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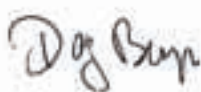
# Rehabilitation Plan for Estero Salado Guayaquil, Ecuador



*Photo: Paul Geerders*

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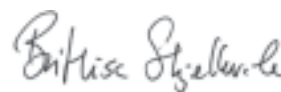
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Abstract The Municipality of Guayaquil invited the Norwegian Institute for Water Research (NIVA) and P. Geerders Consultancy (PGC) from Holland to participate in a two days field visit to the Estero Salado followed by a three days' workshop in Guayaquil together with national experts from Ecuador as an attempt to revive, and add new perspectives to the plans and process of rehabilitation of the Estero Salado. The workshop comprised broad participation of all relevant authorities both from the Municipality of Guayaquil, as well as from the national ministry level (from Quito), stakeholders from the settlements in the Estero Salado area, from the INOCAR (Oceanographic Research Institute of the Navy, which shares the responsibility for the management of the Estero Salado with the Municipality), from the INTERAGUA (the company responsible for water supply and wastewater treatment), from several universities and consulting firms, as well as several NGOs which are engaged in different projects in the Estero Salado, as well as international experts. 34 abatement measures were identified comprising what could be done to reduce the external pollution loading from the catchment (catchment external measures), what could be done with abatement actions within the Estero itself (Estero internal measures), what could be done with and by the local population (environmental awareness programmes, participation, ownership, etc., socio-economic measures), and finally what could be done concerning management practises, regulations, rules, clarifying the responsibility of the different authorities, etc., (management / governance measures). Care will be taken to implement measures in a holistic approach, avoiding that solving one problem would create another.		
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O-10255

# **Rehabilitation Plan for Estero Salado, Guayaquil, Ecuador**

## **Scoping Phase**

based on measures identified at the Workshop in  
Guayaquil March 23-25 2011

Oslo, May 04, 2012

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## Preface

The report represents the first scoping phase for the rehabilitation plan for the heavily polluted Estero Salado in Guayaquil. It is based on measures and information identified on the workshop held in Guayaquil March 23-25 2011 including NIVA as invited participant, represented by senior scientist Dag Berge and coordinator for Latin America Paul Geerders. Before the workshop the NIVA experts had an opportunity to familiarize themselves with the situation of the Estero Salado during a two days field visit by boat and helicopter.

The workshop were held by the university ESPOL (Escuela Superior Politecnica del zona Litoral), excellently organised by Professor Luis Domingez and his crew. They have also given valuable input to the report.

Client for the project is the Municipality of Guayaquil. The initiative was taken by the Mayor, Dr. Jaime Nebot Saadi, while the practicalities were taken care of by Camilio Enrique Ruiz Alvarez.

The current report is compiled and written by Dag Berge and Paul Geerders with input from Luis Domingez at ESPOL.

NIVA wish to express its thanks to the Mayor of Guayaquil for inviting us to take part in this interesting and instructive scoping project, and for the good co-operation with all participants.

Oslo, May 4, 2012

*Dag Berge*

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## Summary

The municipality of Guayaquil invited Norwegian Institute for Water Research (NIVA) and PG Consult (from Holland) to participate in a two days field visit to the Estero Salado followed by a three days' workshop in Guayaquil together with national experts from Ecuador as an attempt to revive, and add new perspectives to the plans and process of rehabilitation of the Estero Salado. The workshop comprised broad participation of all relevant authorities both from the municipality of Guayaquil, as well as from the national ministry level (from Quito), stakeholders from the Estero settlements, from the NAVY (which shares the responsibility for the management of the Estero with the municipality), from the INTERAGUA (the company responsible for water supply and wastewater treatment), from several universities and consulting firms, as well as several NGOs which are engaged in different projects in the Estero Salado, as well as international experts. The aim of the workshop was to identify the rehabilitation measures needed to improve the environmental conditions of the Estero Salado to the level where normal aquatic life could be sustained and the Estero Salado could fulfil the water use interests of the local population and the inhabitants of Guayaquil.

34 abatement measures were identified comprising what could be done to reduce the external pollution loading from the catchment (catchment external measures), what could be done with abatement actions within the Estero itself, what could be done with and by the local population (environmental awareness programmes, participation, ownership, etc., socio-economic measures), as well as what could be done with the management practises, regulation rules, clarifying the responsibility of the different authorities, etc., Management / governing measures).

In addition, an overview of sources of available data, as well as a preliminary overview of what kind of environmental data existed, were identified. It was also identified which institutions in Ecuador could contribute in the rehabilitation projects, and with which services.

The last item that was treated on the workshop was the way forward and sources of financing such a big project. NIVA had already got the responsibility of compiling the scoping project. It was decided that when this report is available, it should be applied for money for a pre-project which should focus on bringing the project further and into the pre-feasibility phase.

## Norwegian Summary (Sammendrag)

Guayaquil kommune inviterte Norsk institutt for vannforskning (NIVA) og PGConsult (fra Holland) til å delta på et to dagers feltbesøk i Estero Salado (det Salte Estuariet), etterfulgt av en 3-dagers lang workshop i Guayaquil sammen med nasjonale eksperter fra Ecuador i et forsøk på å blåse nytt liv i, og komme med nye momenter til planene om å forbedre miljøforholdene i Estero Salado.

Workshopen hadde bred deltakelse fra alle relevante myndigheter, både lokale fra Guayaquil kommune og fra sentrale myndigheter i Quito, stakeholdere fra bydelene rundt Estero Salado, fra INOCAR (en marine enhet som har ansvar for deler av vannforvaltningen i Estero Salado), fra selskapet INTERAGUA (ansvarlig for drikkevannsforsyningen og håndteringen av kommunalt avløpsvann), fra industrien, fra flere universiteter og konsulentfirmaer, og fra flere NGOer som er engasjert med ulike prosjekter innen områdene rundt Estero Salado.

34 ulike avbøtende tiltak ble identifisert. Disse omfattet 1) hva som kunne gjøres for å redusere tilførselene av forurensninger fra nedbørfeltene (eksterne tiltak), 2) hva som kunne gjøres inne i selve vannforekomsten Estero Salado, 3) hva som kunne gjøres ved hjelp av befolkningen i områdene rundt Estero Salado (socio-økonomiske tiltak som awareness programmer, mm), og til slutt 4) hva som kunne gjøres mht. vannforvaltningspraksis og reguleringer (forvaltningstiltak).

