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EGYPTIAN ENGINEERED WETLAND PROJECT

Introductory Notes

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1. PROJECT AND SITE ALTERNATIVES

This section details the various decisions that were made that led to the selection of the wetland treatment as compared to other alternatives such as nitrogen addition, hydrogen peroxide addition, aeration, conventional treatment plant and wetland. The preferred wetland design has been considered in the form of three alternatives: 5 stages system in lake or drain, parallel to drain, or a duckweed system.

1.1 Selection of the Treatment Design

There are several alternatives which have been considered by the project consultant to treat the contaminated drain waters entering Lake Manzala, including:

1. the incorporation or addition of inorganic nitrate to the drain water to stimulate microbial degradation of the organics and gradual aeration of the water.
2. the addition of hydrogen peroxide to the drain water thus releasing molecular oxygen into the water permitting organisms to utilize this as the terminal electron accepter to oxidize the organics in the water.
3. mechanical aeration of the water, thereby increasing the dissolved oxygen content of the water and stimulating the microbial oxidation of the indigenous organic matter.
4. conventional wastewater treatment which rely on chemical precipitation, floculation, oxidation, and biological breakdown of organic materials; and
5. engineered wetland treatment system using sedimentation, adsoption, plant-mediated aeration, and bacterial and plant uptake mechanisms.

An evaluation of these alternatives resulted in the elimination of the first three methods of treatment as viable or effective means to treat the pollutants entering the Lake system.

(1) *Addition of Nitrate:* Given the anaerobic state of the water within the Bahr EI Baqar Drain , the addition of nitrate to the water as an alternative electron acceptor would be totally infeasible. In the organically-rich waters of the drains entering Lake Manzala, if the nitrate is reduced predominantly to ammonium ions, and if the ammonium does not give out gas from the solution prior to its entrance into the Lake, the free ammonium ions in the water would be extremely toxic to the indigenous fish and other organisms of the Lake.

(2) *Additional of Hydrogen Peroxide:* Recent studies on the in situ microbial degradation in the substrata have indicated that hydrogen peroxide can be injected with other microbial nutrients to increase the dissolved oxygen content of the groundwater and increase the rate of microbial oxidation of the organic pollutants. The hydrogen peroxide content must be increased gradually to a maximum concentration of 200 mg/L in order for the indigenous microrganisms to adapt to this alternative electron acceptor and to develop a tolerance toward this strong oxidizing agent. Addition of peroxide to the drain water would not be feasible for several reasons:

1) an extremely large volume of water is discharged into Lake Manzala, between 2.5 and 6 million cubic meters per day. To sustain a peroxide level of 200 mg/L a large quantity of between 50 and 120 T of peroxide would be required each day;
2) by adding a strong oxidizing agent to the water, the metal sulphides in the underlying sediments would be oxidized, releasing free metal ions into solution and oxidizing the sulphide to sulphate. The free metal ions and the increased sulphate ion loading to the Lake could prove toxic to the indigenous aquatic biota of the Lake.

3) *Mechanical Aeration of the Water:* Large electrically driven mechanical aerators are available for approximately $20-25,000 per unit. These aerators will aerate 4,100 cubic meters of water per hour and can be adjusted to draw water from depths of 10-15 feet. The major drawback to such a plan is the fact that the daily water flow into Lake Manzala would require between 26-61 aeration units to aerate the total volume of water. Because of the fluidity of the drain sediments, the maintenance and operating costs of these units would be prohibitive as the metal-sulphide laden sediments would score and abrade the units. Additionally, these units require a 400 volt power supply requiring considerable initial capital investment for the region. Finally, aeration of the drain water would also re-oxidize the metal sulphides, releasing metal ions and sulphate into the water which would then enter the Lake.

After rejecting the first three alternatives, the final evaluation of a suitable treatment facility centered upon the relative merits of conventional wastewater treatment and engineered wetland treatment systems.

4) *Conventional Wastewater Treatment:* Advances in conventional wastewater treatment technology have permitted the establishment of facilities designed to remediate specific water pollution problems, but specialized options can be expensive. Depending upon the level of treatment, a considerable amount of pollutants can travel through the plant unimpeded. For examples, algal nutrients can become more bio available and create 4-5 x more BOD in increased algal production than was in the original waste stream. Because the facilities use end of pipe design criteria, unintended impacts on the receiving waters are not always appreciated. For a long time, these facilities were considered as the only option. However, for many developing countries the high capital, operation, maintenance and power costs associated with such plants have seriously impacted upon the viablity of conventional wastewater treatment facilities. In many instances, unforeseen changes in pollutant loadings or chemical content have highlighted the lack of flexibility of such systems, requiring costly additions or alterations to existing facilities to operate effectively under these changed conditions. These maintenance requirements are often beyond the capabilities of developing countries to provide.
5) *Engineered Wetland Treatment:* Advantages of engineered wetlands include relatively low construction, maintenance and operating costs. Wastewater treatment efficiencies are very good, especially for BOD, TSS, and faecal coliform bacteria. With proper design and adequate treatment area, removal of nitrogen compounds and phosphorus is readily accomplished, and the system can withstand substantial fluctuations in loading rates and hydraulic regimes.

