IRAQI MINISTRIES

Of

Environment

Water Resources

Municipalities and Public Works

NEW EDEN MASTER PLAN

FOR INTEGRATED WATER RESOURCES MANAGEMENT IN THE MARSHLANDS AREA

VOLUME II

Current and Future Water Resources Requirements in The Marshlands Area

Book 6

PLANNING SCENARIOS

Prepared in cooperation with

The Italian Ministry for the Environment and Territory and Free Iraq Foundation

ITALY - IRAQ

21.04.2006

BOOKS IN THE SERIES

Volume 0 - Main Report (Summary of the Entire Study)

Volume I – Overview of present conditions and current use of the water in the marshlands area

Book 1 – Water Resources. Review on climatology, geology and hydrology of the lower course of the Tigris, Euphrates and Kharkeh watersheds.

Book 2 – Water and Sanitation. Description of the present state of Water and urban/rural assets for the villages within the governorates of Thi Qar, Basrah, and Missan.

Book 3 – Agriculture. Evaluation of the water demand for agriculture based on both the past-planned and present conditions in the four governorates of Thi-Qar, Wassit, Missan and Basrah.

Book 4 – Marshlands. Description of the former marshlands. Description of the present state of the marshes and their fauna and flora.

Volume II - Future water resources requirements in the marshlands area

Book 5 – Modeling. Description of: the methodology, datasets, numerical tools (water balance, water management, hydrodynamic and socio-economic models), boundary conditions, calibration and verification.

Book 6 – Planning Scenarios. Evaluation of the benefits associated to marshlands restoration. Description of a set number of water allocation strategies for marshlands restoration in Southern Iraq. Presentation of exemplificative test cases and follow up steps.

Volume III - Implementation Plans

Book 7 – Water and Sanitation Assets. Describe the proposed projects and the financial plans for project implementation in the upgrading of the water & sanitation infrastructures.

Book 8 – Marshlands. Feasibility studies for the implementation of a number of infrastructural changes required to best manage water for marshlands restoration. Feasibility study for the implementation of the New Eden Villages conceptual models.

ROSTER OF EXPERTS

The New Eden Master Plan for Integrated Water Resources Management in the Marshlands Area", was elaborated by:

From the Iraqi Ministries:

Mr. Ali Hashim – Director of CRIM

Arch. Neda A. Hussain, MoMPW, Baghdad

Arch. Riadh Al Wazir, MoMPW, Baghdad

Waleed Abdul Hamid, D.G. Planning - MoWR

Dr. Abbas Balasem, focal point for the MoE of Iraq, Baghdad

Consultant Ms. Sameera Abd Muhiee, Ms. Ikram Qasim Nasir, Dr. Furat Abdul Sattar Haider, & their assistants from the Center for the Restoration of the Iraqi Marshlands (CRIM) – Baghdad, Eng. Mahmood A. Ali (MoMPW), Eng. Amer Khakil Ismail (MoMPW), Eng. Ghazi Naji Majeed (MoMPW), Eng. Maytham Jaralla (MoMPW), Eng. Rengber Sadiq Kittani (MoMPW), Arch. Haitham Obaid (MoMPW), Mohammed S. Al-Shabander (MoMPW), Hazim Fardi Abdul Zahra (MoMPW), Ali Kareem Al Amar (MoMPW), Dr. Salman Salman, Dr. Malik Hassan Ali, Dr. Abd Ridh Alwan, Dr. Ali A. Ghani, Basrah University, Basrah, Dr. Butrus Fakhoury (MoWR), Mr. Ahmed Aziz (MoWR), Ryiad Shinta Jabir, The president, Dhi Qar University

From the New Eden Team:

Dr. Azzam Alwash – Project Leader and Communication Manager

Eng. Augusto Pretner – Project Coordinator

Eng. Andrea Cattarossi – Project Manager

Eng. Marco Gonella – Group Leader Hydrology

Eng. Giorgio Galli – Group Leader Water and Sanitation

Dr. Ali Douabul – Group Leader Iraqi Experts

Dr. Jamal Abayachi - Senior Advisor

Mr. Jasim Dwaij - Socio Economic Project Manager

Consultant Douglas L. Hamilton, P.E., Dr. Alfred Pettinger, D.r. Chris Mackay, D Pravi Shresta, P.E., Dr. Trey Flowers, Eng. Julien Lecollinet, Eng. Paolo Mastrocola, Eng. Polo Paolo, Dr. Carlo Del Grande, Eng. Francesco Pescarolo, Dr. Francesca Piccini, Dr. Elisa Ulazzi, Eng. Paolo Rufini, Dr. Alessandra Cavalletti, Dr. Harry Bader, Dr. Andrea Zamariolo, Eng. Mario Ianelli, Chiara Teatini, Eng. Roland Bernardi, Dr. Francesco Dotto, Elly Ravazzolo, Francesco Ambrosi, Laurent Stravato, Alessandro Bertoni, Paola Naddei, Eng Fabrizio Foltran, Eng. Alessandro Cimo, Arch. Marco Oliviero, Arch. Toni Sopelsa, Arch. Elena Cattarossi, Dr. Riccardo Babolin, Dr. Fabio Zagonari, Dr. Laura Vici, Arch. Alessandro Alì, Arch. Ivan Del Ponte, Arch. Simona Zambelli, Arch. Antonio Longo, Dr. Alessia Buiatti, Dr. Emanuela Semiani

Editing Anna Bachmann, Alison Kagamaster

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF ANNEXES

ACRONYMS

BCM	*Billion Cubic Meters*
COE	*Corp of Engineers*
CRIM	*Centre for the Restoration of the Iraqi Marshlands*
HEC	*Hydrological Engineering Center*
RES-SIM	*Reservoir Evaluation System*
IF	*Iraq Foundation*
IMET	*Italian Ministry for the Environment and Territory*
MoA	*Ministry of Agriculture*
MoC	*Ministry of Culture*
MoE	*Ministry for the Environment*
MoED	*Ministry of Education*
MoFA	*Ministry of Foreign Affairs*
MoH	*Ministry of Health*
MoMPW	*Ministry of Municipalities and Public Works*
MoT	*Ministry of Transportation*
MoWR	*Ministry of Water Resources*
SDP	*Sustainable Development Plan*
UNEP	*United Nations Environmental Programme*
USAID	*United States Agency for International Development*
WTP	*Water Treatment Plant*
WWTP	*Waste Water Treatment Plant*

INTRODUTION

There is no doubt that if water resources were unlimited and interference between marshlands restoration and human-related activities was not an issue, then 100% recovery of the marshlands could be achieved. Unfortunately today, even if water resources were unlimited total marshlands recovery would not be feasible in light of the fact that large portions of land, once occupied by marshes, are now converted to other uses of great importance to Iraq (i.e. agriculture, cities and oil fields). For these reasons, the government of Iraq demands that clear indications must be provided in defining which portion of marshes should be restored and which should not.

Apart from the selection of the most appropriate sites (location and size), clear indication must be provided on how water should be managed inside the marshes (water levels and movement during time) for different hydrological conditions (dry year, normal year, wet year and flood season).

Clearly, definitive solutions do not exist; tentative decisions must be made and small and large adjustments will always be required. The best site for recovery cannot be found until tested, and the same site might have considerably different performances depending on how water flows are managed.

The present book extensively describes a possible approach to the water management for marshlands restoration and it does that integrating all the most relevant information and tools prepared during the New Eden project. Book 6 is subdivided into three main sections: the first one, which includes the following chapter, provides a scientific description of the benefit associated to the restoration of the Mesopotamian marshlands. The second section, which encompasses a chapter on land planning, two chapters on best water management strategies and water allocation scenarios and an exemplificative chapter, provides insight on the bets practices for marshlands management proposed by the New Eden Master Plan. The last section is mostly descriptive of a methodology for the preparation of a sustainable restoration plan.

BENEFITS ASSOCIATED WITH THE REGENERATION OF THE IRAQI MARSHLANDS

INTRODUCTION

The present chapter presents an examination of the potential environmental and ecological benefits associated with the re-inundation of the Iraqi Marshlands. This is a preliminary analysis intended to identify the key aspects and quantify the potential magnitude of selected benefits associated with this action and is based on the current status of the Tigris and Euphrates Rivers, and the Shatt Al Arab, as well as the current environmental conditions within the Abu Zirig marshlands. The areas of emphasis include potential benefits associated with the changes in hydrology, water chemistry, soil chemistry, and wildlife ecology. By addressing these issues, this document also outlines the benefits associated with potential human use practices, including water resource management, pollution control, agriculture, and natural resource management.

This chapter is intended to outline a multimedia conceptual model of the environmental and resource changes associated with the regeneration of the Iraqi Marshlands. It is not specific to a given region, although the quantitative analyses are based on conditions inherent to southern Iraq and relies heavily on observations made subsequent to the reintroduction of water to the Abu Zirig Marsh (Water & Energy Project, 2005). Predictions on potential benefits should only be considered as first approximations because site-specific data was very limited. This required the adoption of broad assumptions that resulted in high variability in the predictions. Where possible, this variability was retained and illustrated. However, the reader is cautioned that the predictions presented are subject to unidentified experimental error that may be significant.

BENEFITS RELATED TO HYDROLOGY

Flood Control

The marshlands of southern Iraq are almost exclusively river fed. The principal sources of surface water are the Euphrates River in the west, the Tigris River in the east, and the Shatt Al Arab in the southern regions. Water is diverted into the marshlands via a series of manmade canals and/or modified flow ways. The average annual rainfall in this region is on the order of 11–14 cm/year

(Water & Energy Project, 2005). Hence, direct inputs from precipitation are of minimal consideration in maintaining the marshlands.

