INTEGRATED FEASIBILITY STUDY FOR THE SANITATION OF THE TUZ LAKE BASIN- TURKEY

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Abstract:

The Tuz Lake Basin is a natural reserve with a special environmental protection centred on a shallow salty tectonic lake located in the Central Anatolian Region, 150 km SSE of Ankara. Its area is shared by the provinces of Ankara, Konya and Aksaray, and holds a population of over 3 million people. The quality of the water in the Tuz Lake Basin, the biggest salt lake in Turkey, has been deteriorated over the last years motivated by intensive agriculture, discharge of untreated wastewater and uncontrolled dumping of solid waste (both urban and sludge from the salt mining industry)

The project funded by the Spanish Government, following a request of the Turkish Government, consisted on a feasibility study for the general sanitation of the Tuz Lake Basin for the conservation of the ecosystem and preservation of the local salt industry business. A first phase was the analysis and diagnosis of different environmental agents acting in the Tuz Lake Basin (ca. 20.000 km^2). The second phase involved making the projections for the next 20 years in master plans for land and water management (nature protection and agricultural development), wastewater treatment and solid waste management of the Tuz Lake Basin and its nearby cities.

The hydrology of the lake showed that the main threat is increased water extraction, which can make the phreatic level drop below the bottom of the lake. Since the Tuz Lake Basin is a closed ecosystem, it is the final recipient of all water pollution, which takes place in three forms: point sources (municipal), diffuse sources (agricultural) and importation (Main Drainage Channel)

The conclusions and recommendations of the study were:

Land Management: It is necessary to define a Natural Resources Management Plan containing three thematic programs:

1. Nature protection,
2. Agricultural development
3. Conservation of the cultural values and promotion of ecotourism

Water Management: The main concern about water management regards the groundwater management. The basin faces a serious risk of over-exploitation of the groundwater resources, whose effects are difficult to reverse. Therefore, the following actions are proposed:

1. Development of a groundwater model
2. Design of an aquifer control network

Wastewater Treatment: Elaboration of the tender documents for the construction of 5 Wastewater Treatment Plants and recommendation of the use of constructed wetlands as buffer zones for lakes

Solid Waste Management: The study showed that the solid wastes produced are mainly urban, medical and industrial. The recommended treatment is based on high-density sanitary landfills and transfer stations. Locations, sizing and investments were determined.

The institutional and financial aspects of the recommended investments were also evaluated, prioritising the projects over time with a focus on the sustainability of the financing of investments through soft loans under OECD-conditions such as Spanish FAD funding.

Introduction

Tuz Lake is shallow salty tectonic lake located in the Central Anatolian Region, 150 km South-South-East of Ankara (See Figure 1). The provinces of Ankara, Konya and Aksaray share its area. The Tuz Lake basin is part of the Konya closed basin. It is a shallow salty lake with an average surface area of 1.600 km^2 and is the second biggest lake in Turkey. The Tuz Lake is fed both by surface water and groundwater. Parts of the groundwater flow through the important salt formations in the sub-soil and are saturated with salt on the way. Thus, the lake is being fed continuously with salt water. The natural regime of the lake shows a rise of the water level during winter and spring and a lowering of the level, due to evaporation, in summer and autumn. The natural fluctuation of the average water level is 0,4 m. depending on the weather conditions.

Figure 1: Tuz Lake Basin Location

Land Use

The land use of the Tuz Lake Basin is dominated by plain steppes and dry agricultural areas, which cover more than 70% of the total area (18 515 km^2) Tuz lake and the salty steppes that are associated with the lake itself occupy the central part of the basin and cover some 19% of the area. Irrigated agriculture, together with urban and industrial use constitutes the most intervened artificial land use practice. Although the total occupation of irrigated agriculture is only 6,2%, it is mainly concentrated in the southern part of the basin, where it is dominating. Fresh and brackish water lakes are insignificant in terms of land use, but they are of crucial importance for nature conservation. Due to human interference, the forests have practically disappeared. Small stands can be found scattered over the area, mainly in the mountainous areas in the south of the basin.