They also provide a number of additional biological and socio-economic benefits for the receiving environment and its inhabitants.

A number of factors have favoured the establishment of an engineered wetland treatment facility to treat the contaminated drain waters entering Lake Manzala, including the following:

1. Rapid and continual changes in wastewater volumes and chemical composition over the next four decades until the Greater Cairo Wastewater Treatment Project is fully operational will prohibit the design of an efficient conventional waste treatment facility. An engineered wetland system can be readily scaled up to meet increased wastewater flows without incurring high initial costs as is the case with the conventional systems, and can be designed to operate in combination with the existing conventional systems, thus providing final polishing or renovation.

2. Apart from producing reusable water for aquaculture and for recharging the local groundwater resources , the engineered wetland will provide considerable benefit in ecological terms through the protection or expansion of existing wetlands which contributes to the regions biodiversity and support a variety of aquatic species and migratory wildfowl; it will also result in a reduction in greenhouse gases, and overall habitat enhancement.

3. Although the construction of both treatment facilities will generate considerable economic benefit, principally in the form of local employment, additional benefits will come to the region from the establishment of an engineered wetland treatment facility, including the generation of recyclable alternatives for the treated water and the harvestable biomass that can provide for several human needs (bricks , fuel pellets, other building products , animal pellets, ect.). Treated water can be used to support various types of aquacultural operations, as the treatment removes bacterial and viral pathogens from wastewaters without any chlorination.

4. In conclusion, an engineered wetland constitutes a whole ecosystem approach to harmonizing human needs for waste disposal, energy, animal food, building materials etc., with natural renewable processes and whole ecosystem enhancement. If implemented, this project would represent sustainable development in action.

Typically, US construction costs range from $0.50-1. 50/gallday of wastewater treated whereas conventional primary/secondary treatment plants handling point source wastes cost $15-16/gallday in construction costs. For example (Hammer 1992), a TVA (Tennese Valley Authority) designed system at Benton, Kentucky which polishes primary lagoon effluent, cost $260,000 in 1986 compared to a 1972 estimate of $2.5 million for a comparable conventional treatment system. Two other systems designed for secondary and tertiary treatment for communities of 500 (Hardin) and 1000 (Pembroke) users varied from $212,000 to $366,000. Operating costs for these systems are less than $100,000 a year. In Egypt, the City of Suez will build a conventional sewage treatment system to treat about 130,000 cubic meters per day at a cost of $110 million. The construction and five year operation of an engineered wetland treatment system to provide equivalent or better treatment is $8 million.

Wetland technology is not a new technology. First publication on the technology goes back to the late 1950's. Engineered wetlands have been constructed in increasing numbers over the last two decades. Although the exact number is unknown, there are at least a few thousand existing or being planned worldwide. There are 250 municipal wastewater systems operating in the US along. Appalaci has over 450 wetland systems for acid mine drainage. The U. S. Federal Department of Agricultural has funded over 100 systems for livestock wastes. There are several large scale systems operating at full capacity or being expanded to full capacity in Florida, California and South Dakota. Lakeland Site in Florida is 1,640 acres (665 hectares), Ironbridge Florida 494 hectares, Lake Apopka more than 2,202 hectares, Lake Balaton, Hungary, 1,800 hectares, and a system being constructed in South Florida is about 14,000 hectares. By contrast, the proposed Engineered Wetland for Lake Manzala is 300 hectares not counting the sedimentation areas.

In the final analysis, the volume of water to be treated proved to be a deciding factor. Current reclamation activities in the area to the south of Lake Manzala where the major drains are located will considerably affect the volume and pollutant composition of waters entering the lake. These variations and the complexity of the non point sources over 100 km of drain prohibit any possibility of establishing any conventional treatment process. A carefully planned and managed engineered wetland treatment facility, however, could effectively operate within a wide range of pollutant volumes and chemical compositions.