In comparison to the rivers, the southern marshlands (due to their flat topography) possess a much lower water capacity per unit surface area, but because of their large area, they constitute a larger overall capacity. Also, because a smaller amount of water is diverted over a greater area, the retention time of the water is increased. It is the aspects of increased area, increased capacity, and increased residence time that will exert the greatest impact on the hydrology, as well as the soil and water chemistry, within the marshlands.

One of the principal applications for the hydrologic properties of a wetland has been in flood control. The larger surface area allows for greater volume capacity for a given rise in water level as compared to a river or stream. Furthermore, the higher surface-area-to-volume ratio produces a reduction in the quantity of surface water, through groundwater recharge and evapotranspiration. In the case of the South Iraqi Marshlands, flooding is of minimal concern because of low local precipitation rates and the presence of upstream flow control structures. Hence, there is little benefit in marshland restoration associated with flood control.

Drought Moderation

Another function for a marshland is seasonal drought moderation. Within any given waterway, marshlands can act as a water sink, providing a source in the summer when precipitation is low and human and agricultural demand is high. In the winter, the marsh can replenish its capacity when precipitation is high and agricultural demand is low. The short-term realization of the benefit on agriculture is small and will initially only be manifest by low intensity subsistence farmers because the current high intensity agricultural infrastructure is associated with the current river courses. However, once the marshlands have proceeded through their early successional stages and reached a status of dynamic hydrologic equilibrium, they may provide opportunities for expanded agriculture where water availability limits the scale of agricultural activity. This has a potential for opening up areas in the south and east to high-intensity agriculture.

A third hydrologic benefit related to the residence time of water in the marshlands is the potential for groundwater recharge. Because of the alluvial and calciferous nature of the underlying bedrock in the Mesopotamian Plain, the groundwater in this area is both shallow and relatively saline. When the marshlands were originally drained, there was a significant reduction in groundwater capacity and an increase in groundwater salinity (IMET 2004). Reversing this trend will result in two direct benefits. First, by increasing the period and area of saturation that would occur with the restoration of the marshlands, the capacity reduction and salinization of the groundwater could be reversed by inhibiting capillary transport and sealing the bentonite-based soil horizons. Second, by increasing the water sink, it would become possible to increase soil desalination in surrounding agricultural regions. To do so would involve periodic flooding of the fields to beyond saturation. Excess salts dissolved in the water would then be removed, either through percolation to groundwater or in excess runoff. The benefit associated with this would be increases in current agricultural production, as well as the potential to introduce more profitable, less salt-tolerant crops.

Microclimate

A potential benefit of the marshlands that is often overlooked is their effect on microclimate. Regions adjacent to large areas of open water experience higher humidity and more moderate temperatures compared to dry land. In Iraq, it has been reported that summer temperatures within the marsh regions were typically 5 °C cooler than the dry regions (IMET 2004). This not only increases environmental quality and reduces domestic, commercial, and industrial cooling costs, it also increases agricultural productivity by reducing heat stress on crops. Furthermore, fields downwind from a marshland, particularly in a desert climate with large day and night temperature ranges, experience significant transfer of moisture from the marshes to the fields in the form of dewfall. Not only can this effect significantly reduce the need for irrigation, but it also will reduce the canopy temperature, thereby increasing crop yields. Furthermore, there was a reported increase in dust storms generated from the desiccated marshlands; regeneration of the vegetative cover will decrease this effect.

Benefits Related to Nutrient Management

Phosphorus

Recent water analyses on the Al-Furat indicate high soluble phosphorus concentrations on the order of 280 μg/L. Historical data indicate that phosphate concentrations in the Tigris River can range as high as 1,400 μg/L. Typical mesotrophic water systems, in this region of the world, have available phosphorus concentrations of approximately 30-50 μg/L (IMET 2004).

Inorganic nitrogen concentrations, predominantly nitrate, in the Tigris River have been reported to range in excess of 840 μg/L, with median values around 300 μg/L (IMET 2004). These can be considered reasonable concentrations in themselves. However, given the high available phosphorus concentrations, the resulting nitrogen-to-phosphorus ratio (N:P) is approximately 3. For a typical mesotrophic water system, the ratio should range from about 7 to 14 (Mitsch and Gosselink 1993). Therefore, the high eutrophication and imbalance in the N:P appears to be solely the result of excess phosphorus.

These high available phosphorus values have been attributed to domestic wastewater and agricultural runoff from upstream sources and are typical of a highly eutrophic system (IMET 2004). Such systems are prone to manifestations of algal blooms, with associated post-bloom plunges in dissolved oxygen concentrations as metabolic carbon concentrations increase as a result of decomposition. From the standpoint of water as a resource, acceleration of this cycle, and increases in its magnitude, results in unpalatable and odoriferous surface water, reduced water clarity, higher pH, and increased potential for toxin loading from blue green algae (cyanotoxins) and *Botulinum* that reduce fisheries productivity and carrying capacities, and can even result in catastrophic fish or bird kills. Furthermore, high nutrient loading to small estuarine and marine receiving bodies, such as the northern Persian Gulf, can result in adverse impacts on the productivity of commercial saltwater fisheries and shellfish cultivation.

There are two approaches to removing unwanted phosphorus in a water body. The first is chemical precipitation using alum, ferric iron, or commercial products such as Phoslock. This is an incurred cost and results in a precipitate that itself must be managed. Another common and economical approach to addressing such nutrient imbalances has been the use of engineered wetlands. Wetlands, such as the Iraqi Marshlands, increase the exposure of the water to terrestrial and aquatic macrophytes by increasing surface area and residence time of the water. Residence times as short as 6 months can result in equilibrium phosphorus concentrations as low as 15 μg/L (Sansanayuth et al. 1996). The macrophytes utilize available nitrogen and phosphorus and sequester them in biomass sinks. These sinks, containing high amounts of slow-degrading cellulose and lignin, effectively trap the organic carbon and nutrients within the detritus. The result of this slowing in carbon cycling is a reduction in oxygen-depleting respiration associated with increased primary productivity. Therefore, unlike open water bodies such as lakes and rivers, there is no dramatic cyclic oxygen depletion that degrades habitat and threatens water potability.

Nutrient removal in wetlands is presumed to be directly proportional to the chemical and biological activity at a given location (Kadlec and Knight, 1996). Hence, the net phosphorus settling rate (k) can be defined as a proportionality constant of phosphorus removal rate to the marshland surface area and nutrient input concentrations. Settling rate constants were employed in the modeling work that predicted phosphorus deposition in the Abu Zirig marshland (IMET 2004). Annualized TP settling rates were calculated using a first-order, area-based model corrected for a background concentration of 9 ug/L (Minimum measured concentration) as follows:

$$[P]_y = [P]_{bkgnd} + \left(\frac{[P]_{in(AZ)} - [P]_{bkgnd}}{e^{\frac{ky}{q_{(AZ)}}}} \right)$$

Where :

$$k_p = q_{(AZ)} \cdot \ln\left(\frac{[P]_{in(AZ)} - [P]_{bkgnd}}{[P]_{out(AZ)} - [P]_{bkgnd}} \right), \quad q_{(AZ)} = \frac{R_{in(AZ)}}{A_{(AZ)}}$$

And

$$R_y = R_{in(AZ)} - \left(R_{in(AZ)} - R_{out(AZ)}\right) \cdot y$$

Where:

$[P]_y$: Predicted output phosphorus concentration at marshland area y (kg/m^3)

$[P]_{in(AZ)}$: Input phosphorus concentration ($2.65 \times 10^{-4} \pm 1.93 \times 10^{-4}$ kg/m^3)

$[P]_{out(AZ)}$: Observed outflow phosphorus concentration ($1.15 \times 10^{-5} \pm 1.44 \times 10^{-6}$ kg/m^3)

$[P]_{bkgnd}$: Minimum background phosphorus concentration (9×10^{-6} kg/m^3)

$R_{in(AZ)}$: Input flow rates ($7.65 \times 10^8 \pm 8.09 \times 10^7$ m^3/yr)

$R_{out(AZ)}$: Output flow rates ($5.17 \times 10^8 \pm 8.35 \times 10^7$ m3/yr)

R_y: Predicted outflow rate given a marshland area of y (m^3/yr)

$A_{(AZ)}$: Total saturated marsh area (1.26×10^8 m^2)

k_p: Phosphorus settling rate (28.66 ± 7.66 m/yr)

$q_{(AZ)}$: Hydraulic loading rate (6.05 ± 0.640 m/yr)

y: Proportion of total marshland area (A(y) x 1.26×10^8 m^2)

The relation between Phosphorus removal and marsh area is illustrated in Figure 1.