Det var også en gjennomgang av hvilke institusjoner som hadde data fra Estero Salado, og hva slags data som fantes og hva som manglet. Det ble også gjort en foreløpig identifisering av firmaer som kunne tenkes å bidra i ulike prosjekter tilknyttet en rehabiliteringsplan for Estero Salado.

Til slutt var det en diskusjon om kilder til finansiering av et slikt rehabiliteringsprosjekt, og om vegen videre for å prøve å realisere rehabiliteringen av Estero Salado, eller i det minste deler av prosjektet. NIVA fikk som oppgave å sammenstille rehabiliteringsplanen man hadde kommet frem til. Denne skulle benyttes til å søke penger til et forprosjekt som kunne bringe prosjektet til pre-feasibility fasen slik som vanlig vis kreves for søknader om internasjonal finansiering.



# 1. Introduction

The informal city expansion along the Estero Salado by unauthorized settling of poor immigrants from the country side, and the pollution it creates in the Estero Salado, the filling in of the fine branches of the Estero, the garbage spill, the wastewater runoff, the health problems among the inhabitants, etc. etc., has for almost a hundred years been a problematic challenge for the municipality of Guayaquil, the largest city in Ecuador, see **Figure 2**.



**Figure 1.** A large part of the Estero Salado has over the last 100 years been gradually converted from a natural mangrove system to a densely populated area where wastewater and solid waste handling systems are poorly developed or lacking. Photo: Dag Berge

Several studies and reports have been given on what needs to be done to improve the situation and solve the problems. The last comprehensive study was given in 2002-2006 by Hidroestudios. CIA. LTDA., which came out with the Plan Integral para la Recuperacion del Estero Salado (PIRES) (The integrated plan for the recovery of the Estero Salado), on commission by the Municipality of Guayaquil. Phase 1 of the PIRES contained nine projects, of which only 3-4 have been implemented, mainly due to lack of funding.

The municipality of Guayaquil contracted Norwegian Institute for Water Research (NIVA) and P. Geerders Consultancy (from Holland) to participate in a two days field visit to the Estero Salado followed by a three days workshop in Guayaquil together with national experts from Ecuador as an attempt to revive the plans and process of rehabilitation of the Estero Salado. The workshop comprised broad participation of all relevant authorities both from the municipality of Guayaquil, as well as from the national ministry level (from Quito), stakeholders from the Estero settlements, from the INOCAR (the Navy Oceanographic Research Institute, which shares the responsibility for the management of the Estero Salado with the municipality), from the INTERAGUA (the company responsible for water supply and wastewater treatment), from the industry of the region, from several universities and consulting firms, as well as several NGOs which are engaged in different projects in the Estero Salado, as well as international experts. A list of the participants is given in the Annex.



**Figure 2.** The eastern bank of the Estero is now in effect a city-like are. The red branches has been filled in and disappeared during the last 70 years. Source: El Universo, 2009.

The intention with the broad participation in the workshop was:

- To identify the right measures as elements of a holistic approach
- To be fully aware of what has already been done (i.e. avoid beginning from scratch)
- To be aware of the possibilities and limitations (constraints)
- To get the opinion and advice from all entities with an interest in the problem
- To hear how they solve such problems in other parts of the world
- To get consensus about the approach
- To develop ownership for the approach as a basis for sustainability
- To lay a good foundation for a fruitful cooperation

The field visits were organised by the municipality one day by boat (March 21), and one day by helicopter (March 22). The workshop itself was organised by, and held at the University ESPOL (Escuela Superior Politécnica del Litoral ) on March 23-25, 2011.

Based on the field visit and the outcome of the workshop, NIVA should draft an approach to the rehabilitation of Estero Salado, including two proposals for specific projects that could be used as a basis for application for funding. The workshop identified a large number of different measures, divided into 4 classes. Because it is not likely that all of these measures could find funding from one single funding source, it was agreed that a process of prioritizing was needed.

The present compilation by NIVA should first of all serve as a basis for applications for funding for further work with the plans, prioritizing, and split it up in different smaller projects that can be used as basis for application directed to specific funding sources, etc.

In addition to presenting their advice and experience to the workshop, NIVA and P. Geerders Consultancy functioned as secretaries for the workshop

## **2. The different phases of the rehabilitation plan**

The planning of a comprehensive rehabilitation project normally has several phases:

1. Scoping (with the workshop was a main contribution)
2. Pre-feasibility
3. Feasibility
4. Detailed design

After the four stages of planning, comes the construction phase where the entrepreneurs are hired and the planned measures are carried out.

All these phases need financing and therefore each of them will need a financing plan.

In the scoping phase all possible options for improving the conditions in the Estero Salado should be collected, sorted, given a preliminary evaluation. All relevant stakeholders should be included in this process. All ideas and opinions should be included. The work shop in Guayaquil is a typical part of the scoping process.

The pre-feasibility phase of the rehabilitation should be based on the measures identified in the scoping phase. All existing data and information on the Estero Salado and its surroundings should be collected, and the different measures and group of measures should be evaluated properly. Each measure should be given a simple economic analysis, and an evaluation of the environmental improvement potential, as well as any negative impact it may have. In this phase the measures regarded as unrealistic should be identified and deleted from the rehabilitation plan.

The feasibility phase should be based on pre-feasibility plan, and in a way it is more of the same, but much more in detail. It will be relevant to launch 4 feasibility studies, one for each of the groups of measures. Each measure should be analysed thoroughly with respect to environment improvement efficiency, as well as cost analysis. This will allow for final prioritizing the measures. The potential negative environmental impacts shall also be evaluated properly. The feasibility phase will end with a prioritized action plan as the last chapter.

In the detailed design phase the different measures should be described in all detail, what equipment they need, how they should be carried out, the time span when they should be carried out, the geographical delineation of the action, all kind of precautions that should be taken by the entrepreneurs, etc. The report from this phase should end with terms of reference for hiring in the entrepreneurs.

## 3. Possible rehabilitation measures identified at the workshop

### 3.1 Realism

A question asked several times during the workshop, often with doubt in the voice: Is it at all possible to restore the water quality and ecological life in this estuary? Just looking at the total transformation of the nature that has taken place (see **Figure 1**), it is quite clear that it will not be possible to bring the Estero Salado completely back to its initial natural conditions, i.e. a total restoration.