1.2 Selection of Engineered Wetland Design

Within the area bordering Lake Manzala , a number of wetland engineering designs are possible to treat the wastewater entering the Lake, including:

(1) Engineered wetlands within the Lake or Drain;
(2) Engineered wetland parallel to the Drain; or
(3) Duckweed Treatment System.

1. Alternative 1 - Engineered wetlands within the lake or drain

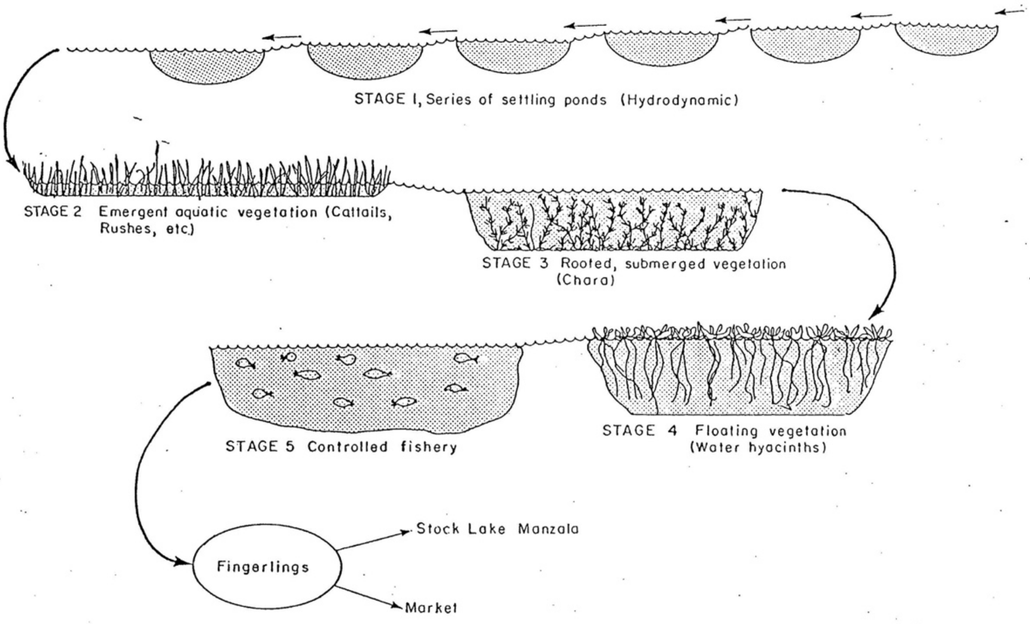
In Alternative 1 presented in figure (1.1), velocity of the water flow is reduced in the first stage to produce a significant deposition of sediments so that further flows downstream would be far less turbid and would allow greater light penetration for the growth of submergents. The heavy metals are then progressively removed by using emergent aquatics which can retain the metals sequestered in the rhizomes. The emergents also introduce further renovation of the water in terms of removing nutrients and chemicals. The third stage comprises specifically Chara spp., a submergent macrophyte which is very efficient in removing sediment loads and metals . The fourth stage incorporates water hyacinth which provide the final stage of water treatment before the water is discharged into the body of the Lake.

This alternative also includes a fifth stage which is designed to develop a controlled fishery to produce fingerlings for stocking the Lake or for other local markets. It is envisaged that this controlled fishery will also be used to produce new fish species which can be introduced into the Lake.

2. Alternative 2 - Engineered wetland parallel to the drain

This alternative uses a series of cuts or bleeder drains going out from the main drain, diverting portions of the main flow into a series of ponds and returning the water to the main drain at a downstream location. The cuts will be made on both sides of the main drain and in several places along the path of the main drain. The number of cuts and the length of the diversions will depend upon the flow volumes, water quality and the availability of land areas to develop the diversions. Figure 1.2 shows the concept. The principal features of this alternative are:

1) The diversion cuts successively bleed the main drain into settling ponds established along the route of the main drain . The settling ponds are designed to effectively remove a large portion of the sediment load in each diversion and reduce the levels of heavy metals, chemicals and nutrients in the flows.
2) Engineered' wetlands are established in these bleeder drains and the settling ponds to reduce flow velocities and absorb the pollutants. It is proposed to establish Chara spp. and emergent aquatic species such as cattail, bulrush and reeds in the diversion channels and mainly water hyacinth in the settling ponds.
3) It is possible to establish more than one pond in each diversion segment, depending upon the magnitude of the sediment load and the flow volume to be treated.
4) The return channels will also will be stocked with emergent species and Chara spp.
5) The mean depth of these diversion channels will be about 2 to 3 m.