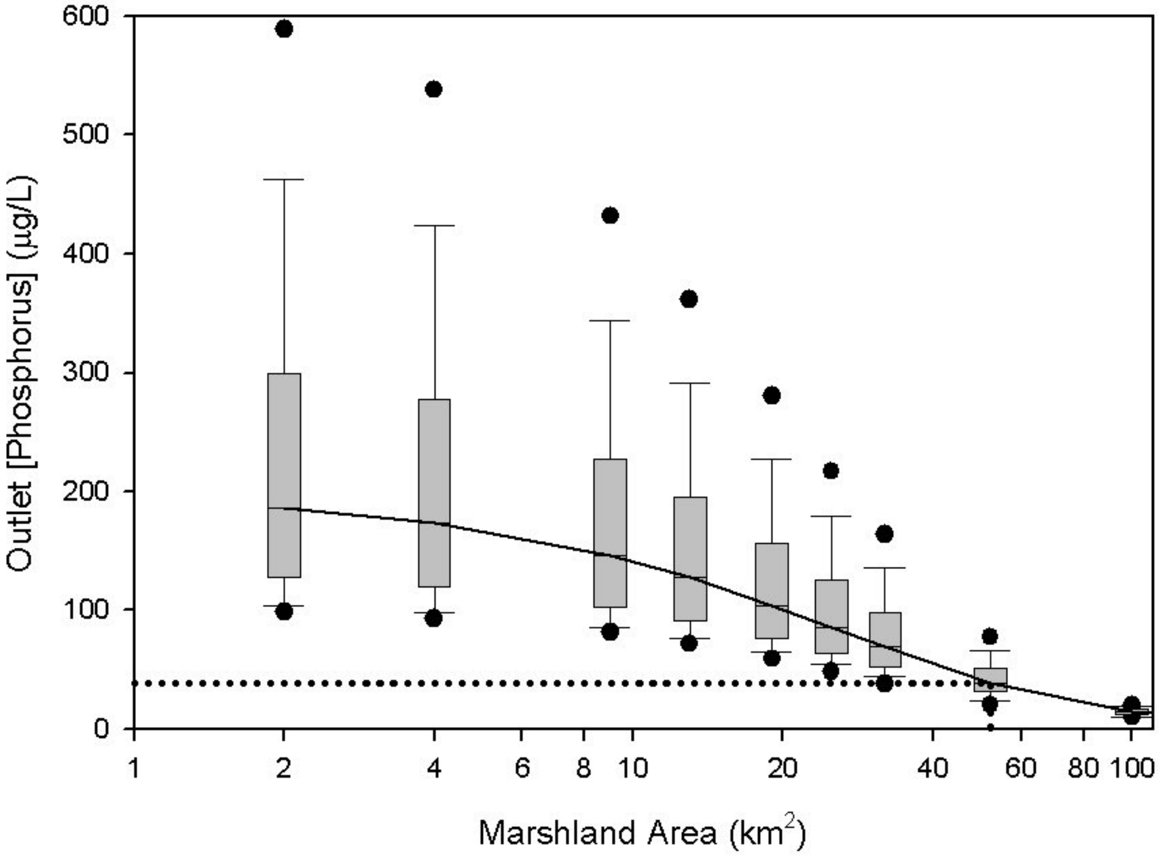


Figure 1: Predicted outlet phosphorus concetration for Abu Zirig marshland based on area and an input flow rate of 7.64×10^8 +/- 8.09×10^7 m^3/yr.

By assuming an acceptable phosphorus concentration of 50 ug/l, which is a conservative limit on a mesotrophic aquatic system, it can be determined that a marshland with in inflow rate equivalent to that for Abu Zirig, would need an area of 52 km^2 (A_{opt}) to achieve this limit. By applying the $q_{(AZ)}$ and $R_{in(AZ)}$:$R_{out(AZ)}$ ratio from Abu Zirig to other Iraqi marshes, a prediction of the Marshlands to phosphorus removed can be made as follows:

$$\Delta mP = \frac{\frac{A}{A_{opt}} \cdot R_{in(AZ)} \left([P]_{in} - 5x10^{-5} \cdot \frac{R_{in(AZ)}}{R_{out(AZ)}} \cdot y \right)}{1000}$$
$$\approx 2.44 \cdot A$$

Where:

A: Area of wetlands capable of reducing $[P]_{in}$ to 50 ug/L (km^2)

ΔmP: The mass of phosphorus removed from the water (tonnes/yr)

The linear relation is illustrated in Figure 2.

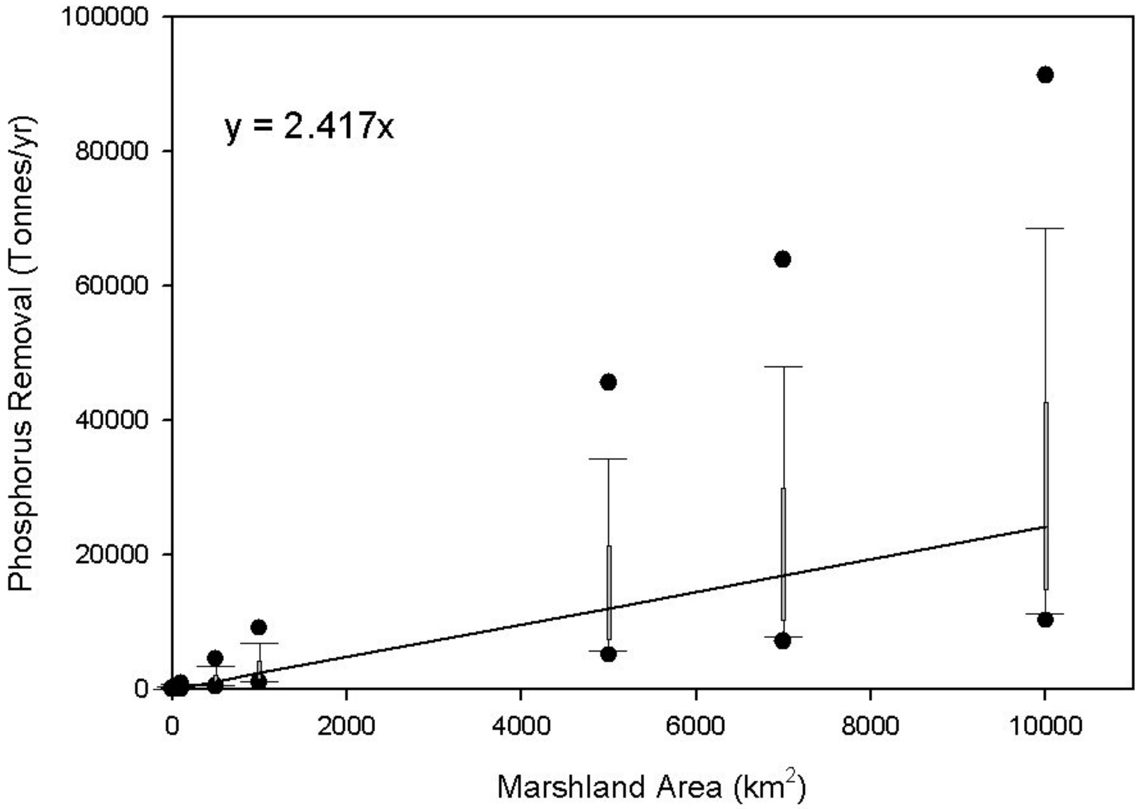


Figure 2: Phosphorus removal rate by marshlands achieving an outflow concentration of 50 μg/L based on the phosphorus removal capacity of Abu Zirig (Figure 1).

Nitrogen

Wetlands such as the Iraqi Marshlands are not only capable of producing net phosphorus reductions, they also can affect the nitrogen to phosphorus (N:P) ratio, such that the proportions of these nutrients can be brought back into balance. Wetlands provide necessary habitat for aerobic cyanobacteria. These bacteria possess the capability to fix atmospheric nitrogen, resulting in increases in aquatic nitrogen concentrations (Mitsch and Gosselink 1993; UNEP 2005). Nitrogen fixation is an inducible process. Therefore, the lower the N:P ratio in the water, the higher the nitrogen fixation activity. As N:P ratios approach 15, the nitrogen fixation rate drops off (Prairie et al. 1989). In this manner, the marshlands are able to reduce the phosphorus while maintaining adequate nitrogen concentrations, resulting in a more balanced ratio of nitrogen to phosphorus in the outflows benefiting downstream use.

Data on total nitrogen concentrations in either the Tigris or Euphrates rivers was not available. Saad and Antione (1978) reported nitrate concentrations ranging from 80 to 800 ug/L and nitrite concentrations from negligible to 120 ug/L (IMET 2004). However, without a measure of ammonium concentrations, it is impossible to derive an accurate N:P balance.

Observed phosphorus removal rates can be used to estimate nitrogen assimilation rates. Redfield et al. (1958) demonstrated that nutrient assimilation rates of nitrogen to phosphorus by algal phytoplankton are on the order of 16:1 (mol/mol) or 8:1 (w/w). By applying this ratio, a prediction of the nitrogen requirements can be developed based on phosphorus assimilation rates (Figure 3). It must be noted however that the inability to characterize the N:P ratio means that it is not possible to determine what proportion of this nitrogen was derived from the inflow waters, and what proportion was fixed *in situ*.

