ayalon canal, the Yarkon River and the Mediterranean Sea (11 sea outlets). The system includes also the means for evacuating storm water from the drainage basins feeding the Ayalon canal and the Yarkon River.

4 Phase III: Actions, Means and Indicators

The actions and means selected, as described in Chapter 3.2 above, for achieving each of the goals set out in Chapter 3.4 above, and the indicators proposed for monitoring their effectiveness and rate of progress are listed in the following tables.

It is seen that for most of the goals (the first columns) more than one activity or means have been proposed (the second columns) and their effectiveness and rate of progress will be monitored by more than one indicator (the third columns).

All in all, there are 18 goals, 37 actions and means and 48 indicators. These have been divided into four tables, one table (Table 4) for goals common to all of Tel-Aviv-Yafo's

urban water systems and three tables (Tables 5, 6 and 7) - one for the goals of each the three systems.

For each indicator three figures have been established, one for its desirable or ideal

Value (the fourth columns), one for its current value (the fifth column) and one for a target value, deemed practical and aimed to be achieved within the next 5 years.

We have also included, for informational purposes, a fifth table (Table 8) which lists the indicators that, as noted in Chapter 3.2 above, were considered but rejected by the Steering Committee members and the top Mei Avivim technical and administrative personnel as being impractical or too difficult or too expensive to monitor (e.g., the percent of storm water run-off within the total amount of sewage transported by the municipal sewage system to the regional headers).

As can be seen, since a relatively large number of indicators did pass this screening, some of those rejected were actually different ways of measuring the effects of the same actions and means, and their contribution to these measurements would have been marginal.

Also, for the sake of simplicity, some cumbersome and complicated indicators were replaced by their abbreviated versions. For example, one of the rejected indicators for measuring the success in achieving the goal of "development, operation and maintenance of each system at optimal costs" was to compare the actual cost with a "normative costs" table, which would cover the reasonable costs of a representative list of major works and items of equipment. Instead, as can be seen from Tables B, C and D, the "normative costs" of a minimal reference list of only one type of equipment, 3–5 pipe sizes, was used for each of the three municipal systems.

Table 4. Goals, actions, means and indicators common to all municipal water systems

Goals	Actions and Means	Indicators	Desired values	Current values	5 year target
Improving consumer service	Formulating and adopting a Service Charter	Consumers' satisfaction	5*	No information currently	4*
	Improving the efficiencies of the organizations and procedures dealing with consumer needs and complaints				
	Rapid and efficient responses to failure events in any system	Failure events' notifiers' satisfaction	5*	3.4*	4*
Information transparency	Making all information relating to any system easily accessible to the public	Consumers satisfaction with the information's quality and transparency	5*	No information currently	4.5*
Fairness and affirmative action to the city's southern and eastern sections	Under equal conditions, giving priority to the improvement of infrastructure and services to these less affluent and developed city sections	The specific city sections' residents' satisfaction	5*	No information currently	5*

- On a scale of 0 to 5

Table 5. The municipal sewage system's goals, actions, means and indicators

Goals	Actions and Means	Indicators	Desired values	Current values	5 year target
A reliable water supply to all the municipal consumers	Adding new water supply sources by desalinating groundwater impaired by seawater intrusion near the shore for local gardening	Extent of municipal desalination	2 million m^3/year	0	0.5 million m^3/year
	Increasing the system's storage capacity	Municipal water storage capacity	60,000 m^3	45,000 m^3	55,000 m^3
	Augmenting and renewing the system's infrastructure and equipment	Average age of pipelines-	25 years	30 years	28 years
		Annual pace of replacing old and/or leaking pipes - as % of total pipelines length - as km per year	 4% 40 km	 0.8% 8 km	 2.5% 25 km
		Annual number of local water supply cutoffs due to equipment failures	4,000	9,000	8,000
	Rapid and efficient responses to failure events in the system	Average time for starting repair of equipment failure events	2 hours	3 hours	2.5 hours
	Putting in place means for providing water during emergencies and repairing rapidly infrastructure damaged as a result of war and/or sabotage	The extent of emergency means in place – as percent of means required by government regulations	100%	40%	70%

Table 5. The municipal water supply system's goals, actions, means and indicators (continued)