Experience from all over the world shows that when a natural area is transformed into a densely populated living area, the run off of nutrients, organic material, and several other pollutants will increase even if the sewage and industrial wastewater is taken care of. In Norway, a typical forested area has a runoff of the nutrient phosphorus of about 5-6 kg P/km<sup>2</sup> whereas a city-like living area has a runoff about 50 kg P/km<sup>2</sup> when the sewage is diverted (SFT 1995).

The Estero Salado is a very special water system. It is like a slow flowing salt water river where the water flows for a large part back and forth. I.e. the water renewal is restricted. The salt water is heavier than freshwater, which means that too much inflow of freshwater in this system will easily form a layer on top of the salt water preventing gas exchange with the atmosphere, and reduced possibilities for oxygen influx. The salt water contains large amounts of sulphates, which will easily be reduced to sulphides when exposed to low oxygen. Sulphides are bad smelling, bad looking and toxic to many organisms. Organic load, nutrient load, as well as freshwater load into such a recipient system will create conditions for sulphate reduction. The Estero Salado is therefore of the weakest types of aquatic recipients for human wastes.

However, experience has also shown that even in the biggest cities with very polluted recipients, it has been possible to improve the environmental situation in the city-waterways so much that the different forms of aquatic life is re-established and the waterway satisfy many of the former human use interests like fishing and bathing, and the waterways again start to increase the cosiness of the living area, as well as the value of the houses and the residential property. This should also be possible for the Estero Salado.

### 3.2 The different abatement measures

All in all, the workshop identified 34 different actions that could contribute to the improvement of the Estero Salado. The measures were divided into four groups:

1. Catchment external measures
2. Estero internal measures
3. Socio-economic measures
4. Management/governing measures

The first group of measures deals with what can be done with respect to reduce the inputs of pollutants from the human activities on land. The second deals with what can be done of rehabilitation in the Estero itself, the third about awareness programmes among the population bordering the Estero, and the fourth what are necessary/beneficiary to do with the legal regulation system, governing fields of responsibility, practicing the rules, etc. The measures are given in **Table 1**.

**Table 1.** The measure identified at the workshop (March 23-25, 2011 in ESPO, Guayaquil) which should be further evaluated for inclusion in the rehabilitation plan for Estero Salado. So far this is just a summary table from the workshop, no ranking of the measures has been made yet.

**All measures will need some base line data to allow a proper evaluation to find out if the proposed measure is relevant or not. This must be checked for all measures. If data don't exist, they must be provided by studies, at least the most important data.**

Catchment External Measures	Estero Internal Measures	Socio-economic Measures	Management / governing Measures
Reduction of sewage discharge	Sediment removal	Information about the project	Split the catchment into subunits that is natural to manage as a unit
Reduction of industrial discharges	Sediment treatment, Ca(NO <sub>3</sub> ) <sub>2</sub>	Public consultation – let the local population feel ownership	Split the Estero Salado into subunits (different water bodies) that is natural to manage as a unit
Reduction of discharges via the storm flow system	Aeration/oxygenation	Establish Environmental awareness programme	Strengthening of env. Authorities
Build Effluent treatment plant	Understand the hydrodynamics of the Estero	Establish Efficient garbage /solid waste collection system	Coordinate governmental /institutional responsibility related to water management
Nature based treatment system in remote areas	Evaluate options for increase of the water renewal of the Estero	Provide water supply system	Use the existing rules and regulations more strictly, fees, penalty, fine, etc.,
Incentives	Reforestation of Estero banks	Provide sewerline connection or other nature based sanitary system if sewer connection is not possible	Include both concentration and amount in the discharge permits.
Identify the pollution sources properly	Establish efficient trash hunting systems on the water and banks	Urban Planning-Settlement control Stop the property gorillas	Split the Estero Salado into subunits (different water bodies) that is natural to manage as a unit
Discharge and compliance monitoring	Cut remains of old pillars	Compliance monitoring - control	Define the catchment of these subunits
Check if existing baseline data are sufficient, if not, provide such	Check if existing baseline data are sufficient, if not, provide such	Shoreline rehabilitation and bank strengthening	
	Monitoring		
<b>All implemented measures should have some monitoring programme connected to see if they work in accordance with the intention</b>			

Before the measures can be included in a rehabilitation plan, the different measures needs to be evaluated, to get an idea of its complexity, its improvement potential, the time it will take, the cost etc. All this is a long process in itself, and will require several project phases. This workshop is only the beginning of sorting out the options into groups of measures, give each measure a short description, and start the process of evaluation. Some of these measures are already in operation in several areas of the Estero. We need to evaluate how far they have come, how good the effect is so far, etc. This document will have to go a few times back and forth between the different authorities, agencies/institutions and experts involved, and also looking into existing data and experience from the actions performed hitherto, before it can end in a fully prioritised action plan. However, some hot spots, and actions will be obvious, i.e. they will obviously end on the top of the prioritised list of actions anyhow. These measures do not have to wait for the final prioritisation of the whole plan.

This document is drafted in such a way that it can be used to apply for funding of single projects of the 34 we have identified. We will therefore start with a short description of each measure so the reader will get an impression of what it is about, how it works and to some extent, what improvement potential it has.

### **3.3 Management / governing measures (MAM)**

A preliminary ranking of the measures within this group is given in the list below:

- MAM-1 Split the catchment into subunits that is natural to manage as a unit
- MAM-2 Split the Estero Salado into subunits (different water bodies) that is natural to manage as a unit
- MAM-3 Coordinate governmental /institutional responsibility related to water management
- MAM-4 Use the existing rules and regulations more strictly, fees, penalty, fine, etc.,
- MAM-5 Include both concentration and amount in the discharge permits.
- MAM-6 Strengthening of environmental authorities

#### **3.3.1 MAM-1 Split the catchment into subunits that is natural to manage as a unit**

The area in question is already divided into several administrative units (districts, regions) which have evolved over the years because it has been a practical subdivision of the city for many purposes, geographical delimitation, distance to schools, etc. With respect to sewage collection, drinking water supply, pollution loading to certain water bodies, it is often necessary to divide the area into smaller units / and/or to use other border than the administrative borders. The subdivision of the catchment into pollution management area should be done in close connection with the next measure; splitting the Estero into different water bodies.

#### **3.3.2 MAM-2 Split the Estero Salado into subunits (different water bodies) that are natural to manage as units**

Some branches of the Estero are heavily polluted, while others are more or less un-impacted. Such units will have different environmental goals and needs different measures to be taken, the good branch needs pollution prevention measures, while the poor one may need all kind of rehabilitation measures.