Table 1: Land use distribution in the Tuz Lake basin

Biotope	Surface (km^2)	%
Freshwater lake	7	0,04
Brackish water lake	13	0,1
Salt water lake	1.632	8,8
Salt steppe	1.784	9,6
Plain steppe	7.002	37,8
Dry agriculture	6.756	36,5
Irrigated agriculture	1.148	6,2
Urban area	132	0,7
Forest	41	0,2
TOTAL	**18.515**	**100**

Salt mining

As the lake is extremely shallow with an average depth of 0,5 m., during summer extensive areas dry out and leave a thick salt layer behind. During winter part of the salt is re-dissolved in the fresh water that is introduced to the lake by precipitation and surface runoff. This mechanism is used as a basis for the process of the salt mines in the lake. The three mines operating in the lake produce of the order of 70% of the salt consumed in Turkey. The salt mining generates industrial activity in the region, mainly related to salt processing and refining.

Hydrology

In terms of the hydrology of the basin, the surface water flows are of little importance as there are only few rivers and creeks. Most of the water is transported as groundwater, and the large aquifer that extends in the subsoil of the region is of great importance for the water management of the basin. The aquifer has a more superficial freshwater layer and a deeper, salty one, which is the result of the interaction with geological materials such as gypsum. The aquifer is intimately linked with the numerous salty, brackish and freshwater lakes present in the basin. The natural hydrological regime has been altered severely by the construction of dams for irrigation (Cihanbeyli and Uluirmak), extraction of groundwater for irrigation and the construction of an inter-basin channel that conveys drainage water and untreated wastewater from the Konya basin to the Tuz Lake.

In September 2000, an area around the Tuz Lake was declared Specially Protected Area and as such put under the responsibility of The Authority for the Protection of Special Areas (APSA)

The environmental situation of the lake has been deteriorating over the years motivated by the effects of intensive agriculture, discharge of untreated wastewater and uncontrolled dumping of solid waste both urban and resulting from the salt mining industry. In 2001, the Spanish Government, following a request of the Turkish Government, granted non-reimbursable funds for the financing of the Integrated Environmental Feasibility Study for the Sanitation of the Tuz Lake through its FEV program. The study took account of the fragile hydrological and biological equilibrium of the basin, its socio-economic development, especially related to agriculture and salt mining and had as objectives:

- Develop an integrated view of the situation
- Define the projects and studies needed for the sanitation of the basin
- The preparation of the technical part of the tender documents of the different projects, including their pre-feasibility studies
- Propose the financing for the projects
- Define and propose a model for the coordination of the different Administrations and the social and economical parts involved

The study, which was broken down in two phases: Diagnosis and Master Planning lasted 6 months.

Diagnosis

During the diagnosis phase the basic information for the planning was collected, processed and interpreted.

Hydrology

The hydrology of the Tuz Lake Basin is characterised by the following three elements:

? Tuz Lake,
? The watershed,
? The aquifer of the Konya-Cumra-Karapinar and Sultanhani-Obruk-Aksaray region.

A schematic diagram showing the water fluxes affecting the lake can be found below:

Figure 2: Quantitative fluxes in Tuz Lake Basin

The data presented in Figure 2 was obtained from hydrological and groundwater mathematical modelling of the basin in its natural regime. To assess the influence of the alterations of the natural regime due to groundwater extraction and inter-basin water transfer, different simulations were made, from which the following conclusions can be drawn:

1. **Water import:** Changes in water import, even if they are important, will affect the main level of the lake, but will not have durable or accumulative effects neither in the water level, nor in the salinity of the lake[1].
2. **Extractions:** Changes in the aquifer, especially if they are related with increasing extractions, can make the phreatic level drop below the bottom of the lake. If that situation becomes real, the groundwater flow to the lake will be interrupted.

Lake evaporation is the balancing mechanism to control these alterations. As the lakeshores have a very low gradient, the variations in the amount of water entering into the lake are reflected much more in the surface area of the lake than in differences in the water level. An excess of water is therefore eliminated through evaporation. Thus, the increase in the total evaporation flux neutralises the water import. The present values of the Konya drainage channel, in the order of 50 hm^3, will not have a real influence. Konya drainage channel collects excess waters and wastewater of Konya City and discharges them to Tuz Lake, which is about 150 km away.

Land Use

The area under the study is covered by APSA-law due to its unique historical, natural and cultural values. These areas have been granted special environmental protection to ensure sustainable conservation and use for future generations, which implies a territorial distribution of the land uses compatible with conservation.

