Sofia Strategic Modelling Study – A Case Study

WaPUG Meeting – Scotland 2003, Hilton Dunblane
19 June 2003

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1. Introduction

In October 2000 Sofiyska Voda AD (SV) took over the operation of the water and wastewater services of Sofia, through a 25 year concession agreement signed between the Municipality of Sofia and International Water/ United Utilities.

SV is the first water industry concession of its kind in Bulgaria and attracts much attention. Almost daily newspapers profile the activities of the company. Social and political aspects take a prominent position, reflecting the changing culture in the country.

As part of the agreement SV has the right to operate the water and wastewater services for the Municipality of Sofia and to make investments. However, the assets (the treatment plants and pipes) will remain in the possession of the City.

SV provides services to a population of about 1.3 million people and operates and maintains a water supply network extending to 3,500 km, together with 1,550 km of sewerage network. More than 1,000 people work for the company.

The concession agreement will bring the long-term benefits of modern water and wastewater service to SV. Through the concession SV will invest more than BGN 300 million over the next 15 years.

This paper highlights the work of the Asset Management Department, which has delivered water and wastewater strategic models for the city of Sofia within a timescale of 16 months.

These models are being developed in two phases. Initially the strategic part of the water and wastewater networks was modelled and completed in March 2003. Subsequently, the models will be enhanced to provide a detailed model. The detailed model of the water distribution network will be completed by October 2004 and the sewerage model by October 2005.

For both the water and wastewater network models approximately 80 Bulgarian staff are working full time with the support of United Utilities, International Water and Ewan Associates Ltd.

This paper focuses on the work of the sewerage modelling team, the unusual characteristics of an Eastern European drainage system, technology transfer and investment planning.

2. Catchment geography

Sofia, the capital of Bulgaria, is located in the northwest region of the country. It has good transportation links with Europe through Romania and Yugoslavia.

Sofia nestles in the heart of the Balkans 650m above sea level with mount Vitosha rising to 2000m nearby.

Government buildings, churches, shops and museums dominate the city centre. Most of the City's population live in high-rise apartment blocks in the suburbs.

Light industry dominates the city's economy, with intensive agricultural land use around the suburbs. The trade effluent is currently estimated at 55,000m^3/day, which is anticipated to increase by 20,000 m^3/day by the year 2020.

The largest trade effluent discharger is the City's District Heating System, which provides central heating to many of the city's homes.

There are 12 watercourses running through the city, though none of these are particularly large. The largest river has a 95-percentile flow of approximately 2m^3/s, which is less than the average dry weather flow for the catchment, which is approximately 2.3 m^3/s. Several of the watercourses run through culverts and channels, which incorporate added capacity for the high flows associated with the snowmelt during the months of February to April.

2.) Catchment deficiencies – an overview

There are a number of deficiencies within the sewerage system that need to be addressed. Some of these include:-

- To provide sewage treatment to the whole city - approximately 20% of the city's sewage is currently untreated and outfalls directly to local watercourses.
- To significantly reduce infiltration, which is currently well in excess of 1 DWF.
- To improve the hydraulic and operational performance of 113 of the 162 combined sewer overflows in the catchments.
- To reduce the frequency of flooding by implementing capital schemes and increasing the level of proactive sewer cleaning and maintenance.

The Level of Service obligations (LoS) to meet these deficiencies are summarised in Table 1.

Description	LoS Targets		
	Year 6	Year 11	Year 16
Sewage treatment -' % of connections'	98%	100%	-
Infiltration reduction – '% of 1 DWF'	40%	-	25%
CSO performance (pass 6 DWF – Bulgarian Law)	-	ALL	-
Flooding (No of properties to be protected)	80%	100%	-

Table 1: Level of Service Obligations for Sofiyska Voda.

The data collected as part of the strategic modelling study has initially identified that significant system improvements could be obtained by implementing proactive sewer maintenance, and changing the operating characteristics of the system in some areas of the catchment. As shown in Photograph 1, some overflows contain sluice gates to allow diversion directly to the river. In some locations these gates have been partially closed due to hydraulic overload problems downstream due to sediment levels. As a result a schedule of sewer cleaning downstream of the system would allow the system to operate normally and allow the overflow to pass 6 DWF (which is Bulgarian law).

Photograph 1: Photographs of a CSO internally and spilling to the river Suhodol in dry weather.

In addition to the LoS requirements listed in Table 1, SV also has to undertake a comprehensive structural rehabilitation programme.

4) Sewerage infrastructure

Construction of the Sofia sewerage system began in 1897, and has grown over the years with the development of the city. The length of the sewerage network is approximately 1550km, with approximately 25,000 manholes.

All the sewers drain to a single wastewater treatment plant (WWTP) at Kubratavo, via two main trunk sewers (open channel) which serve 7 drainage catchments: Kakach, Suhodol, Vladaiska, Perlovska, Slatinska, Trunk and WWTP. The catchments of the natural watercourses generally define the drainage catchment boundaries.