### **3.3.3 MAM-3 Coordinate governmental /institutional responsibility related to water management**

There is some overlap in the water management responsibility of the different governmental entities and institutions which may hamper the work. For example has the Navy with the entity INOCAR responsibility for the water phase in the Estero, the Municipality of Guayaquil of most of the settlement area, whereas the Ministry of Environment for the protected part of the Estero. Several other overlaps and unclear fields exist. The flow of data among these entities is not always updated. Things like this should be clarified and coordinated so it will not impede the rehabilitation planning and work.

### **3.3.4 MAM-4 Use the existing rules and regulations more strictly, fees, penalty, fine, etc.,**

Instead of looking into the legal system of environmental laws and regulations, it was claimed that there existed a need for using the existing rules more consequently and strictly. There is a wide spread practise that the authorities “look through the fingers” with a lot of environmental violations. This should be tightened up.

### **3.3.5 MAM-5 Include both concentration and amount in the discharge permits.**

In the discharge permits for industry, requirements are normally set only for concentrations in the effluent water, not for the amount of pollutant that is discharged. This leads to that several enterprises add a flow of water into the discharges (diluting it) and thus comply with the standards and avoid requirements of installing purification of the discharges. There is also a practice of informing the enterprises about when the inspection will be. In this way the enterprises have good time for reducing the discharges before the inspections come. The frequency of un-announced inspections should be increased.

### **3.3.6 MAM-6 Strengthening of environmental authorities**

The sector authorities (industry, fishery, agriculture, etc) are often stronger than the environmental authorities when it comes to conflicting areas. The environmental regulations are often regarded as “brake pads” for business development. This attitude is rapidly changing in the broad society nowadays, and the need for environmental protection is widely accepted. There is a general need for strengthening of the environmental authorities in Guayaquil. This would also include the capacity of the authorities to monitor the condition of the Estero Salado through a dedicated, operational monitoring programme.

## **3.4 Catchment external measures (CEM)**

A preliminary ranking of the proposed measures from the list in **Table 1** is given below:

- CEM-1 Identify the pollution sources properly
- CEM-2 Check if existing baseline data are sufficient, if not, provide such
- CEM-3 Reduction of sewage discharge
- CEM-4 Reduction of industrial discharges
- CEM-5 Reduction of discharges via the storm flow system
- CEM-6 Build effluent treatment plant
- CEM-7 Nature based treatment system in remote areas
- CEM-8 Incentives
- CEM-9 Discharge and compliance monitoring

### **3.4.1 CEM-1 Identify the pollution sources – making rough pollution budgets**

In each subcatchment of the Estero the different pollution sources should be identified, with respect to location, type of pollution, approximate loading amounts (if possible), if it is a diffuse source or a point source, etc. The pollution sources should be grouped into categories, like point sources and diffuse sources. Based on the type of pollution and loading size, the pollution sources should be evaluated and ranked. The responsibility for cleaning up should also be addressed as far as possible.

### **3.4.2 CEM-2 Check if existing baseline data are sufficient, if not, provide such**

To evaluate the nine points concerning external pollution, data will be needed. Some of the data exist already, while for some others data has to be provided by studies. The identification of existing data did start at the workshop (see Chapter 4), but was far from completed. A special project should be devoted to the identification, acquisition and integration of existing data and information on the Estero Salado, and to making this data and information available to the project partners through a dedicated data and information system, including a Geographic Information System (GIS) component.

### **3.4.3 CEM-3 Reduction of sewage discharge**

In this field INTERAGUA and the Guayaquil municipality already has a plan which is in operation. It consists of building sewer lines and connecting houses to them and transporting the sewage to treatment plants. The treatment is however, so far very simplistic. This work is in good hands, and the slow speed of the rehabilitation and expansion of the works is mainly due to restricted funding. This work is focussed for the whole city of Guayaquil, and not only on the parts draining to the Estero Salado.

It should be made a subplan on how to speed up the diversion of wastewater from entering the Estero Salado. INTERAGUA will be central in this work.

### **3.4.4 CEM-4 Reduction of industrial discharges**

The picture concerning pollution load from industries to the Estero Salado seemed rather unclear. This applied both for the larger industries, but perhaps even more unclear for the many small back-street enterprises. There exists little information on the quantitative pollution loading from industry, as the monitoring does mostly measure the concentration in the effluent, not the quantity.

Bases on the mapping, all industrial pollution sources should be grouped into categories, 1) with effluents that can be lead into the municipal wastewater system, and 2) with effluents that need own specialized treatment.

In the long term scope, the industry should plan for switching into more clean technology, and recirculation of the process water.

### **3.4.5 CEM-5 Reduction of pollution discharges via the storm flow system**

A problem is that the storm flow drainage system is also heavily contaminated with sewage and other wastewaters. This is partly due to leakages, but also due to the fact that people and enterprises connect illegally their effluents to this pipeline system.

All rainwater drainage system entering the Estero Salado should be monitored for contaminants. Particularly in the low flow season the water flow in this system should be very low and the water, which in such periods should be in-leakage of groundwater, should be very clean. The monitoring in



such periods will easily see if something is wrong. The monitoring should be done several sites along the lines, so the location of the wrong couplings could be localized and brought to a stop.

### **3.4.6 CEM-6 Build effluent treatment plant**

INTERAGUA is responsible for the drinking water supply and municipal wastewater collection and treatment and final disposal. So far the sewage collection does not cover much of the residential areas along the Estero Salado, where a large part of the population don't have modern sanitary standard. In most cases they have only pit-latrines or latrines that are emptied by the municipality or dig down by hand in the garden, or dumped into the filling down towards the Estero, or directly into the Estero waters.

All spill of organic wastes, including nutrients, will seep through the soil, reduce the oxygen content of the ground water, reduce the ferric iron into ferrous state, reduce the sulphate to sulphide, which will be dissolved in the ground water and percolate to the Estero. There it will form dark and bad smelling water and black sediments of iron sulphide. Such sediments have low retention capacity for phosphorus which then easily will leak to the waters and create algal growth.

If the collected wastewater is only pumped into the mangrove system without any previous treatment, some of it may re-enter the Estero Salado.

The ideal situation in the future would be the all the densely populated areas along the Estero should have modern sanitary systems and be connected to the sewerage system. All sewage and industrial wastewater (after possible pre-treatment) should be conveyed to a central sewage treatment plant located downstream of Guayaquil city, with effluent of treated wastewater to the Guayas River, which has the necessary recipient capacity.