Goals	Actions and Means	Indicators	Desired values	Current values	5 year target
Water quality, at the consumers' taps, meets all requirements of the national Public Health Regulations	Maintaining the system intact and clean to avoid water contamination and dealing rapidly with excursions in water quality events	Annual number of exceeding water quality events	0	8	1
		Number of streets that could not drink tap water during the year due to excursions in water quality	0	10	0
		The number of annually reported water borne disease cases	0	Unknown	0
		Average time for starting to deal with exceeding water quality events	2 hours	4 hours	3 hours
		Average time for overcoming exceeding in water quality events	2 days	4 days	3days
	Ensuring proper disinfection of the water supply	Chlorine residual concentration levels at the connections to the consumers	0.1-0.5 mg/l	0.1-0.5 mg/l	0.1-0.5 mg/l
	Ensuring proper monitoring of physical-chemical and bacteriological water quality within the system	Samples in which excursions in water quality were detected as percent of all the tested samples	0	0.8%	0.6%

Table 5. The municipal water supply system's goals, actions, means and indicators (continued)

Goals	Actions and Means	Indicators	Desired values	Current values	5 year target
Avoiding water supply and environmental contamination and advancing the removal of existing pollutants	Better inspection of potential groundwater pollution sources threatening municipal wells and stronger enforcement of the law against polluters	Number of municipal wells that are still usable, water-quality-wise	20	11	15
	Pressing for the removal of existing groundwater pollutants by and at the expense of the polluters and/or the government	Annual quantities of groundwater that may be derived through the municipal wells - million m^3/year	5	2.5	3
	Substituting treated effluents for fresh water , where possible	Quantity of effluent utilized for municipal garden	5	0	2
Avoiding waste of water and energy in the system	Informing and educating the public to conserve water Promoting the use of water saving devices by homes and businesses Accelerating the introduction of water meters at the individual consumer's level	Per capita water consumption - Municipal - m^3/c/year - Domestic - m^3/c/year	 100 60	 122 70	 105 65
		Average per business water consumption - m^3/year/ business	400	530	450
		Public gardening specific water consumption - m^3/year/ hectare of garden	4,000	5,300	4,500
		Public institutes water consumption - million m^3/year	1.5	1.85	1.7

Table 5. The municipal water supply system's goals, actions, means and indicators (continued)

Goals	Actions and Means	Indicators	Desired values	Current values	5 year target
Avoiding waste of water and energy in the system (continued)	Reducing unaccounted water losses	Unaccounted water losses	3.5%	4.4%	4%
	Reducing system energy consumption by improving equipment efficiencies, optimizing delivery pressures, etc.	System energy consumption - Absolute – million kWh - Specific – kWh/m^3	 2.5 0.055	 3 0.070	 2.7 0.065
Development, operation and maintenance of the system at optimal costs	Reducing costs through strict bidding processes	Specific cost of water supply	1.7 NIS/m^3	2 NIS/m^3	1.9 NIS/m^3
	Close control of investment and O&M budgets	Costs of laying new steel water pipes, with internal concrete lining and external winding of trio, including accessories, in the 3 main system pipe diameters - 6" - 8" - 10"	Current costs – indexed escalation factors to be applied: 1,700 NIS/m 1,900 NIS/m 2,400 NIS/m	Current costs – indexed escalation factors to be applied: 1,800 NIS/m 2,000 NIS/m 2,500 NIS/m	Current costs – indexed escalation factors to be applied: 1,750 NIS/m 1,950 NIS/m 2,450 NIS/m

Table 5. The municipal water supply system's goals, actions, means and indicators (continued)

Goals	Actions and Means	Indicators	Desired values	Current values	5 year target
Fairness and affirmative action to the southern and eastern sectors of the city	Under equal conditions, giving priority to the improvement of infrastructure and services to these less affluent and developed city sections	Annual pace of replacing old and/or leaking pipes in these sectors vis-à-vis the other city sectors: South (Yafo) sector - as % of total pipelines length - as km per year Eastern sector - as % of total pipelines length - as km per year	Will be established in the future	Unknown	Will be established in the future