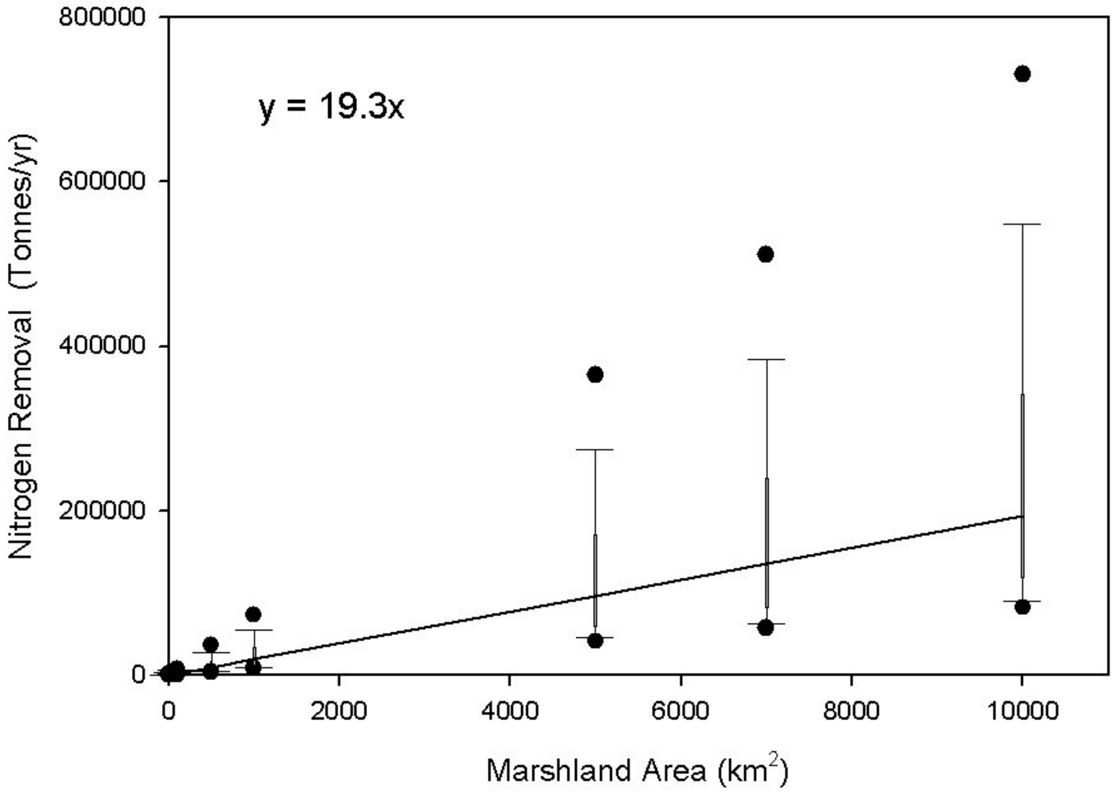


Figure 3: Nitrogen removal rate of marshlands achieving an outflow concentration of 50 μg/L phosphorus based on the removal capacity of Abu Zirig (Figure 2) and an assimilation ratio of 7:1 N:P.

Sulfur

Sulfur is a nutrient of special consideration in the context of the Iraqi marshland ecosystems. Sulfur, in the form of sulfate, is a natural constituent of the gypsum ($CaSO_4$) bedrock that is indigenous to southern and central Iraq. As a result, sulfate concentrations in surface waters tend to be high. High sulfate concentrations represent a salinity stress to aquatic macrophytes, wildlife and fish populations, and crops under irrigation. Sulfate is very difficult to remove from water because of its high solubility. Furthermore, there are very few cations that are able to precipitate sulfate, and none of them are commercially viable as water treatments.

One method by which sulfate can be removed from water is within a marshland. Marshlands usually consist of a thin aerobic sediment layer overlying an anaerobic sediment sink. Within this sink, sulfate-reducing anaerobic bacteria that use metabolic carbon leached from the upper layers concurrently reduce sulfate to sulfides and polysulfides (Balla and Kalettka 2005).

Little data is directly available for sulfate reduction in Iraqi marshes. Therefore, in order to predict the effect of marshlands on sulfate concentrations, a model was developed using Storm Water Treatment Area 1-West (STA 1-W) in the Florida everglades (Chimney et al. 2001). STA-1W is one of a number of engineered marshes that are being used to treat agricultural runoff prior to release. As was applied in estimating phosphorus removal, a settling rate constant was derived STA-1W using first-order kinetics as follows:

$$[S]_y = \frac{[S]_{in(STA)}}{e^{\frac{ky}{q_{(STA)}}}}$$

Where:

$$k_s = q_{(STA)} \cdot \ln\left(\frac{[S]_{in(STA)}}{[S]_{out(STA)}}\right), \quad q_{(STA)} = \frac{R_{in(STA)}}{A_{(STA)}}$$

And

$$R_y = R_{in(STA)} - \left(R_{in(STA)} - R_{out(STA)}\right) \cdot y$$

Where:

$[S]_y$:	Predicted output sulfate concentration at marshland area y (kg/m^3)
$[S]_{in(STA)}$:	Input Sulfate concentration ($6.24x10^{-2}$ kg/m^3)
$[S]_{out(STA)}$:	Observed outflow sulfate concentration ($5.05x10^{-2} \pm 2.15$ $x10^{-3}$ kg/m^3)
$R_{in(STA)}$:	Input flow rates ($2.23x10^4 \pm 3.11x10^3$ m^3/yr)
$R_{out(STA)}$:	Output flow rates ($2.17x10^4 \pm 2.85x10^3$ m3/yr)
R_y:	Predicted outflow rate given a marshland area of y (m^3/yr)
$A_{(STA)}$:	Total saturated marsh area ($1.55x10^7$ m^2)
k_s:	Sulfate settling rate ($3.13x10^{-4} \pm 7.53x10^{-5}$ m/yr)
$q_{(STA)}$:	Hydraulic loading rate ($1.45x10^{-3} \pm 2.10x10^{-4}$ m/yr)
y:	Proportion of total marshland area (A(y) x $1.55x10^7$ m^2)

The relation between sulfate removal and marsh area for STA-1W is illustrated in Figure 4.

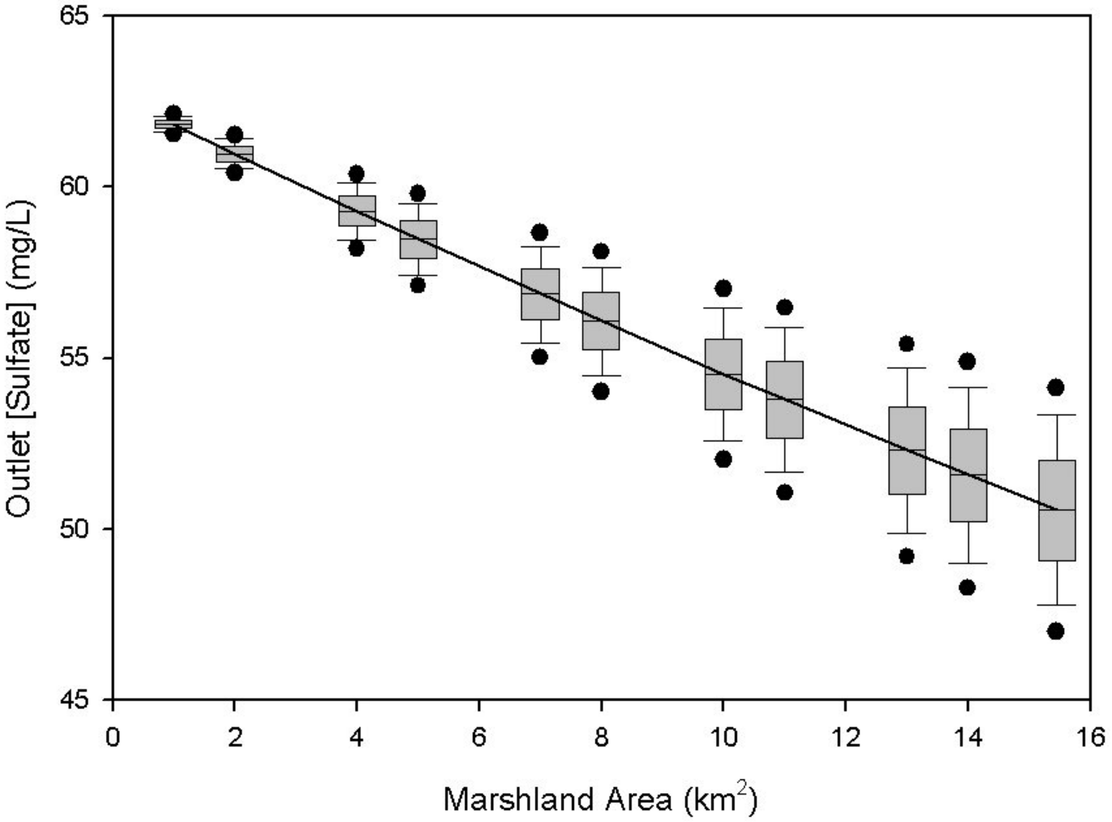


Figure 4: Sulfate reduction with area based results from the Florida Everglades' Storm Water Treatment Area 1-West.

By applying the sulfate settling rate (k_s) derived from STA-W1 to the conditions defined in the phosphorus-optimized marshlands described above, a prediction for the relation between the amount of sulfate removed based on the area of marshlands can be derived. In this case, a sulfate input rate of 161.0 ± 34.7 mg/l was used to determine the rate of sulfate removal illustrated in figure 5 (IMET 2004).