The treatment should at least be mechanical and biological to remove the organic and oxygen consuming material. It should also have a sludge handling and sludge disposal. It should have the option of adding a step of phosphorus removal by chemical precipitation as well.

No wastewater should be allowed to enter the Estero Salado. This weak recipient has only the capacity of receiving the diffuse pollution runoff coming from the residential areas remaining after the sewage is diverted.

However, these things are easy to say and to agree upon, but it is necessary to be realistic and take it gradually. But the course should be in the direction outlined here, so every little addition of sewer lines will be a step in the right direction. It should be based upon what INTERAGUA already has built up, and for the immediate period stick to the existing plans. However, INTERAGUA's plans has to be coordinated with the rehabilitation plan for the Estero Salado, as with any other water rehabilitation plan run by Guayaquil municipality.

### **3.4.7 CEM-7 Nature based treatment system in remote areas**

In remote areas with scattered population there should be built nature based waste water treatment facilities. They should be built in a planned and coordinated way so that they will not contaminate the drinking water well of the downstream located neighbour. There are mainly two types of nature based wastewater system, 1) based on infiltration, and 2) based on wetlands. For single houses there are mixed solutions like infiltration of the grey water (washing water, etc) and collecting tank for black water (toilet water) with municipal emptying, with subsequent delivering into the nearest sewage treatment plant. More primitive solutions exist, as pit-latrines, and several types of composting latrine systems.

Marine wetlands like mangrove systems are less suited for wastewater treatments than freshwater wetland systems because of the sulphate reductions that takes place in the former.

All wetland and infiltration systems will after some years use become saturated, the active binding sites for pollution agents will be occupied, and the retention capacity of the system will be reduced.

### **3.4.8 CEM-8 Incentives**

One should develop a system where it should be advantageous not to discharge pollution into the Estero Salado. This should apply for those responsible for municipal sewage effluents, solid waste and garbage handling, industrial effluents, small enterprises, and even for single houses. This field is actual for several groups of measures.

### **3.4.9 CEM-9 Discharge and compliance monitoring**

To be able to identify pollution sources, what kind of pollution that is entering the Estero at different times and places, to see if the different units are within their discharge limits, and to see if the abatement measures helps or not, a set of different monitoring programmes is needed. In the first phases monitoring is mostly needed to identify the pollution sources and to find the ways by which they are entering the Estero. The monitoring of the later phases needs to be designed as part of the rehabilitation plan, and should result in a permanent, operational environmental monitoring system of the Estero Salado and its relevant periphery, as a facility for integrated management and sustainable development of the area: decision making, planning and policy development.

## **3.5 Estero internal measures (EIM)**

It is clear that the most important types of measures are those aimed at preventing the pollution of entering the Estero. However, there are several measures that can be taken directly within the Estero itself. These types of measures are often called internal measures, unlike the external measures treated in the former session. Preliminary ranking of the proposed Estero internal measures is given in the list below:

1. EIM-1 Check if existing baseline data are sufficient, if not, provide such
2. EIM-2 Understand the hydrodynamics of the Estero
3. EIM-3 Evaluate options for increase of the water renewal of the estero
4. EIM-4 Establish efficient trash hunting systems on the water and banks
5. EIM-5 Cut remains of old pillars
6. EIM-6 Reforestation of Estero banks
7. EIM-7 Aeration/oxygenation
8. EIM-8 Sediment treatment,  $\text{Ca}(\text{NO}_3)_2$
9. EIM-9 Sediment removal
10. EIM-10 Monitoring

### **3.5.1 EIM-1 Check if existing baseline data are sufficient, if not, provide such**

Also under this group of measures different data are needed to be able to evaluate if a measure should be taken or not. This will be an important part of the pre-feasibility phase of the project. See also section 3.5.2 and 3.5.9.

### 3.5.2 EIM-2 Understand the hydrodynamics of the Estero Salado

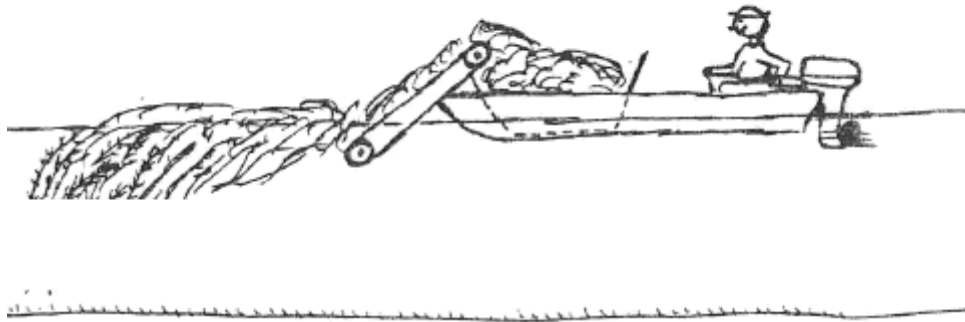
The water renewal in the Estero is limited, particularly in the innermost branches. This applies both for freshwater influx, natural and anthropogenic, as well as for saltwater renewal. The water renewal should be clarified, both with measurements as well as by hydrological modelling. Also the stratification in the water column should be clarified, i.e. to what extent there is a freshwater lid on top which prevent oxygen exchange with the atmosphere.

### 3.5.3 EIM-3 Evaluate options for increase of the water renewal of the Estero

Based on the clarification from the former point, there should be looked into the possibilities of increasing the water renewal. This should comprise the possibilities for uni-direct the current from the ebb and tide by installing gates and locks, as well as look carefully into the possibilities for more freshwater renewal. Both these evaluations should include environmental impact assessment of the measure.

### 3.5.4 EIM-4 Establish efficient trash hunting systems on the water and banks

Today, trash hunting is mostly done by hand. This is a laborious work. Trash hunting on the water surface can easily be streamlined by a so-called self-made belt-skimmer. The simplest version is to mount a tilted netting based conveyer belt in the front of a boat, see drawing in **Figure 3**. It needs to be made of netting to prevent the formation of a pressure wave pushing the garbage away.



**Figure 3.** A simple easy-to-make trash hunting device based on a tilted conveyer belt of netting in the front of a boat

On the steep river bank it is not easy to find any better trash hunting device than picking by hand. But it might be that this could be organised in an efficient way by utilising the local inhabitants based on incentives.

### 3.5.5 EIM-5 Cut remains of old pillars

Several places remains of old house pillars are still standing in the water. These are bad looking, passively damming floating garbage, impeding boat traffic, as well as preventing efficient trash hunting from boat. These should be cut.