Table 6. The municipal sewage system's goals, actions, means and indicators

Goals	Actions and Means	Indicators	Desired values	Current values	5 year target
Connecting, collecting and transporting the sewage efficiently from all its producers	Expanding and augmenting the system to new developed sectors	Number of cesspools in the city	0	About 700	About 350
	Increasing collection in old lesser developed sectors				
Avoiding sewage related sanitary & environmental hazards (including sea and river pollution)	Renewing and reinforcing the system's existing infrastructure and equipment	Annual pace of replacing old lines (with a priority to lines near protective radii of the municipal water wells) - as % of total pipelines length - as km per year	 2.5% 15 km	 1.6% 10 km	 4% 25 km
		Annual number of equipment failures in the system	4,000	9,800	8,000
		Number of annual sea and river pollution events due to system failures	0	5	0
	Rapid and efficient responses to failure events in the system	Average time for starting repair of equipment failure events	3 hours	6 hours	4.5 hours

Table 6. The municipal sewage system's goals, actions, means and indicators (continued)

Goals	Actions and Means	Indicators	Desired values	Current values	5 year target
Avoiding sewage related sanitary & environmental hazards (continued)	Separating storm water runoff from the sewage system	Length of lines receiving both sewage and storm water runoff	0	6 km	4 km
		Number of annual sea and river pollution events due to excess loading by storm water runoff	0	2-3	1-2
Avoiding contamination of the municipal sewage by hazardous industrial and commercial effluents	Better inspection of potential industrial and commercial pollution sources and stronger enforcement of the law against such polluters	Extent of inspection coverage of potential industrial and commercial pollution sources	Coverage of all potential pollution sources	Partial coverage of about 100 potential pollution sources	Expanded coverage of potential pollution sources
Development, operation and maintenance of the system at optimal costs	Reducing costs through strict bidding processes Close control of investment and O&M budgets	Costs of laying new steel water pipes, with internal concrete lining and external winding of trio, including accessories, in the 3 main system pipe diameters: - 25 cm - 30 cm - 50 cm	Current costs – indexed escalation factors to be applied: 3,200 NIS/m 3,500 NIS/m 3,700 NIS/m	Current costs – indexed escalation factors to be applied: 3,500 NIS/m 3,800 NIS/m 4,000 NIS/m	Current costs – indexed escalation factors to be applied: 3,400 NIS/m 3,700 NIS/m 3,900 NIS/m

Table 6. The municipal sewage system's goals, actions, means and indicators (continued)

Goals	Actions and Means	Indicators	Desired values	Current values	5 year target
Fairness and affirmative action to the southern and eastern sectors of the city	Under equal conditions, giving priority to the improvement of infrastructure and services to these less affluent and developed city sections	Annual pace of replacing old and/or leaking pipes in these sectors vis-à-vis the other city sectors: South (Yafo) sector - as % of total pipelines length - as km per year Eastern sector - as % of total pipelines length - as km per year	Will be established in the future	Unknown	Will be established in the future

Table 7. The municipal drainage system's goals, actions, means and indicators

Goals	Actions and Means	Indicators	Desired values	Current values	5 year target
Managing the runoff within the city limits in a manner that maximizes its benefits and minimizes its damages	Utilizing the runoff within the city limits in a manner that maximizes its benefits	Percent of total runoff within city limits that is utilized beneficially	20%	Unknown	10%
	Increasing the ability of the surfaces of public and private areas to percolate runoff into the groundwater	Percent of paved surfaces in new developed sectors that are capable of percolating rain water	15%	Unknown	15%
Advancing the integration of municipal runoff within the management of the drainage basin runoff	Promote the diversion and utilization of Ayalon and Yarkon Rivers flood waters upstream, within the drainage basin	Annual number of flooding events as a result of extreme rain events and Ayalon River and Yarkon River flows – one flood events per number of years	1 per 10 years	1 per 5 years	1 per 7 years
Reducing flood damages, including environmental damages, as a result of abnormal rain events	Renewing and reinforcing the system's existing infrastructure	Annual number of flooding events as a result of infrastructure failures	700	900	800
		Annual flooding damage costs	250,000 NIS	500,000 NIS	350,000 NIS
	Rapid and efficient responses to failure events in the system	Average time for starting repair of equipment failure events	2 hours	6 hours	4 hours

.