ALTERNATIVE WETLAND DESIGN NUMBER ONE

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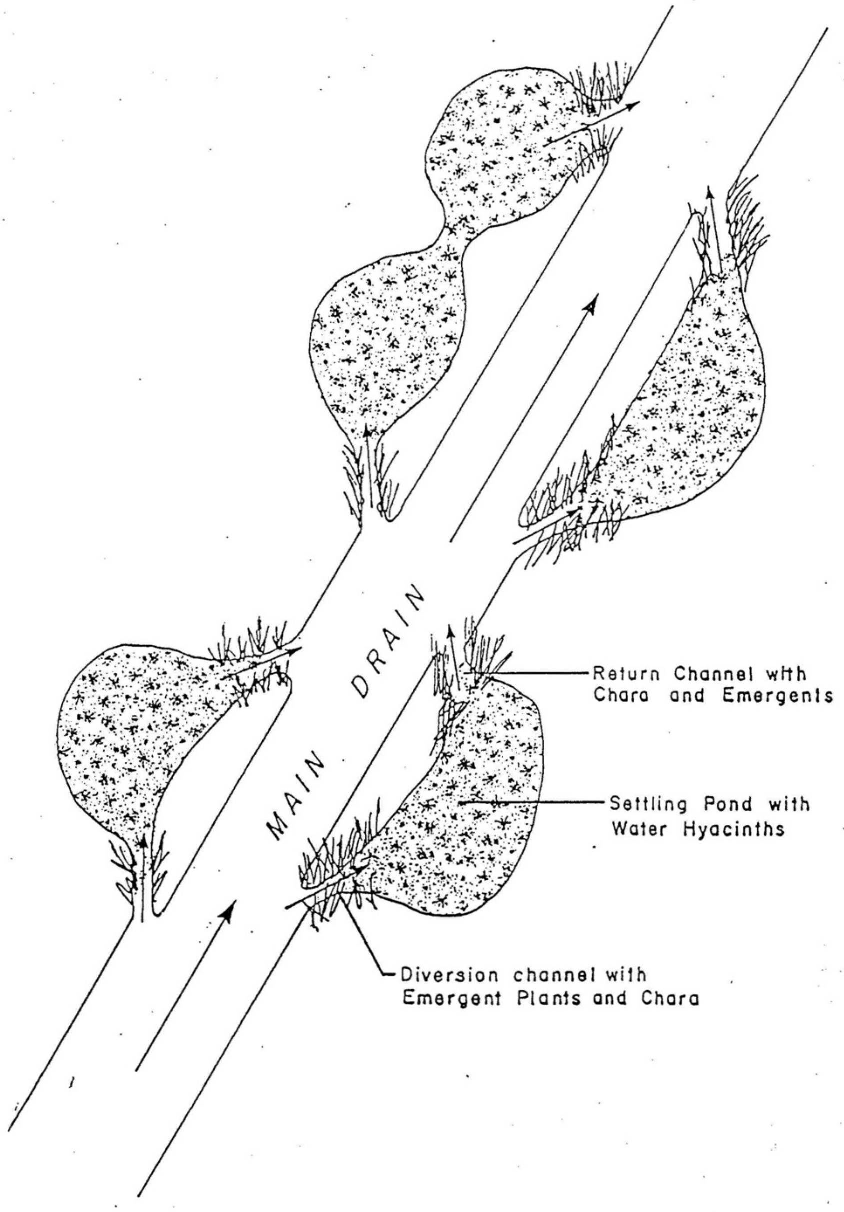
FIGURE 1.1



ALTERNATIVE WETLAND DESIGN NUMBER TWO

6) The return segments will be designed such that when the water is returned to the main drain, a moderate mixing with mild turbulence is created to produce aeration and coagulation of suspended particulates.

There are certain disadvantages which may affect the economics of this alternative. These are:

1) Land area required to create the lateral diversion channels may be taking away valuable land from agriculture.
2) Only a portion of the main drain flow will be treated through the alternative and may require a large number of such channels and large areas to produce a major impact on the water quality of the entire drain flow.
3) Access to the main drain will be curtailed by the outgoing and returning sections of the channels, which may affect the annual dredging operations in the main drain.

3. Alternative 3 - Duckweed Treatment System

This alternative uses duckweed exclusively as a wetland species to treat the water. Duckweed, in the genera *Lemmna* spp., and *Wolffia* spp., have all been tested for pollutant removal or used in wastewater treatment systems. These duckweeds are the smallest and the simplest of the flowering plants and have one of the fastest reproduction rates. Duckweed systems are capable of high levels of BOD and SS removal and significant levels of metal and nutrient removal. However, as compared to water hyacinth the duckweed plant plays a less direct role in treatment due to its small size.