### 3.5.6 EIM-6 Reforestation of Estero banks

Several places along the Estero in the populated areas there are no vegetation between the buildings and the water, see **Figure 1**. However, several other places even within the city, the Estero has a brim of trees along the shoreline, as for example shown in **Figure 4**.

There is a long ray of advantages of having vegetation belt along the Estero, with respect to water ecology, bank ecology, land-water interaction, bank strength (slide protection), as well as an element of cosiness for living areas. Just compare the right panel of **Figure 1** with the picture below, **Figure 4**.

Reforestation of the banks of the Estero therefore will be a good measure for many purposes and should be given high priority.



**Figure 4.** Several places within the city the Estero Salado has a brim of trees along the shore. This has several positive effects. Photo: Dag Berge

### 3.5.7 EIM-7 Aeration/oxygenation

In several areas, particularly in some of the innermost branches, the water is likely characterised by oxygen deficiency. The measurements confirming this, however, are scarce. The oxygen regime in the Estero should be mapped thoroughly. It could be relevant to deploy aerators or oxygenators in some areas, if the situation is very bad. However, the effect of an aerator will be mainly local, and the Estero is shallow and has many branches. Aerators can also be deployed on board boats that go back and forth over a certain stretch. This will distribute the oxygen better, and is not so prone to theft. The prevailing oxygen regime has to be mapped better before any decision is taken on this measure.

### 3.5.8 EIM-8 Sediment treatment, $\text{Ca}(\text{NO}_3)_2$

The sediments of many regions of the Estero Salado have a black appearance and it smells sulphide. The black sediments are iron sulphide. It can be formed in the Estero itself if the oxygen concentration is very low, and ferrous iron is released from the sediments or seeping in via oxygen poor ground water. It can, however, also be formed in the ground or in the drainage pipes entering the Estero. This should be clarified. Reduced sediments containing iron sulphide will not bind phosphorus as good as oxidised sediments. Oxygenation of the water masses will also oxidise the sediments, but it is a slow process. Addition of calcium nitrate or another form for nitrate directly to the sediments may be more efficient and easier to apply. The nitrogen will denitrify and the oxygen will oxidise organic material

(act as electron donor for the denitrification). Pelletized salpeter will possibly could sink to the bottom and into the sediments in the shallow Estero, and if so, spreading on the surface may be possible and an easy application method. Then large parts of the sediments can be treated in an easy and efficient way. However, tests have to be carried out in advance before the measure can be recommended in large scale.

### **3.5.9 EIM-9 Sediment removal**

If the sediment also contain severe amounts of environmental toxins, like PCB, DDT/DDE, dioxin, PAHs, mercury, etc. it may be necessary to remove the sediments. If organic material and lack of oxygen is the main problem, our experience is that the sediments improve by itself when the external pollution loading is removed in such a shallow water body as the Estero Salado. Another reason for dredging may be for increasing the sailing depth. We noted complaints about increased sedimentation along the Estero. This can be due to erosion from the soils that are used to expand the land area for house building by filling in the estuary banks, see **Figure 2**. The removal of the bank trees has also been a factor for bank erosion by the tidal current going back and forth. It may also be that the denuding the landscape from vegetation has created terrestrial soil of more distant areas more prone to rain erosion which can reach the Estero, particularly during storm flow runoff.

The extent, and reason for increased sedimentation in the Estero Salado should be clarified before launching a large and costly dredging programme. Also, special care should be taken concerning the dumping of the dredging products, in view of its toxic character.

### **3.5.10 EIM-10 Monitoring**

A monitoring programme covering the whole Estero Salado should be run for one year including both chemical and biological parameters (water phase and sediment phase) to assess the ecological status and pollution impact in the different parts of the Estero Salado. This would serve as an important basis for evaluating need for abatement measures.

Monitoring of the pollution and ecological status of the Estero Salado should also be conducted as a mean of evaluating the effects of the rehabilitation measures, and should develop a permanent facility for the management of the area by the local authorities, see also section 3.5.2 and 3.5.9.

## **3.6 Socio-economic measures (SEM)**

As many as 10 measures were identified at the workshop. A preliminary ranking of the proposed measures is given in the list below:

- SEM-1 Information about the project
- SEM-2 Public consultation – let the local population feel ownership
- SEM-3 Establish Environmental awareness programme
- SEM-4 Establish Efficient garbage /solid waste collection system
- SEM-5 Provide water supply system
- SEM-6 Provide sewer line connection or other nature based sanitary system if sewer connection is not possible
- SEM-7 Urban Planning-Settlement control
- SEM-8 Stop the property gorillas
- SEM-9 Compliance monitoring - control
- SEM-10 Shorline rehabilitation and bank strengthening

### **3.6.1 SEM-2 Public consultation – let the local population feel ownership**

These two points are very much related to each other, so they can be clarified jointly.

The people living along the Estero Salado are, as all other people, concerned about their own living area. This intrinsic interest in own area can be a driving force in a rehabilitation plan if the people are included in the planning and work in a good way.

It is the municipality that owns such a project, and they must first of all inform the population in the project area about the project good in advance. In the planning phase there should be arranged public consultation meetings free for all to participate. Local stakeholders should be involved in the planning at least by sitting in a reference group for the project, and, for those measures that the local population can take part in directly, local stakeholders should be part of the planning group for the project.

This is necessary for having the local population feel ownership to the project and to be motivated to participate.

### **3.6.2 SEM-3 Establish Environmental awareness programmes**

Awareness amongst the local population on the connections between health, environment, and pollution, and how their own attitude and behaviour can improve the conditions, could facilitate the implementation of a rehabilitation programme. This was also recognised in the plan of Hidroestudios (2004) as: Environmental education programme. Such programmes, also involving primary and secondary schools, could also increase the interest of the local community in taking actively part in the projects, as well as come up with valuable ideas for solving different problems. However, it should be kept in mind that easing the burden of unemployment and poverty is important to achieve sustained awareness of the importance of the environment.

### **3.6.3 SEM-4 Establish Efficient garbage /solid waste collection service**

The municipality must provide the areas with efficient garbage / solid waste collection service. It must be easier for the inhabitants to throw the garbage correctly into the containers than to throw in into the Estero Salado. The containers must be emptied at least weekly, possibly twice a week.

People from the local population could be engaged in garbage collection and sorting, and in this way the project could serve to create paid work in these areas where there is a lot of unemployment.