Table 7. The municipal drainage system's goals, actions, means and indicators (continued)

Goals	Actions and Means	Indicators	Desired values	Current values	5 year target
Development, operation and maintenance of the system at optimal costs	Reducing costs through strict bidding processes Close control of investment and O&M budgets	Costs of laying new pipes in the 5 main system pipe diameters: - 60 cm - 80 cm - 100 cm - 125 cm - 150 cm	Current costs – indexed escalation factors to be applied: 4,000 NIS/m 4,600 NIS/m 5,000 NIS/m 5,300 NIS/m 5,700 NIS/m	Current costs – indexed escalation factors to be applied: 4,200 NIS/m 4,800 NIS/m 5,200 NIS/m 5,500 NIS/m 6,000 NIS/m	Current costs – indexed escalation factors to be applied: 4,100 NIS/m 4,700 NIS/m 5,100 NIS/m 5,400 NIS/m 5,860 NIS/m
Fairness and affirmative action to the southern and eastern sectors of the city	Under equal conditions, giving priority to the improvement of infrastructure and services to these less affluent and developed city sections	Annual pace of replacing old pipes in these sectors vis-à-vis the other city sectors: South (Yafo) sector - as % of total pipelines length - as km per year Eastern sector - as % of total pipelines length - as km per year	Will be established in the future	Unknown	Will be established in the future

Table 8. Municipal water system's actions, means and indicators that were considered but rejected

System	Goals	Actions and Means	Indicators
Water Supply	A reliable water supply to all municipal consumers	Augmenting and renewing the system's infrastructure and equipment	How many consumers in the year did not receive water for more than 3 hours
	Avoiding waste of water and energy in the system	Reducing system energy consumption by improving equipment efficiencies, optimizing delivery pressures, etc.	System water delivery pressures
	Development, operation and maintenance of the system at optimal costs	Reducing costs through strict bidding processes	Compare actual costs with a developed "Normative Costs" table for the major works and equipment
Sewage	Connecting, collecting and transporting the sewage efficiently from all its producers	Augmenting and renewing the system's infrastructure and equipment	Annual investments in augmenting and renewing the system's infrastructure and equipment as % of their total value
	Avoiding sewage related sanitary & environmental hazards	Separating storm water runoff from the sewage system	Percent of storm water run-off within the total amount of sewage transported by the municipal sewage system to the regional headers
	Development, operation and maintenance of the system at optimal costs	Reducing costs through strict bidding processes	Compare actual costs with a developed "Normative Costs" table for the major works and equipment

Table 8. Municipal water system's actions, means and indicators that were considered but rejected (continued)

System	Goals	Actions and Means	Indicators
Drainage	Managing the runoff within the city limits in a manner that maximizes its benefits and minimizes its damages	Demand water sensitive planning for each newly developed neighborhood	The relative percent of runoff in the new neighborhoods that percolates to the groundwater compared to the percentages in older neighborhoods
		Utilizing the runoff within the city limits in a manner that maximizes its benefits	Area of public gardens irrigated by runoff - hectares
	Reducing flood damages, including environmental damages, as a result of abnormal rain events	Monitoring storm water runoff water quality at key selected point, and particularly at its discharge points to the Ayalon canal, the Yarkon River and the sea, and trying to identify and eliminate pollution sources	Storm water runoff quality at these key selected points
	Development, operation and maintenance of the system at optimal costs	Reducing costs through strict bidding processes	Compare actual costs with a developed "Normative Costs" table for the major works and equipment
		Close control of investment and O&M budgets	Total Drainage Department annual budget

4.1 Conclusion on Phases II and III

It is the hope and the wish of all those who participated in generating this report that their efforts will prove fruitful, and the vision, goals, actions, means and indicators developed and formulated by them will be:

- adopted by the Municipality of Tel-Aviv-Yafo,
- incorporated into its water sector's strategic master planning, and
- employed by the management of each of the three municipal systems.

5 Members of TEL-AVIV "WATER CLUB"

Co-chairs : Avi Aharoni

Prof. Avner Adin

Steering Committee

Avi Aharoni - Mekorot

Prof. Avner Adin – HUJI

David Jackman – Water Corporation "Mei Avivim"

Tami Gavrieli – Tel Aviv Municipality

Guido Segal – Tel Aviv Municipality

Amity Harlev – Facilitator

Daniel Hoffman – "ADAN", Editor Phase II and III

Name	Institute	Position	e-mail
Avi Aharoni	Mekorot	Head of effluent Reuse Dept., TA City Coordinator	aaharoni@mekorot.co.il
Prof. Avner Adin	Hebrew University (HUJI)	Switch Project TA Israel coordinator	adin@vms.huji.ac.il
Dr. Haim Cikurel	Mekorot, advisor	Managing Mekorot's part in Switch Research	Hchikurel@mekorot.co.il
Luba Rubinstein	Hebrew University (HUJI)	Administrative Managing HUJI's part in Switch	lubar@vms.huji.ac.il
Daniel Hoffman	ADAN Technical &	The writer of the "water	adantec@netvision.net.il