Duckeweeds can be established in the main drain or in the lateral diversion channels similar to the channels in Alternative 2. The area of duckweed growth will be protected and maintained by a system of floating booms. There are several advantages to the establishments of duckweed populations for treating the water. These are:

1. Duckweed is easy to establish in a waterway in good densities.
2. High rates of nutrient removal can be achieved with high plant productivity.
3. Duckweed can be periodically harvested and used as an excellent animal feed for livestock and poultry.
4. Duckweed can, through photosynthesis, produce oxygen whic hcan aerate the ambient environment.

There are definite and important disadvantages, however, to the use of this alternative which should be considered. These are:

1. Duckweeds can only influence the quality of water within a depth of less than 0.3 m. The channels of the main drain will have to be very shallow to make use of this method.

2. Duckweeds require a long retention time to produce reasonable removals of nutrients and pollutants. Under the flow conditions encountered in the drains discharging into the Lake Manzala, the path length required to produce substantial water quality improvement would be more than 100 km.
3. High insolation can depress the rate of photosynthesis (Stephenson et al., 1980) in duckweeds reducing its ability to bring about water quality improvement.
4. The lack of an extensive root zone provides very little substrate for attached microbial growth.
5. The small size of duckweeds makes than susceptible to even moderate winds and requires floating booms or cells to hold them in place.
6. The rapid growth and die-off will invariably result in a large portion of the dead cells sinking to the bottom creating highly anaerobic conditions resulting in intense odours and increase in BOD.
7. Duckweed's ability to remove metals is rather limited compared to other plants such as water hyacinth, Chara spp., or cattail.
8. The flow velocities encountered in the drains may make it very difficult to maintain a good suspension of duckweeds and maintain a full cover of the water surface.
9. Harvesting duckweed from a large water surface may pose some practical problems.

1.3 Selection of Treatment Design

There are several alternatives possible:

1. Sedimentation traps followed by emergent, submergent and floating engineered wetlands.
2. Diversion channels with sedimentation traps and engineered wetlands, parallel to the drain.
3. Duckweed ponds in the drain.

Criteria for the selection of the most preferred treatment alternative:

1. Availability of land area to implement the treatment alternative.
2. Availability of sufficient drain length to implement the treatment alternative.
3. Potential impact on the local populations in terms of resettlement, encroachment and socio-economic hardship.
4. Ability to reduce or remove a variety of pollutants in the wastewater including nutrients, heavy metals, toxic chemicals and pathogens.
5. Creation of sustained aerobic conditions in the wastewater flows.
6. Complexity of harvesting requirements in terms of frequency and scope.
7. Susceptibility to variations in flows.
8. Susceptibility to changes in pollutant loadings.
9. Susceptibility to human interferences.
10. Susceptibility to biological interaction due to grazing and competition.
11. Susceptibility to changes in physico-chemical parameters such as pH and salinity.

12. Commercial potential for producing anumal feed from the harvested biomass.
13. Commercial potential for providing duel use such as fuel pellets and biogas.
14. Commercial potential for producing construction materials.
15. Biomass and sludge disposal alternatives.
16. Health risks/vector borne diseases.
17. Capital cost.
18. Labour intensity: operation and maintenance.
19. Legal restrictions.

Summary

1. There is considerable pressure for land on either side of the major drains. Water from the drain is constantly used for irrigation, fish fanning and animal husbandry by the local population. Human settlement will preclude use of the second treatment alternative, either in the upstream reaches of drains or close to the Lake. The second treatment alternative requires large tracts of land on either side of the selected drain which would encroach upon the planned land development for crop production and fish farming.

2. The complexity of pollutants in the drain water and short residence times available make stringent demands on the ability of aquatic plants to provide rapid treatment. Duckweed has several limitations in terms of shallow operating depths, slow uptake kinetics and low productivity compared with other floating aquatic plants such as water hyacinth.

3. The first alternative uses a two-pronged approach to the wastewater treatment consisting of sedimentation-traps to reduce sediment load followed by an engineered wetland to remove heavy metals and chemical residues. The wetland stage uses emergent, submergent and floating aquatic plants to accomplish the treatment process. This approach uses specific characteristics of these different plants to bring about a progressive reduction in suspended solids, heavy metals and chemical residues in the wastewater.

4. Site-specific land related parameters, socio-economic concerns and wastewater treatment requirements impose severe limitations on using second and third treatment alternatives. The first treatment alternative is recommended as it satisfies most of the requirements and provides a defined measure of control on the wastewater remediation.