### **3.6.4 SEM-5 Provide water supply system**

Safe drinking water is a prerequisite for a healthy population. The best would have been to have piped water to each house, but until this can be provided, tap water should be available at central places for groups of closely located houses.

### **3.6.5 SEM-6 Provide sewer line connection or other nature based sanitary system if sewer connection is not possible**

If you provide drinking water, you also create runoff water if you don't provide sewer connection at the same time. It may be far into the future that water closet can be available to each home. The collection of the toilet water should be equally easy as flushing it into the Estero. Otherwise that will be done. Pit latrines in such permeable soils (fillings along the Estero banks) will for a large part end up in the Estero with only poor retention of pollutants. Toilets separating urine and faeces may be a solution, where the urine is infiltrated in the ground and the faeces is collected by the municipality service and composted.

### **3.6.6 SEM-7 Urban Planning-Settlement control**

The urban planning should go ahead of the immigrations, so that these areas can be provided with infra structure as early as possible. Therefore the urban planning should be enforced to have the

necessary capacity. There should also be launched campaigns that ease the life in the country side (active district policy) to reduce the movement of people into the cities and large towns.

### **3.6.7 SEM-8 Stop the illegal property business**

Even though it is forbidden to establish new homes on the Estero, it still happens (see Universo 2009). The local district leaders, and/or others with connections to the land owners, are often involved in illegal business related to property trading and financing the purchase of homes and land. As the population gets dependant on them, they become powerful and factually control the district. What they say is often regarded as more important for the population than what the municipality says.

### **3.6.8 SEM-10 Shoreline rehabilitation and bank strengthening**

This measure could also belong to the group Estero internal measures. In the planning and construction phase it must be led by those responsible for the last mention group, but in the long run the maintenance of the shoreline areas must be a responsibility of the local communities. That will serve preventive with respect to throwing garbage in the banks and into the Estero.

### **3.6.9 SEM-9 Compliance monitoring – control**

Also in this group of measures it is necessary with some kind of monitoring, both with respect to controlling the effect of the measures, as well as some compliance monitoring.

## 4. Existing data and information on the Estero Salado

A subgroup during the workshop focused on existing data and information on the Estero Salado, where it is held, as well as on which data and information is still lacking. The result of the group work is presented below. This should be considered as a first approach and a more dedicated approach is required as a basis for the follow up activities.

### SUBGROUP: AVAILABLE SCIENTIFIC INFORMATION (HOLISTIC)

#### PARTICIPANTS:

INP:	QF. PATRICIA MACIAS
MUNICIPALITY:	VICTOR HUGO MOLINA
DIRNEA:	QF. LEONARDO SAENZ
INOCAR:	DRA. GLADYS TORRES, DR. LUIS BURGOS
ESPOL:	LUIS DOMINGUES
MAE:	BLGO. SANTIAGO COELLO
PGC/NIVA:	PAUL GEERDERS

Activities	Interior part of the Estero Salado	Exterior part of the Estero Salado
Geographic areas	Kenedy, Urdesa, Miraflores (track A-B), 5 de junio bridge, bridge at 17 and Portete de la A (city sector)	Estero del Muerto, Puerto Guayaquil, access channel to the Estero Salado, rio Guayas (shrimp sector)
<b>EXISTING INFORMATION</b>		
INP (National Fisheries Institute)	1993-1996 ESTERO SALADO 2010 (MAE-INP) biodiversity (plankton and macrobenthos), physical, chemical, microbiology, contaminants (water and sediments)	1993-1995 biodiversity (plankton and macrobenthos), physical, chemical, microbiology, contaminants (water and sediments)
MUNICIPALITY	Identification of industrial discharge: data base of inputs since 2009; there is partial information on industrial sources as a basis for achieving a complete baseline	Identification of industrial discharge: data base of inputs since 2009 (city sector Guayas).
DIRNEA (National Water Directorate)		Information on regulation and inventories of the shrimp industry; control of industrial discharges.
INOCAR (Navy)	1996-1997 Bridge at A and Trinitaria, physical, chemical and biodiversity	1996-1998: Estero del Muerto, Puerto Guayaquil, access channel to the Estero Salado, río Guayas (physical-chemical and contaminants, plankton, benthos) 2009: Estero El Muerto (physical-chemical and contaminants).
ESPOL (Escuela Politecnica del Litoral)	Physical-chemical data; intertidal benthos 2007-2008-2009 (thesis)	Intertidal Benthos Inventory (planned) 2011-2012 (Churute)



MAE (Ministry of Environment)	2010 (MAE-INP), biodiversity (plankton and macrobenthos), physical, chemical, microbiological, contaminants (water and sediments); Baseline Study of the Reserva de Manglares del Salado (to be confirmed)	Biodiversity of Santay Island (Río Guayas)
INTERAGUA	Quarterly waste water discharge data	
<b>WHAT IS MISSING</b>		
	Information on terrestrial and aquatic flora and fauna	
	Inventory and health of the mangroves	
	Inventory ichthyoplankton and fish stocks	
	Identification of expert taxonomists for the various biological sectors	
	Formats, standardisation and validation of the physical, chemical, biological, and toxicological information on the aquatic ecosystem (water and sediments) and the terrestrial ecosystem (flora and fauna)	
	Establish an inter-institutional expert group for the monitoring; reports; workshops; prepare a project for the monitoring (coordination of the annual institutional activities; reserve budget for monitoring for 5 years with renewal; monitoring sites; indicators for control and follow up; annual reports	
	Updating of environmental and biological baseline, both terrestrial and aquatic, before starting the project; during the project use indicators to detect improvement of the Estero Salado	
	Distribution of the results through workshop, publications, brochures, folders, and other means.	
	Meetings between scientists and managers, responsible for the regulations concerning the parameters of quality indicators; updating of the standards for quality control of the Estero Salado	
	Participation of thesis students in the monitoring activities.	

## **5. Financing - the way forward – preprojects**

The last session of the workshop addressed the possibilities of financing the comprehensive rehabilitation plan that was developed and outlined during the workshop. If all the proposed measures should be executed in full scale, including complete wastewater diversion and new sewage treatment plants, this would cost roughly 200-400 million USD, a considerable sum and probably difficult to find.

Probably a breakdown in smaller sub-projects would be more feasible and acceptable for funding agencies. Therefore the workshop agreed that several alternatives for funding should be identified, as a basis for the search for funding. The initial result of the discussion is given below.