	Economic Services Ltd	indicators for Tel-Aviv " document	
Amity Harlev	The facilitator of the meeting	CEO of MODUS	amitay@modus.org.il
David Jackman	TA Municipality		jackman@tel-aviv.gov.il
Mo Provizor	Water authority	Head of Design Unit	Mop10@water.gov.il
Miki Zaide	Water authority	Engineer in Design Unit	Michaelz10@water.gov.il
Dr. David Pargament	Yarqon River Authority	General Director	David@yarqon.org.il
Hezi Bilik	Municipal Water Works Administration	Chief Engineer	hezibi@moin.gov.il
Nelly Tal	Shafdan WWTP	Director	ntal@mekorot.co.il
Amit Tal	Amphibio co.	CEO	amittal@netvision.net.il
Prof. Yoav Kislev	Faculty of Agriculture HUJI	Economist	kislev@agri.huji.ac.il
Valeri pohoryles	Ministry of Health	Tel Aviv County Engineer for Environmental Health	valerie.pohoryles@telaviv.health.gov.il
Prof. Uri Shamir	Technion	Expert on urban planning	shamir@techunix.technion.ac.il
Prof. Carmon Naomi	Technion	Faculty of Architecture and Urban Planning	carmon@technion.ac.il
Elian Lazovski	Water Engineering Journal	The editor of the journal	snercom@inter.net.il
Dr. Giora Alon	National Wastewater Infrastructure Administration	Chief Engineer	algiora@gmail.com
Yiftah Naor	Tel-Aviv water company	General Director	Naor_y@mail.tel-aviv.gov
Dr. Benny Maor	Tel-Aviv Municipality	Director of engineering administration	maor_b@mail.tel-aviv.gov.il
Yehudit Vest	Tel-Aviv municipality	Education and social training in Environmental Quality Authority	
Aharon Strull	Tel-Aviv municipality	Environmental Quality Authority	
Tami Gavrieli	Tel-Aviv municipality Strategic Planning Dept.	Head of Dept.	gavriely@tel-aviv.gov.il
Gal Lederer	Tel-Aviv Municipality Strategic Planning Dept.	Planner	
Eldad Merhav	Tel-Aviv Municipality	Deputy of City Engineer	
Denial Salomon	IGUDAN – Dan Region Associations of Towns for Sewage	Chief Environmental Engineer	daniel@igudan.org.il
Dr Yossi Drayzin	Water Expert	Advisor to the Water Authority for the National Water Master Plan	

6 References

Ben-Sasson, Moshe, Aharoni, Avi, Adin, Avner, Jackman, David, Amoyal, Einat, Lederer, Gad, Rubinstein, Luba, **Strategic Planning for the Urban Water System of Tel-Aviv-Yafo Phase I: The urban water system profile**, SWITCH publication 018530, February 2010.

Duong T.T.H., **Application of a total urban water cycle model to develop urban water management strategies for Tel Aviv, Israel, water balance and energy consequences**, UNESCO IHE, MSc Thesis ES 09.23, 2009.

Center for Economic and Social research, **Statistical year book**, Tel-Aviv municipality, (2008).

Harding R., **Ecologically sustainable development: origins, implementation and challenges**, *Desalination*, 187 (2006) 229-239.

Mitchell V., **Applying Integrated Urban Water Management concepts: A review of Australian experience**, *Environmental Management*, 37 (2006), 589-605.

Municipality of Tel Aviv Yafo, **City – The strategic plan for Tel-Aviv Yafo**, *Meiri Print*, (2006) pp. 1-207.

Spinosa L., Di Berardino S. E., **Energy optimization: improving sludge management sustainability**, Water 21, December (2009) 23.

Sverdlov, Erez, Municipal Water Systems Planning – Goals Analysis, ***Matrix***, January 2008.

Sverldov E., Gvirtzman S., **Planning of the supply, sewage and drainage water systems**, Matrix, (2009).

Summary of Water Club meeting of 18.9.08

While S., Turner A., **The role of effluent reuse ion sustainable urban water system: Uptapped opportunities**, *National Water Recycling in Australia Conference*, Brisbane, Australia, September (2003).

http://www.isf.uts.edu.au/publications/whiteturner2003effluentreuseopportunities.pdf