In the Tuz Lake Basin three types of zones have been distinguished, based on:

? **Natural values**. The most valuable values are birds and plants. These are associated with particular areas.
? **Water values**. Fresh water is the limiting factor for the socio-economic development of the area, but is also very important for the natural resources conservation. Salty water has an economic value (salt mining) as well as an ecological importance for conservation. Their cycles are closely linked and are represented in the Tuz Lake basin by the aquifers and the lakes.
? **Cultural values**. The Tuz Lake basin is a historically rich area with an important cultural heritage in the form of tumulus, historical buildings and ruins. The Silk Road passed through the southern part of Tuz Lake APSA-area.

For Tuz Lake SPA four different zones have been identified, as can be observed in Figure 3 below.

[1] In fact, the salinity is so high that when the level drops because of evaporation, salt precipitates in the bottom and re-dissolves when level raises again due to precipitation. Therefore, total volume of water in the lake has no proportionality with salt concentration.

? **Strictly Protected Areas**. Areas that have to be strictly protected to preserve the most important natural, water and cultural values.
? **Partially Protected Areas**. Areas that have to be partially protected to preserve the natural, water and cultural values of the SPA but which can allow some activities.
? **Compatible Use Areas**. Areas that should be used in production activities with some restrictions in order to prevent the decrease of its natural and water values.
? **Development Areas**. Areas that are focused on the development of socio-economic activities: agricultural, urban, industrial, etc.

Figure 3: Lake Tuz Basin Protection Zones

Wastewater

Since the Tuz Lake Basin is a closed basin, it is the final recipient of all pollution. The same applies to other lakes and wetlands in the region of the study, which do not have a surface connection to the lake, but communicate through the subsurface (groundwater). This is the case of Duden Lake, Bolluk Lake, Tersakan Lake and Esmekaya reeds. These lakes and wetlands act as a sump of contaminants and as such run the risk of becoming overloaded. The main concern regarding water quality and wastewater treatment in the basin is directed to the wastewater generated in the 5 main cities that affect the Tuz Lake basin and the drainage water from three irrigation projects that is conveyed by drainage channels to lakes in the basin. The cities are Kulu, Cihanbeyli, Aksaray and Sereflikochisar, located within the Tuz Lake Basin and Konya, which is outside the basin, but whose wastewater is conveyed to the Tuz Lake through the Main Drainage Channel.

? **Point sources**. The relative pollution loads from domestic and industrial sources are presented graphically in Figure 4 below. The main sources are the cities of Konya and Aksaray, while also the towns of Sereflikochisar, Kulu and Cihanbeyli are important contributors. Though Sereflikochisar and Aksaray possess wastewater treatment plants (WWTP), they are either poorly operated or out of operation, thus not providing effective treatment. The Sereflikochisar plant could be rehabilitated to provide some more years of service, but the Aksaray plants have to be replaced by more efficient technologies

Table 2: Tuz Lake basin WWTP audit

City	Existing WWTP	Effective Treatment	Possible Rehabilitation
Konia	X	-	-
Aksaray	✓	X	X
Sereflikochisar	✓	X	✓
Kulu	X	-	-
Cihanbeyli	X	-	-

Figure 4: Organic Loads in the Study Area

? **Diffuse contamination** The diffuse contamination due to agriculture, livestock breeding and leachate from small waste dumpsites was difficult to quantify. A coarse estimation indicates that the pollution load of nutrients emitted from irrigated agriculture may contribute in 1/3 to the total nutrient load in the basin.
? **Imported contamination** is brought into the basin through the Main Drainage Channel consists of organic material, nutrients, but also heavy metals discharged by the Konya industry. The total load is in the same order of magnitude as the total load produced inside the basin.

? **Water quality.** The evaluation concluded that all the lakes in the study area receive a high nutrient load, with exception of Esmekaya and Kozanli Lakes, which are freshwater lakes that are in mesotrophic and eutrophic state. Special attention has to be paid to Duden Lake (Kulu). Duden Lake is a brackish lake that serves as a feeding site for large colonies of flamingos and other high ecological value species. It already shows signs of a high level of eutrophication and it is foreseen that this process will accelerate after the termination of the construction of the municipal sewer system, currently under construction

Solid Waste

The production of solid waste in the study area was centred around municipal, medical and industrial wastes. Other types, such as agricultural and construction wastes do not constitute a management problem, as they are largely reused.

? **Municipal Solid Waste.** The municipal solid waste is managed by each village and town, resulting in numerous small dumpsites. The generated amount of municipal solid waste responds mainly to the size of the population and the standard of living. Taking into account these factors, the development of the quantity of waste was estimated and is represented in Figure 5.
? **Medical Solid Waste** is generally not separated or finally ends up at the municipal dumpsite, without specific treatment
? **Industrial Solid Waste** could not be quantified. Only data from the salt industry was predictable through manufacturing data.