### **FUNDING OPPORTUNITIES**

- Donation (percentage of company revenue) through tax arrangement, to support the rehabilitation of the Estero Salado.
- Tax incentive
- Monthly tax (1 dollar or less) to support rehabilitation of the Estero Salado; proposed to INTERAGUA.
- INTERAGUA: tariffs are regulated and cannot be increased; maybe taxes can be levied on discharges, this has to be studied.
- Use the income from fines or sanctions to support the rehabilitation of the Estero Salado.

### **NATIONAL FUNDS**

- Environment Ministry “Guayaquil Ecológico”
- Incentive for recycling
- Responsible Production: recuperate funds (for the inhabitants) with the sales of the products
- Waste recollection: door-to-door recollection to minimize environmental impact.

### **INTERNATIONAL FUNDS**

- Trust Funds of Norway and/or Netherlands at IADB for specific projects up to USD 75000; simple format, submit to IADB office in Quito, evaluation takes 2-3 months, include local complementary funding or in kind counterpart.
- Netherlands’ Embassy in Quito: “Small Projects” fund; projects up to USD 30000; direct benefit to population required; simple format and short evaluation period; include local complementary funding or in kind contribution.

The list given above of national and international sources of financing is not complete. It represents the suggestions given during the closing discussion at the workshop.

It was recognised that it will be necessary to apply for funding from international sources in addition to the national sources. As the workshop and this report represent the first phase in the rehabilitation plan, The Scoping Phase, (see section 2, on the different phases in a rehabilitation plan), it was agreed that as a first step we should apply for a pre-project to further elaborate the plans.

An important first step will be to identify, acquire and analyse the existing data and information on the Estero Salado in order to see what new studies will be required as a basis for evaluating which of the proposed measures should be taken, and in which order. Some measures are obvious and could be started right away, but they have to be planned carefully, keeping in mind the need for a holistic approach. Therefore, it seems realistic to go through the four phases of planning as presented in section 2.

The data and information assessment should be done the summer of 2011, and following the evaluation of the data, the need for new data by studies can be formulated. This should be finished by November 2011. In this way the missing data could be collected through studies in 2012. In 2013 the prefeasibility studies should be carried out, and in 2014 the feasibility studies. Parallel to this a financing plan should be developed for the measures that finally will be taken, a work that will take years to achieve.

During the workshop, a preliminary identification was made of which companies, institutions, and governmental entities that could participate in the further planning and execution of the rehabilitation work, see **Table 2**.

**Table 2.** Preliminary list (identified at the workshop) over institutions and entities in Ecuador that could contribute in the rehabilitation planning and work (to be completed locally).

#### ENTITIES WITH A POTENTIAL ROLE/CONTRIBUTION

NAME	ROLE/CONTRIBUTION
UEES	Awareness, inventories of flora and fauna
ESPOL	Monitoring, ecotoxicology, aquatic biodiversity, training, development of methods, master studies, data centre CTI
INOCAR	Physical, chemical, biological monitoring; physical oceanography; bio testing
INP	Physical, chemical and biological monitoring and laboratory facilities
RED ECOSAN-ECUADOR	Awareness on responsible use of water, expertise in ecological purification
DIRNEA	Regulations for fixed and floating shrimp farms
MUNICIPALIDAD MDA	Coordinator, boats, vans, control and monitoring, existing technical information, evaluation of the legal context through decrees, spatial planning
MAE	Monitoring, education, awareness, relocation
INTERAGUA	Monitoring, education, awareness, relocation
PREFECTURA	Environmental education, reforestation of the mangroves
Cámara de INDUSTRIAS	Protection of the basin
CAMARA DE CONTRUCCION	Protection of the basin
SENAGUA	Protection of the basin
SECRETARIA NACIONAL DE	

RIESGOS	
Ministry of Education and Health	
SUBSECRETARIA DE ACUICULTURA, CNA EMPRESAS LIMPIADORAS	
UNIVERSIDADES	
VOLUNTARIOS AMIGOS DEL ESTERO SALADO	
ONG'S	
IGM	

In the context of this pre-project, two follow-up projects are proposed:

**PROJECT 1: EXISTING DATA AND INFORMATION ON THE ESTERO SALADO**

An important first step will be to identify, acquire, compile and analyse the existing data and information on the Estero Salado. A first aim of this project is to identify what additional studies will be required to complete the total view of the Estero Salado as a system. A second aim is that the information serves as a basis to develop a holistic approach to the rehabilitation as a context for evaluating which of the proposed measures should be taken, and in which order. The project will lead to a comprehensive data and information system on the Estero Salado, including a GIS component, as an essential basis for the further development and implementation rehabilitation project. The data should include in situ data, as well as remote sensing (aircraft, satellite) data, while it would also be valuable to identify existing numerical models.

**PROJECT 2: UPDATED MAP OF THE ESTERO SALADO**

An updated map of the Estero Salado would serve to develop a model of the Estero Salado system, allowing the simulation of the impacts of different kinds of measures and scenarios, and to optimise these before implementing them in practice. This project aims at a complete and updated map of the Estero Salado and the surrounding basin, including the system of channels (location, width, depth), the land use along the shores (houses, industry, agriculture, vegetation), and the known sources of contamination (including the pipes at various places along the shores of the Estero Salado). Specifically the map serves as a basis for developing measures EIM2 and CEM1. This map could be developed using the contents of the data and information system of Project 1. Of course, provisions should be made for a regular updating of this map in the future, as it is an essential tool for the operational integrated management of the Estero Salado by the authorities, including for decision-making, planning and policy development.

Both projects can be carried out by local experts from the relevant entities, under guidance by Paul Geerders of P. Geerders Consultancy, based upon his extensive experience with environmental data and information management, and related technologies and methodologies.

The data and information assessment could be done the summer of 2011, and following the evaluation of the data, the need for new data by studies can be formulated. This could be finished by November 2011, and also provides a basis for an initial version of the updated map of the Estero Salado. The missing data could be collected through studies in 2012, which data also provides the basis to finalize the updated map of the Estero Salado. In 2013 the prefeasibility studies should be carried out, and in 2014 the feasibility studies. Parallel to this, a financing plan should be developed for the measures that finally will be taken. It may be expected that the full rehabilitation of the Estero Salado will take several years to complete.

## 6. Literature

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List over participants in the workshop

Taller: Nuevas Perspectivas para la Recuperación del Estero Salado  
 CADS-ESPOL ; MIMG-DMA  
 23, 24 y 25 de Marzo del 2011

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