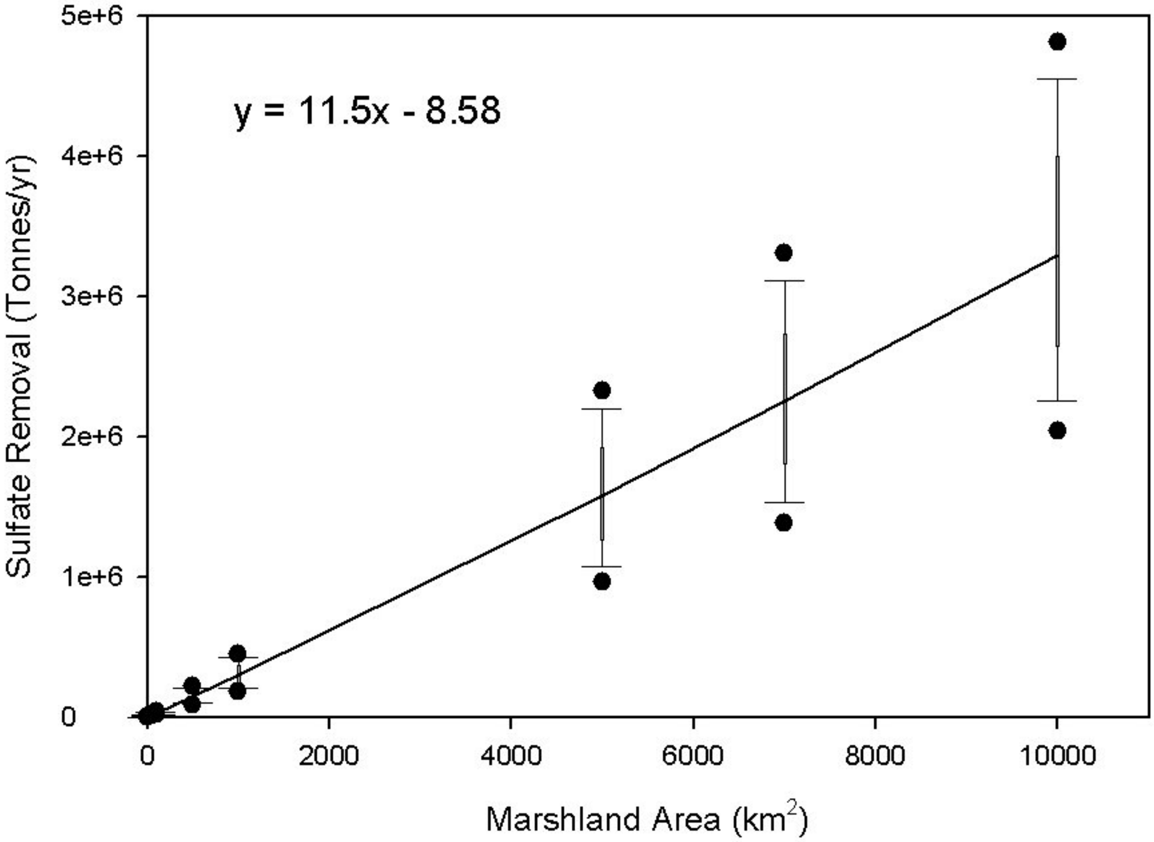


Figure 5: Sulfate removal rate by marshlands achieving an outflow concentration of 50 µg/L phosphorus, based on the sulfate removal capacity of the Everglades' Stormwater Treatment Area 1-West (Figure 4).

The removal of sulfate from the water has other benefits associated with water chemistry beyond those associated with salinity and water hardness. Sulfate reduction also provides a mechanism for the removal of other pollutants such as heavy metals. This aspect is discussed in detail in the pollution management section.

Benefits Related to Soil Management

Erosion

The potential benefits of the marshlands are not limited to impacts on water. There are also potential benefits associated with soils. The soils in the southern Iraqi lowlands are alluvial in nature, consisting of a deep horizon of clay and silty clay, with a high concentration of montmorillonite (IMET 2004). With the draining of the Iraqi Marshlands and the corresponding loss of organic material, the soil structure degraded rapidly, with significant cracking and subsidence of the soil strata. The remaining silt and clay became highly susceptible to both splash and wind erosion. This increases the sediment load of receiving water bodies and generally degrades the air quality of the local environment.

Inundating the Iraqi Marshlands will immediately prohibit the current splash and wind erosion simply by virtue of the presence of the overlying water. The rate of soil loss should be approximately proportional to the area inundated. While the flooding of such an unripe soil will likely result in some temporary increase in bulk soil transport, this effect should be limited by the low flow rates through the marshlands. Furthermore, as the organic carbon content increases with plant detritus cycling, the structure of the soil will ripen, and it will become resistant to resuspension and transport. This will likely happen quickly—within a period of a few years—with a net benefit of dramatic reductions in erosion transport.

Soil Salinity

One of the significant effects associated with the draining of the Iraqi Marshlands was inadvertent soil salinization. Because of the deep cracking and subsidence of the soil when the marshlands were drained, saline groundwater from the deep aquifers migrated to the surface through capillary action. As the water evaporated, the dissolved salts (predominantly chlorides and sulfates) were deposited on the surface, forming saltpans (IMET 2004). These saltpans represent an extremely harsh soil environment, within which only the most salt-tolerant plant species are able to survive.

The reintroduction of the marshlands will reverse soil salinization in two important ways. First, inundation will solublize the saltpans. This will result in a temporary increase in water salinity as the salt is flushed into the Persian Gulf. However, once the existing saltpans are gone, the salinity will return to normal levels, and the areas of the original saltpans will become productive once again. Second, saturation of the upper soil horizons will reverse the water flow, allowing percolating surface water of limited salinity to recharge the shallow groundwater, which tends to be of higher salinity. This not only will reduce local soil salinization, but also will improve the quality of the shallow groundwater, potentially to a point where it may again be used for agricultural irrigation. Third, rehydration of the bentonite-based soils will result in the swelling of the clay layers, thereby inhibiting the migration of shallow groundwater to the surface in regions that are inundated only seasonally. This potentially will allow the expansion of agriculture to the seasonal upland areas of the marshlands.

Soil Quality and Potential Expansion of Agriculture

In considering overall agriculture in Iraq, the Marshlands play a very important role. They are the nurseries within which fertile land is generated. Marshlands are a successional environment. Low-lying areas that are inundated for prolonged periods build up sediment and organic matter until they form layers of new soil that rises above the water level (refer to the discussion of the historical marshlands in Book 4 for an explanation of how early Sumerian agriculture developed the land in this way). Such areas will remain dry, fertile, uplands until depletion and erosion return them to a wetland condition. This cycle takes decades to centuries to complete. Modern agriculture slows this process by maintaining the uplands through the artificial introduction of fertilizers, erosion control, and management of nutrients and organic matter. Unfortunately, economical agricultural management has its limits, and these are being manifested most prominently in Iraq as salinization resulting from decades of irrigation (IMET 2004). In order to reduce the salt build-up in current agricultural soils, it may be necessary to flood these lands for a prolonged period.

The soils produced through unmanaged draining of the marshlands are unripe. This means that the soil has no higher structure and forms a loose mud when hydrated. These soils have very poor water and nutrient retention capability, are very difficult to work mechanically, and are highly susceptible to wind and water erosion. This lack of structure is due predominantly to low organic matter content in the soil. To provide the structure necessary to optimize the silt/clay alluvial soils for agriculture, a significant increase in organic material, particularly humic material (degraded lignin and cellulose), must be achieved. The most economical means to increase the organic carbon content is through prolonged periods of constant inundation. Therefore, Iraq's marshlands of today could be their intensive agricultural lands of tomorrow.

Benefits Related to Pollution Management

Another benefit that potentially could be attributed to wetlands is economical pollution management. Aside from the nutrients discussed previously, reports indicate the presence of enteric organisms, heavy metals (including mercury), hydrocarbons, and chlorinated organic compounds in both the Tigris and Euphrates Rivers (IMET 2004). These pollutants represent potential risks to environmental receptors, and to human health through ingestion of water, aquatic organisms (especially shrimp and fish), and other contaminated foodstuffs.

The best method of reducing levels of these contaminants is though source control. Barring that, chemical removal of these contaminants though water treatment is difficult and expensive to the point of impracticality given the more pressing infrastructure need of the region. The only post-release treatment that provides any type of reasonable contaminant mediation is the use of wetlands.

The physical, chemical, and biological properties of the Iraqi Marshlands provide methods to sequester and transform anthropogenic contaminants, thereby reducing their potential adverse impacts. The concentration and speciation of specific types of contaminants can be mediated as described below.

Heavy Metals

Marshlands remove heavy metals from the overlying water in four ways (McIntosh 1991). First, the longer retention times and exposure to clays and organic matter produce tight binding of metals such as cadmium, lead, nickel, zinc, and copper to the particle surfaces, thereby removing them from solution. Second, aquatic macrophytes indigenous to the marshlands absorb metals such as lead through their roots and incorporate it into the lignin and cellulose, where it is retained as plant detritus. Third, the aerobic metabolism of bacteria can cause oxidation of heavy metals. Oxides of metals such as lead, zinc, and copper have significantly lower solubilities and are removed effectively from the water column. Fourth, the before-mentioned sulfur reduction in the presence of ionized transition metals, such as lead, cadmium, and nickel, zinc, manganese, and copper, results in the formation of metal sulfides that are practically insoluble, thereby removing the metals from the water column.

Because of lack of site-specific information on the character of the marshlands, predictions for the removal of heavy metals from the water column by the marshlands were based solely on the capacity resulting from the formation of insoluble metal sulfides. Rates of sulfide production were developed based on sulfate removal as presented in a previous section. The rate of sulfur reduction can be inferred as the differential of the concentrations change across the marshland. As a result, a size-specific sulfate reduction rate was developed as follows based on results attained from the Florida Everglades' STA-1W:

Marshland Area (km^2)	$\Delta[SO_4]$ (nM)	k_{rate} (nM/sec)
1	6.67	1.13×10^{-6}
50	3.33×10^{2}	5.65×10^{-5}
100	6.67×10^{2}	1.13×10^{-4}
500	3.33×10^{3}	5.64×10^{-4}
1000	6.65×10^{3}	1.13×10^{-3}
5000	3.30×10^{4}	5.59×10^{-3}
7000	4.60×10^{4}	7.80×10^{-3}
10000	6.54×10^{4}	1.11×10^{-2}

Anaerobic sulfide-reducing bacteria excrete hydrogen sulfide (H_2S) as a metabolic byproduct. Hydrogen sulfide will combine with transition metal cations in solution to form insoluble sulfides. The principle sulfide produced in Marshland environments is FeS (USEPA 2002). This is because of the high iron concentrations relative to other metals. Water column Iron concentrations were not available for either the Tigris or Euphrates River. As a surrogate, the Pecos River in the US, which is also a river fed primarily from gypsum-rich sources, was used as a surrogate system, and the iron concentration was scaled relative to the ratio of sulfate concentrations in the Pecos and Euphrates rivers (Hopkins 2000). The iron concentration used was 100 ug/L. The rate of sulfide formation as follows:

Reaction	Equilibrium Constant[1]	Rate of Formation (k') ($nm^{-1}s^{-1}$)
$Fe^{+2} + HS^{-} \rightarrow FeS_{(s)} + H^{+}$	4.37×10^{3}	2.71×10^{7}
$Cd^{+2} + HS^{-} \rightarrow CdS_{(s)} + H^{+}$	1.26×10^{14}	7.82×10^{17}
$Pb^{+2} + HS^{-} \rightarrow PbS_{(s)} + H^{+}$	4.68×10^{14}	2.90×10^{18}
$Ni^{+2} + HS^{-} \rightarrow NiS_{(s)} + H^{+}$	1.70×10^{9}	1.05×10^{13}
$Zn^{+2} + HS^{-} \rightarrow ZnS_{(s)} + H^{+}$	4.37×10^{9}	2.71×10^{13}
$Mn^{+2} + HS^{-} \rightarrow MnS_{(s)} + H^{+}$	4.00×10^{12}	2.48×10^{16}
$Cu^{+2} + HS^{-} \rightarrow CuS_{(s)} + H^{+}$	1.5×10^{22}	9.62×10^{25}

[1] Taken from USEPA (2002)

Since assumptions of equilibrium cannot be inferred in this situation, the amount of metal removal from the water column required a determination of the rate of potential metal sulfide production relative to the rate of sulfate reduction over the time constraints of the residence time of the water within the marshland. A solution to this was derived by applying the stochastic solution of Gillespie (1976) as applied by Mackay et al. (2006). This solution permits the prediction of the M species in a sequential Monte Carlo simulation based on the probability density function of a given reaction Rμ with a rate constant of k'μ occurring in a time increment between t+τ and t+τ+dτ (P(τ,μ)) and where:

$$P(\tau,\mu) = P_1(\tau) \cdot P_2(\mu \mid \tau)$$

Where

$$P_1(\tau) = a \cdot e^{-\tau a} \quad \text{Where} \quad a = \sum_{\mu=1}^{M}\left(j_\mu \frac{k'_\mu}{V} \right)$$

Therefore

$$\tau = \frac{1}{a}\ln\left(\frac{1}{R_1}\right) \quad R_1 \in Uniform\{0 < R_1 < 1\}$$

and

$$P_2(\mu \mid \tau) = \frac{j_\mu \dfrac{k'_\mu}{V}}{a}$$

Therefore

$$\mu \equiv \sum_{v=1}^{\mu-1}\left(j_v \frac{k'_v}{V} \right) < R_2 a \le \sum_{v=1}^{\mu}\left(j_v \frac{k'_v}{V} \right) \quad R_2 \in Uniform\{0 < R_2 < 1\}$$

Where V is the volume, j_μ is the number of distinct molecular reactant combinations for reaction R_μ found to be present at time t and is principally the product of the concentration of the reactants.

In this investigation, the stochastic solution was solved using an iterative computer model that solved for all possible j_μ values as well as Σj_μ at all time steps of t+τ until Σj_μ is equal to resident time of the marshland under consideration. In order to reduce the number of irrelevant high frequency time steps and speed up the computation of the output result, R_2 was approximated as follows:

$$R_2 = \left(10^{35}\right)^{-R_3} \; Where \; R_3 \in Uniform\{0 < R_3 < 1\}$$

This approximation results in an uncertainty in the timing of a given reaction by ± 1×10^{-2} seconds. This was felt to be insignificant in the context of the overall results.

The model was executed for marshlands of 1, 50, 100, 500, 1,000, 7,000, and 10,000 km^2 over 100 iterations to provide a distribution of possible values for t_{nX}.

Results of the model indicate that the 50th percentile concentrations of the water column metals fell below the resolution of the model (1 nmol/L) within a marshland area of greater than 1,000 km^2 (Figure 6). For marshlands of areas less than 1,000 km^2, the concentrations of the water column metal concentrations were approximated as a 4-parameter Hill sigmoid regression. Unfortunately, the cadmium regression did not converge under this assumption, and therefore was approximated as a 2-parameter hyperbolic regression. The parameters of the functions were as follows:

$$[M^{+2}]\left(\mu g/_{l}\right) = y_0 + a \cdot \frac{Area^b}{c^b + Area^b}$$

Metal	Initial Conc. (ug/l)	Y_0	a	b	c
Lead	20.5	0.207	29.5	-5.86	1.14
Nickel	34.2	-0.0339	33.88	-3.82	152
Zinc	55.6	55.2	-55.1	18.1	524
Manganese	63.2	61.7	-61.7	13.3	506
Copper	10.3	10.2	-10.1	28.9	47.7

$$[M^{+2}]\left(\mu g/_{l}\right) = a \cdot \frac{Area}{b + Area}$$

Metal	Initial Conc. (ug/l)	a	b
Cadmium	1.64	0.112	-0.924

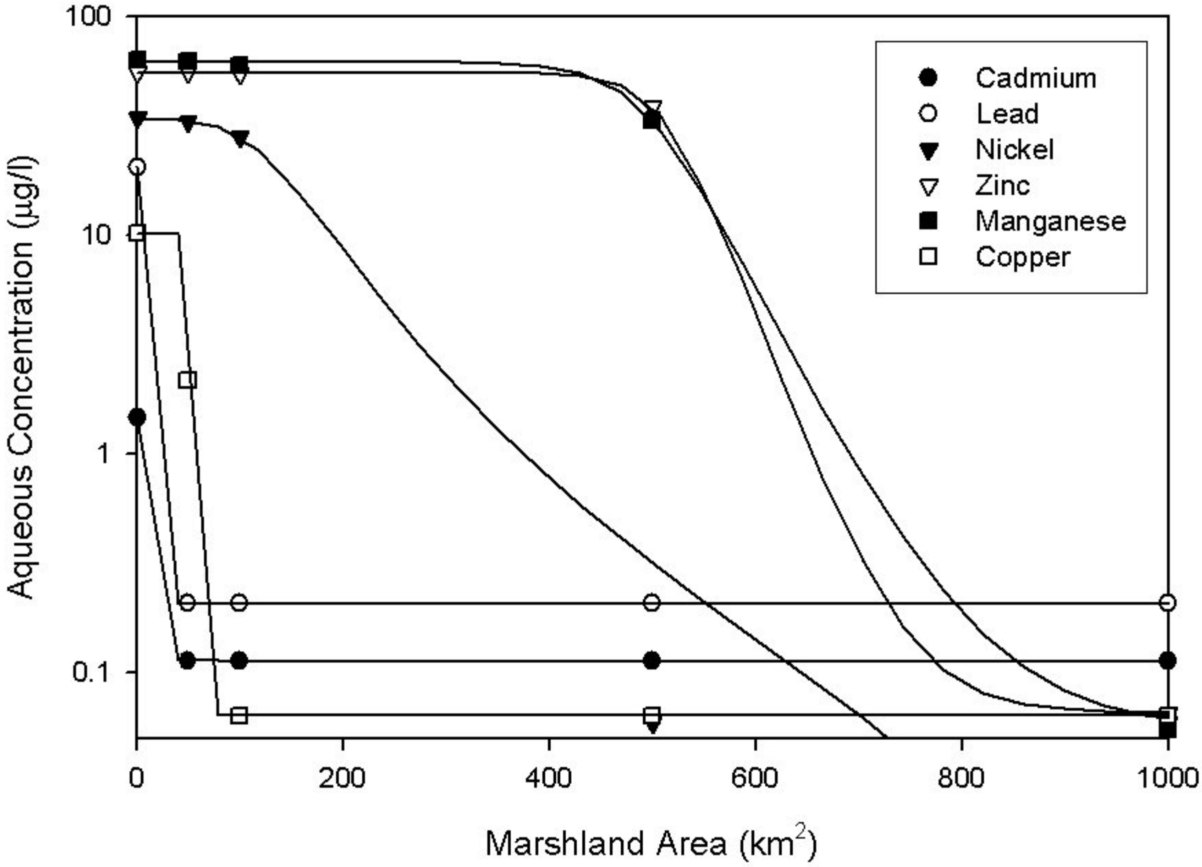


Figure 6: Fiftieth percentile change in aqueous concentration of metals based on the area of marshland.