Due to Bulgarian law, all of the sewers have a diameter not less than 300mm. The majority of pipes are made out of pre-cast concrete and are normally 1m in length.

There are no pumping stations within the catchment as all the sewers drain by gravity to Kubratavo. The largest network structure is the Gintsi structure, which is the termination point for three major interceptor sewers and the starting point for one of the open channel trunk sewers (approx. 6000mm x 2500mm) which outfalls to the works. The Gintsi structure is also an overflow, with a weir approximately 30m long.

On commencement of the study there were a reported 40 CSOs in the catchment. However, during the course of the study 162 CSOs have been identified and surveyed.

The majority of the impermeable areas drain to the combined sewer network. The cracking of the roads due to repeated freezing and thawing that occurs in winter, and the heavy application of salt and grit, means that initial losses can be very high, and blocked gullies are common.

5) Data collection

The following data has been collected for the strategic modelling study, some of these are discussed in further detail below.

- Population distribution
- Future development plans
- Rainfall
- IAS data
- Historical rainfall
- River flow and level data
- Customer billing data
- Trade effluent data
- Manhole data
- Flow data
- Operation schedules
- Hydrology and hydrogeology data
- Ancillary surveys
- Inlet works survey

Manhole survey:
On commencement of the study in November 2001 the only sewer network data available was a network GIS database, which had been populated from old sewer records, some of which were 100 years old. As a result a comprehensive manhole survey was required. However, as SV required a strategic model by March 03 only a proportion of the 25,000 manholes in the catchment could be surveyed. As a result 5,000 manholes have been fully surveyed and entered into the strategic model. All of these details have been recorded into a new GIS database where the data has been checked and audited. The data has been integrated with other survey data and, where appropriate, existing network data.

Flow survey:
In February 2002 a long-term flow survey commenced. The survey included 7 ADS flow monitors, 1 '2 channel Accusonic monitor' and 17 rain gauges.

Between March and May 2002 SV undertook a short-term sewer flow survey. This survey measured rainfall at an additional 15 locations and concurrently monitored sewer flows at a further 68 strategic sites in the network. 6 significant storms were recorded, each storm having a peak intensity of at least 6mm/hr for 4 minutes and a total depth of 5mm. This survey reported two dry days for analyzing infiltration and dry weather flows. All the data collected was used for calibrating the model.

IAS survey:
The overland flow and connectivity characteristics of the catchment were assessed by undertaking an impermeability area survey. Sample locations within the catchment were identified and categorised into different land use types. The surveyors then visited a selection of different land use types and assessed their impermeability and overland flow characteristics. The results were recorded on a map and compared to the GIS record. Calibration coefficients were extracted, based on the variation between the GIS and the observations.

Historical rainfall:

Historical rainfall was required in order to generate benchmark rainfall events for the hydraulic performance assessment of the system. This data was obtained from the Hydro-Meteorological Institute.

The data was available in two formats. The first format was in paper records and this dated pre 1970. The second format was in digital form. The paper records were digitised in order to get the data into a digital form. From this data the HMI selected a 'typical year' of events. These were divided into summer and winter events and each group was analysed to determine a typical 50% peaked unit hyetograph shape. The local Intensity, Duration and Frequency (IDF) curves were then mapped to these shapes to produce a family of standard time-varying rainfall events.

6) Project structure and technology transfer

The project delivery team was organized in a 'pyramid structure' (Figure 1), so that information could be passed up and down the pyramid to the appropriate level. Everyone in the structure is therefore aware of the project's goals and objectives as this information is disseminated from the management. This allows all the team to understand the importance of their role in achieving the LoS requirements defined in the concession contract.

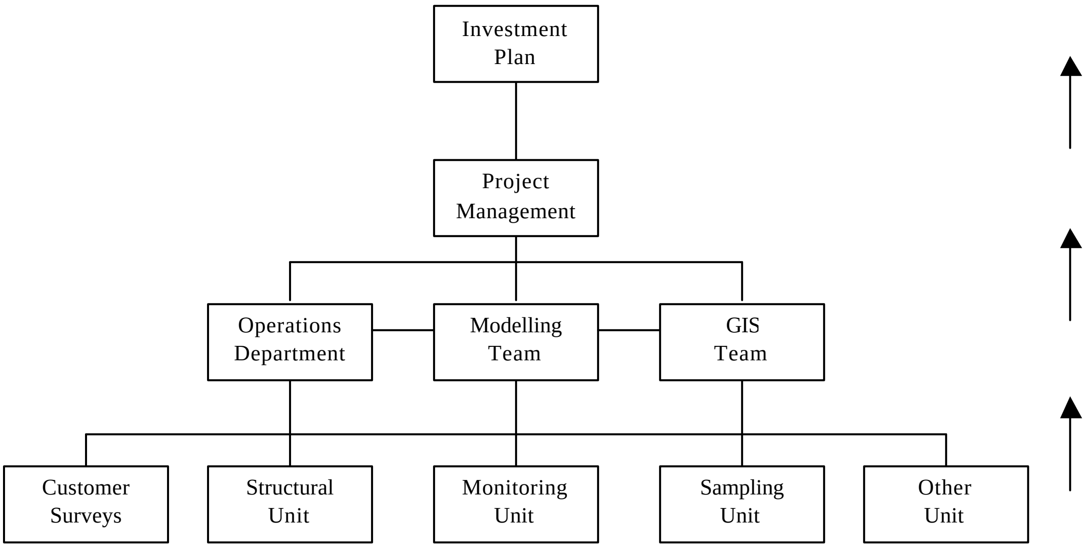

Figure 1: Project Structures & Data Flow Diagram.