Figure 5: Gravity Centres and Small production Centres ofSolid Waste Production

? **Waste Management** the existing system does not meet the desirable standards. No separation of wastes takes place, the disposal sites are not adequately designed and constructed, dumping is not controlled and recycling is scarce.

Master Plan

The planning has been structured along four tasks:

? Land management (Nature protection and agricultural development)
? Water management
? Wastewater treatment
? Solid waste treatment

Land Management (Territorial Management Programs)

A Natural Resources Management Plan, which will constitute the main management tool for APSA will be defined. The objective of the plan is to establish the spatial and normative definition for the protection and rational use of the existing resources. This plan contains three thematic programs related to:

? Nature protection,
? Agricultural development
? Conservation of the cultural values and promotion of ecotourism.

In the frame of the feasibility study the guidelines and key actions for the sustainable development of the Tuz Lake SPA were identified and reflected in the terms of reference of the studies that will be required to prepare the plan and its programs.

Water Management

The feasibility study indicated the necessity to carry out:

? **Development of a groundwater model** to synthesise the understanding of the aquifer characteristics and mechanisms and will be the tool to evaluate in detail the effect of extractions depending on the situation of wells and the amount of water they extract.

? **Design of an aquifer control network** to provide the necessary information on the state and evolution of the groundwater system in every moment. Both, quantity (level) and quality of water must be controlled, especially in the surroundings of Tuz and the other minor lakes, where salinization or salt intrusion may occur. The information should also be used (through the necessary studies), to enhance the mathematical model and improve the prediction capacity of the future development of groundwater, from the quality and quantity points of view. The total estimated area of the zone to be controlled is around 35.000 km^2 and should count with a control point every 250 – 500 km^2.

Wastewater Treatment

The master plan has two main components

? **Wastewater treatment plants for main urban centres** The master plan foresees the construction of wastewater treatment plants (WWTP) for the cities of Kulu, Cihanbeyli, Aksaray, Sereflikochisar and Konya. These WWTP will treat the wastewater to the level of secondary treatment, with the aim to remove the organic pollution, to retain heavy metals and to minimise the health risk. Though the eutrofization of the lakes in the study area is a recognised problem, tertiary treatment is not included in the treatment concept, as this aspect will be dealt with in the constructed wetlands

? **Constructed wetlands as buffer zones for lakes** In order to control the entrance to the lake of the dispersedly generated contaminants, as well as the treated effluents of WWTP´s, buffer zones will be planned to retain and/or eliminate the contaminants and hence, to protect the lakes from eutrophication. In fact, such buffer zones in the shape of extensive reed beds exist already in a natural way, as they respond to the presence of fresh water. In the master plan the enhancement of these reed beds as sinks for pollution and a compensative measure for lost natural habitats for wildlife was included. The plan had in mind that as the costs of construction and operation of the wetlands cannot be charged as public services, the investment costs should be low.

All of the wetlands that were identified in the “pollution focal points” can be considered more or less natural wetlands or are located in swampy areas along the Tuz Lake. This characteristic imposes two considerations for the implementation of the wetlands.

A: Due to their value as natural habitat, it is not convenient to execute extensive civil work.

B: Since the proposed wetlands are located in swampy areas, the use heavy machinery should be minimised.

Solid Waste Management

The study area was divided into 4 management areas, based on the identification of gravity centres of waste production, geographical conditions, road infrastructures and province and district borders. In Figure 6 the management scheme is presented.

Figure 6: Urban Waste Management Plan

? **General Conception** The treatment is based on sanitary landfills. Recovery of recyclable material is not considered as this is already taking place as part of a submerged economy. Composting of the organic material is not considered, as the quality of the material will not be fit for its utilisation, due to the presence of hazardous

waste. For reasons of environmental control and economy of scale the plan shows that large centralised landfills are preferable over small local landfills. In order to rationalise transporting costs, transfer stations are located in minor gravity centres, from which the waste will be conveyed to a central landfill. The sanitary landfills will receive also industrial waste, salt sludge and wastewater treatment sludge. The latter will be disposed of in specific cells. For the collection of domestic refuse it is recommended to continue with the existing street collection system.