For marshlands of greater than 1,000 km², it can be assumed from the results of the model that the outflow concentrations would be below its resolution. Hence, the amount of the metal removed is proportional the amount of water passing through the wetlands (Figure 7). This simplifies to a series of simple linear regressions as follows:

$$\Delta M\left(\frac{Tonnes}{yr}\right) = m \cdot Area$$

Metal	Initial Conc. (ug/l)	m
Cadmium	1.64	0.0092
Lead	20.5	0.123
Nickel	34.2	0.207
Zinc	55.6	0.336
Manganese	63.2	0.382
Copper	10.3	0.0618

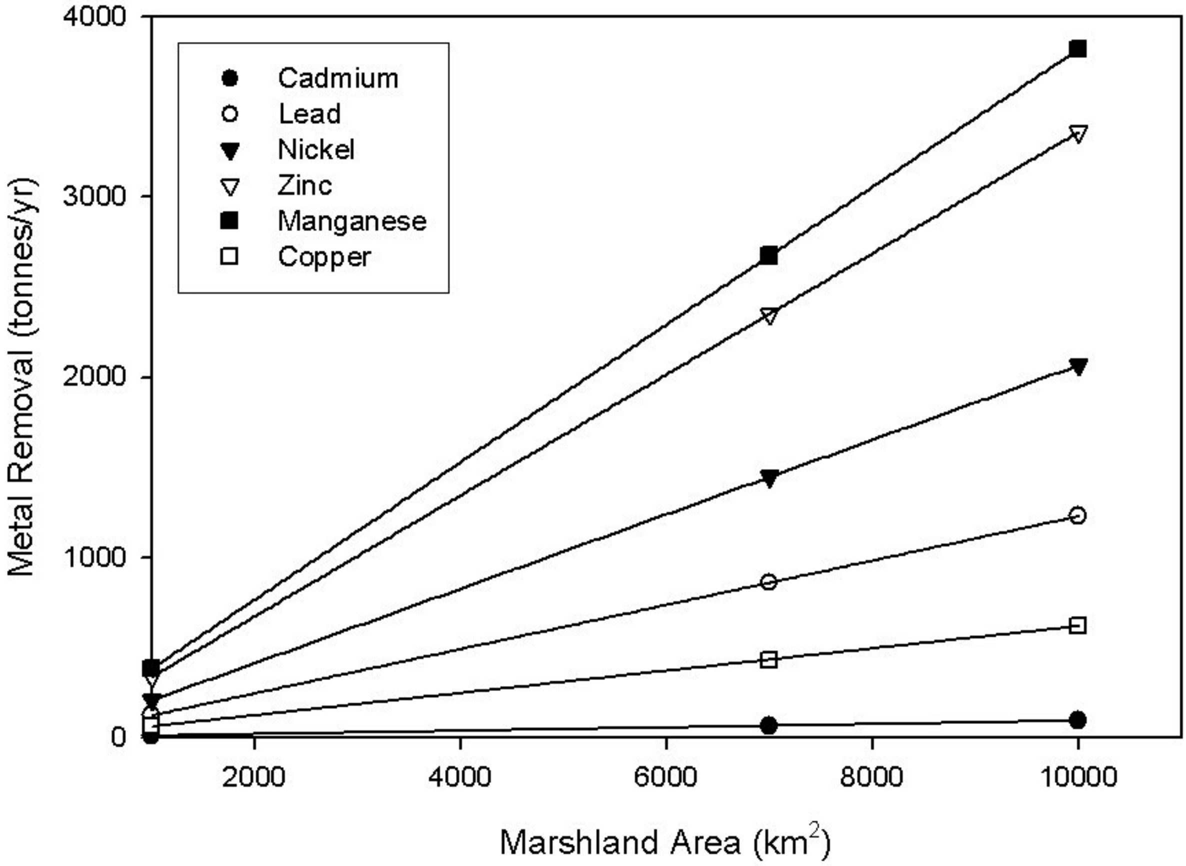


Figure 7: Removal rate of metals from water for marshland areas greater than 1000 km^2.

Organic Contaminants

Unlike heavy metals that cycle from one form to another, organic contaminants such as petroleum constituents and chlorinated compounds can be converted or metabolized through less harmful products or metabolites to inorganic constituents such as carbon dioxide and salt. The process is referred to as mineralization. The rate of mineralization depends on the recalcitrant nature of the material, and the chemical or biochemical activity of the environment. The marshlands represent an excellent environment for the decomposition and mineralization of organic contaminants. First, the high organic carbon content of the sediments binds organic contaminants to the sediments, thereby removing them from the water column. This is especially important for highly recalcitrant contaminants, such as DDT, that may take years to mineralize (Neilson 2000). Second, the shallow nature of the marshland permits sunlight penetration to the sediment bed. This is important because many organic contaminants that are photoreactive degrade much faster in light than they would in the dark sediments of a deep river. Third, the marshlands represent a highly diverse and active biological environment that is conducive to the destruction of organic contaminants. This is because the marshland contains both an aerobic and anaerobic zone in close proximity. Organic compounds that are resistant to oxidation in the aerobic zone tend to be susceptible to reduction in the anaerobic zone, and vise versa. As a result, labile constituents such as petroleum products will mineralize quickly within the marshland. More recalcitrant contaminants, for the most part, will remain bound in the marshland. Overall, they will be removed from the water column and removed from the vadose zone through sediment accumulation.

Benefits Related to Habitat Regeneration

Another important benefit associated with the regeneration of the Iraqi marshlands is the provision of wildlife habitat. In river systems, the vast majority of the primary productivity is algae based, with some contribution from submergent macrophytes. In a marsh or wetland environment, emergent macrophytes and associated periphyton become the more dominant form of primary production. This provides a biological structure to the marshlands that can efficiently transfer carbon to higher trophic organisms.

Fish

Probably the most direct and quickly realized result of the habitat regeneration would be increases in the abundance and diversity of fish species, both in the marsh and in other hydraulically connected water bodies. In the late 1980s, the marshlands provided 60% of the fish caught in Iraq (FAO 1990), representing a significant source of protein and income for the local inhabitants. During desiccation, the fish catch plummeted. A major impetus for the re-flooding of the marshlands was the desire of the local inhabitants to restore their traditional fishing grounds; fishermen were one of the first major groups to return to the re-flooded marshes.

Current activities are focused on reintroducing *Barbus sp.*, an important commercial species (IMET 2004). However, other native species will also follow, including the cichlidae (perch) and the sisoridae (catfish). While the latter are of limited commercial value (catfish are prohibited to eat in the Islamic tradition), they provide a food source for the commercial Barbus and Shad, thereby increasing their productivity.

Terrestrial Wildlife

The regeneration of the marsh's vegetation and fisheries will also directly benefit terrestrial wildlife. The habitats associated with the re-flooding include shallow open water, reed stands, and transitional uplands (riparian trees). High primary productivity, as well as aquatic food sources, will provide a support basis for many indigenous species both in food and nesting/cover habitat. Although such benefits may not be capitalized immediately, it will provide a general increase in the regional quality by providing higher quality human residential areas, as well as providing a basis for future international environmental support.

Conclusions

The benefits associated with the reintroduction of the Iraqi wetlands are numerous and varied. They affect hydrology, water quality, soil quality, and wildlife. These effects can be directly related to benefits for human health, agriculture, and other primary industries. Others, such as social organization and ecological restoration, are more indirect and related to overall sustainability and quality of life. Both types are summarized in Table 1. The key to the important benefits of the marshlands is an understanding that they are an integral part of the hydrodynamic cycling of the Mesopotamian plain and are responsible for many of the key environmental factors that provide this area with the carrying capacity that it enjoyed for thousands of years. The draining of the marshlands interrupted this cycle, leading to degradation in water and soil quality. By reinstating the marshlands, the watersheds of the Tigris and Euphrates Rivers will see an increase in both aquatic and agricultural productive capacity, as well as an increase in the capacity to withstand the impacts of intensive human use the Iraqi Marshlands

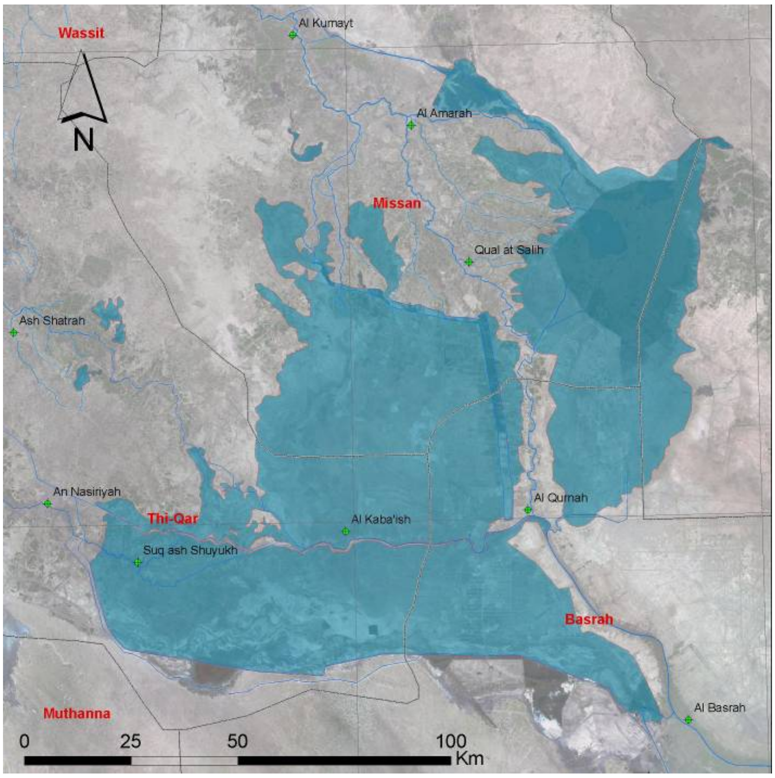
General Category	Potential Benefits
Hydrology	Downstream flood control Increased residence time and capacity for seasonal drought moderation Expanded agriculture due to reduced cost for irrigation transport and storage Groundwater recharge and associated reductions in the salinity of shallow groundwater, and possibly making it partially available for irrigation and human use Reductions in local temperature and increases in local humidity, reducing cooling and irrigation costs, increasing agricultural productivity, and improving general environmental quality
Nutrient Management	Net reductions in phosphorus concentrations Restoration of better N:P ratios Reduced water hardness with limited impact on alkalinity Reduction in downstream algal blooms and associated reductions in dissolved oxygen Higher nutrient retention in marshland biomass Reduced sulfate concentrations (reduced salinity) Reduced natural toxin production Reduced adverse nutrient impact on estuarine and marine receiving bodies, resulting in increases in saltwater fisheries productivity General reduction in water pH
Soil Management	Reductions in wind and splash erosion Reduced soil salinity from the saltpans Rehydration of bentonite-based clay horizons Improved soil structure through the introduction of organic matter Mechanism for renewal of high-intensity agricultural areas suffering soil salinization Provision of future land capable of sustaining high-intensity agriculture
Pollution Management	Reductions in the concentrations of dissolved heavy metals through oxidation and sequestration as metal sulfides Reduction in the transmission of enteric pathogens by increased retention time, binding to insoluble organic matter, and destruction by indigenous marshland microflora Sequestration and destruction of organic contaminants through binding to insoluble organic carbon, and mineralization through photooxidation and bacterial metabolism
Habitat Regeneration	Increases in the productivity and diversity of freshwater fisheries Improved environmental quality in both marshlands and transitional (riparian) environments Support for endangered species, providing good stewardship credit among the international community General improvement in environmental living quality through improved ecological quality

Table 1 - Summary of environmental benefits associated with the reintroduction of the Iraqi Marshlands

LAND AVAILABLE FOR MARSHLANDS RESTORATION

The New Eden Master Plan provides indication on how to best manage available water resources to achieve an optimum level of marshlands restoration. Indications are ultimately supported by several numerical tools which allow for a prompt recalculation of results shall the boundary conditions change.