Information was collected and processed by the 'Units'. All relevant processed data is passed to the GIS team, Operations Department and Modelling team. The relevant outputs are passed to the management for processing and incorporation in the investment plan.

This management structure has allowed the successful implementation of technology transfer initiatives. One example of this is the flow survey data collection phase of the study. The initiative here was to use an experienced UK Contractor to supply the equipment and train SV staff in the use of the equipment both for data collection and analysis. This has been very successful and after only 16 months SV had two fully equipped flow survey crews.

Technology transfer initiatives have also been implemented for:

- Implementation of the WaPUG Code of Modelling Practice
- Manhole survey
- Impermeability surveys
- CCTV survey and data analysis
- Health and Safety awareness
- Quality assurance

7) Hydraulic model

The Strategic model was built in Mouse using the ArcView GIS platform and includes 5,000 manholes; all of which have been surveyed.

The strategic model is a composite model of 7 sub-models, which represent the drainage catchments listed in Section 4. The sub-models were calibrated by data collected both from a short-term flow survey and a long-term survey. The long-term and short-term data were both used in the same way.

The strategic model is a Type 1 model as defined in the WaPUG Code of Modelling Practice.

The majority of data collected to support the model build (Section 5) was collected by SV staff, who were trained in accordance with the appropriate standards.

With the strategic modelling now complete attention moves to the detailed modelling with a target deadline of October 2005.

8)Investment plan

To meet the LoS targets specified in the concession contract, the strategic modelling has identified that SV need to invest in excess of BGN 200M in their wastewater assets.

The majority of this investment will be in the form of new sewer connections and repairs to CSOs, to ensure that sewage flows to Kubratovo WWTP for treatment, rather than being discharged to rivers. A significant investment will be required to reduce infiltration through relining and target rehabilitation schemes in structurally deficient sewers.

Significant investment would also be required to upgrade a large number of CSOs to pass 6 DWF at first spill, which is a requirement of Bulgarian law.

9)Wastewater planning hits the tabloids

Since the commencement of the model build data collection activities there have been a series of articles released in local newspapers and on one a occasion a television programme, informing the Bulgarian population of the investigations going on in the world ‘beneath their feet’. Extracts from some of these articles are provided below.

„Софийска вода" проучва водопроводната мрежа

Робот с камера брои шупли в тръбите

'Stoclichen' - A local metropolitan paper
'A ROBOT WITH CAMERA COUNTS THE PIPE CAVITIES'

Translated extract:
The little tractor-toy-camera penetrates even into the most inaccessible places. Pictures taken by the robot show underlying cracks. This is how a pipe in Iliensti looks like in the robot's view.

Петър влиза в каналите, а те в компютрите

Клошари, плъхове и змии се крият в тръбите

'Stoclichen' - A local metropolitan paper
Box 1: 'BUMS, RATS and SNAKES ARE HIDING IN THE SEWER'

Translated extract:
A 'rendezvous' with a **snake** is number one on the list of **unpleasant meetings in the sewerage system**. 'I met one in Gorubliane three months ago. I pressed it with the meter-line and it crept away'; Petar Gospodinov told.

Translated extract:
'Prior to going down in the pipes, the workers, **some of whom are engineers**, pass a special training course. Gas-detection precedes each team entering the sewer for safety reasons. If the environment appears to be permitting human presence, **a brave man is bound to a pulley**, thus allowing him to be pulled up to the surface in each moment'.

EvroCom Cable TV Station
'A day in the life of a flow survey worker'

This programme was shown at 10.00am on a Saturday morning, and was 30 minutes long, dedicated to the **science of sewer flow survey measurement**, starring one of SV's flow survey's team.

10) Conclusions

The Sofia Stratagic Modelling Study is the first of its type to be completed in Bulgaria and represents a technological breakthrough for SV.

During the Strategic Modelling Study a number of specialists have worked alongside the SV staff, in a technology transfer role. The technology transfer has been very successful and there are now a number of well-trained and equipped engineers and data collection technicians within SV. This technology transfer will allow SV engineers to develop the strategic model into a detailed model by October 2005.

The study has demonstrated that the key to successful technology transfer is to consider location conditions, economics and culture when deriving strategies.

In Sofia, SV has seized the opportunity to place the modelling work in its proper context as one part of an integrated asset management system, a critical element in the day to day running of their business.