- **Sanitary landfill**. A high-density landfill design has been chosen both for economical and environmental reasons. The fundamental principle of a high density landfill is the reduction of the volume of the urban solid waste (USW) through its compaction and automatic baling, allowing to obtain densities of 1.000 to 1.200 kg/m^3. The lifetime of the landfill will be 20 years, but will be constructed in cells, each with a lifetime of some 5 years. In this way the capital costs for the first phases are reduced and the risk of possible damage to the basal liner is limited.
- **Incineration plant for medical waste.** The plan recommends the construction of an incineration plant for medical waste in order to comply with the legislation. This plant could be located in Aksaray, which is the gravity centre of the medical waste production in the Tuz Lake basin.
- **Closure of existing dumpsites.** The existing small dumpsites have to be closed. Depending on their size and the type of material they contain, either the dumpsite can be lifted and its contents deposited in the new sanitary landfill or the dumpsite can be sealed. The plan recommended the preparation of an inventory of existing dumpsites and a plan for the closure and sealing of the sites.

Institutional and Financial Aspects

Priorization of Investments

The methodology for prioritising the implementation of the investments in the study area is based on the assessment of key factors: urgency, accumulative effects, relevance for the environmental protection, involved health risk and the institutional support that may provide the municipality. Following this multicriteria analysis priorities were given for the construction of wastewater plants, sanitary landfills and carrying out further in-depth studies.

Investment Costs

The costs of the necessary infrastructures and studies were presented discriminating civil works, equipment and construction plus contingencies.

Financing

The environmental projects identified in the Tuz Lake area are eligible for funding through soft loans under OECD-conditions. A financial analysis was carried out taking into account actual financing conditions of loans under OECD and under the Spanish Development Aid Fund (FAD) program. This study was based on the application of the principle of cost-recovery tariffs to wastewater treatment and to urban solid waste management and produced tariff evolutions of the different water and waste management services.

Institutional Arrangements

The recommended institutional options for project development, implementation, operation and maintenance of the WWTPs and SWTs of related municipalities were evaluated depending on the size and preparation of the different actors. Operative models providing to each hierarchical level both responsibilities and duties were created to function under the common umbrella of the APSA.

Conclusion

A feasibility study for the sanitation of the Lake Tuz basin has been carried out through multidisciplinary systematic engineering covering the analysis and diagnoses of the present situation as a first phase and the definition of requirements in a second phase. The definition of these requirements involved both a technological study of the best available solution and a functional financial scheme to support them through the application of cost-recovery tariffs under the polluter pay principle.

This is an efficient and operative approach to evaluate ecosystems under threat in order to define the actual risks and determine sustainable investments to ensure conservation. This approach could be applied to similar regions of particular natural value in Egypt where water is equally scarce due to consumption and pollution.

Glossary of Terms & Abbreviations

Aquifer: An underground bed or layer of earth, gravel, or porous stone that yields water.
APSA: The Authority for the Protection of Special Areas (Turkey).
Biotope. An area that is uniform in environmental conditions and in its distribution of animal and plant life.
Eutrophication: Having waters rich in mineral and organic nutrients that promote a proliferation of plant life, especially algae, which reduces the dissolved oxygen content and often causes the extinction of other organisms.
FEV: Acronym in Spanish for Feasibility Study Fund. Funding program of feasibility studies from the Spanish Economy Ministry.
FAD: Acronym in Spanish for Development Aid Fund. Funding program of poverty destruction from the Spanish Economy Ministry.
Mesotrophication: In lake ageing, stage between oligotrophication and eutrophication.
OECD: Organisation for Economic Co-operation and Development
Oligotrophication: Having waters poor in mineral and organic nutrients that have a low proliferation of plant life.
Phreatic: Of or relating to ground water.
Salinization: Build-up of salts in soil, eventually to toxic levels for plants.
SPA: Specially Protected Zones
USW: Urban Solid Waste.
WWTP: Wastewater Treatment Plant.

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About the Author

Ander Gorostiaga is a graduate of Imperial College holding a Masters in Chemical Engineering. His professional experience starts in 1996 working for USFilter and consequently Vivendi Environment (now Veolia) as a process engineer in the design of chemical and wastewater plants. He then joined the commercial department as a sales manager being responsible for the Middle East and Far East market carrying out these duties since 2000. In 2003 he joins **Idom Ingenier?a y Consultor?a** as a sales manager in the international department of this engineering and consulting firm. He has travelled to four continents in promotion and selling missions and has gained hands on experience in start-ups and troubleshooting of facilities both domestically and internationally in diverse countries such as Egypt, Indonesia, Slovakia, Italy...