In order to restore the marshes it is necessary to provide large volume of water which is scarce in Iraq today. Besides water, of primary importance it is the definition of the land which can be re-flooded while attempting for restoration. Some larger portions of the lands once occupied by the marshes are today off-limits as rural communities of medium-large size have developed their homes and their permanent agriculture projects. On the other hand, some other areas, which might be suitable for marshlands restoration, could be naturally restored only if large volume of water is used due to the fact that they lay on higher spots.



If 100% of the marshes of 1973 were restored, then, the land occupied by wetlands will be the one depicted in the figure on the left. Recuperation of this surface will bring 8926 km² of wetlands back in Iraq and additional 640 in Iran. Recuperation of 100% of the 1973 marshlands extension will ultimately provide approximately 10000 km² of wetlands surface distributed as follow: 3121 km² in the Central Marshes, 2729 km² in the Hammar Lake and 3717 km² in the Hawizhe Marshes.

It is also important to note that

marshes are naturally subjected to extensive seasonal variation and are capable of shrinking and expanding on the rate of several thousand of kilometer during different hydrological seasons (droughts, normal years and flood seasons). For this reason, setting a target marshlands restoration level does not imply that such level should be maintained at any point in time but that, in average, the marshlands should fluctuate around that level. To keep the marshlands at a fixed level might not the best choice both from the stand point of water management (see following chapter in this book) and ecology (as biodiversity largely depend on the opportunity for marshlands extension variation).

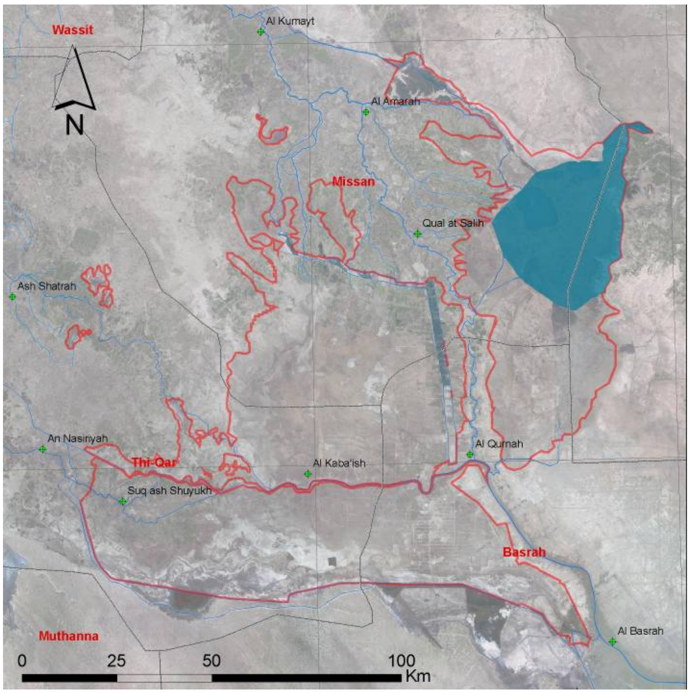
On the contrary, a variable restoration level will imply that, according to the hydrological conditions of the river basin (draughts, normal year, wet year and flood season), marshlands size might considerably vary. This condition is the most natural and provides most chances for the restoration of bio-diverse ecosystems. In order to exist, this restoration method requires that large portion of land is left available for the marshes to expand and reduce during the years.

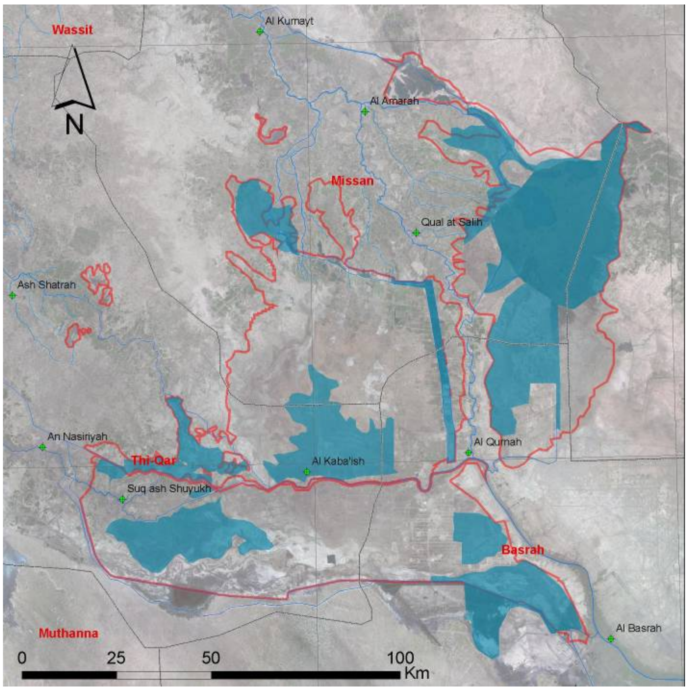
This chapter provides a discussion of the opportunity to set the maximum boundary of the marshes at approximately 75% of the former 1970's extent. The proposed 75% marshlands coverage does not interfere with other present or proposed future land uses. Keeping this land free from uses other than marshland restoration, is necessary to ensure that storm buffering and flood abutment functions are maintained around the permanent marshlands for rare to very rare hydrological events.

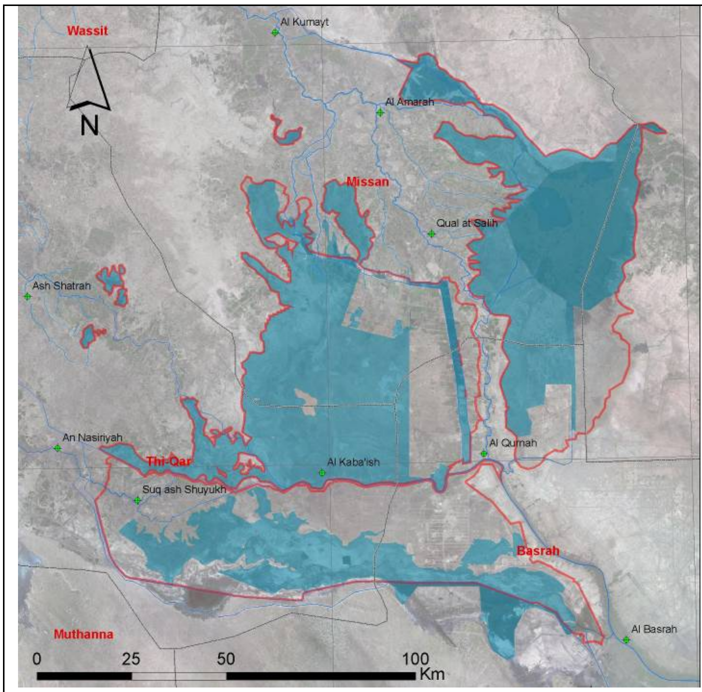
However, under any of the scenarios it must be emphasized that all land villages and settlements must be provided with safety measures in case of flood events.

With respect to the restoration percentage, the exact delineation of the marshlands remains flexible. It would be possible to re-flood different percentages of each marsh that would result in an overall 75% restoration scenario: the marshes are fed by different sources, and in each area re-flooding is to some extent, independent from other areas.

As an example of marshlands restoration, the following four re-flooding scenarios provide some guidance on the lands and actions required to achieve from a minimum to a maximum level of restoration. The four scenarios assume that a recovery might take place between the following proportions: 0-25%, 25-50%, 50-75%, 75-100%.

Recovery: 0%-25%	
	**Area restored:** the restored area will equal the 2000-2002 conditions. The total recovered area will range between 0 to 2,400 km². **Steps required:** significant investments required in order to rehabilitate some the existing drainage structures **Methodology:** little to no intervention. **Limitations:** It is likely that such level of recovery will happen only during very dry years or if no effort from the Iraqi government will be made to restore the marshes. In the latter case, it is possible that for some years Haweizhe marsh will remain alive. In the long term, all Hawizhe marshes will disappear with decreasing input from Iran.
This level of restoration is not recommended because it would require significant rehabilitation of the drainage structures that were disabled or fell into disuse after 2003. Furthermore, none of the benefits of marsh restoration, described in the previous section, would accrue to the region. Finally, this scenario would meet with serious resistance from the local inhabitants who have demonstrated their strong desire to have the marshlands restored at a higher level than this scenario.	

Recovery: 25%-50%	
	**Area restored:** the restored area would equal the 2005 conditions. The total recovered area would range between 2,400 to 4,800 km². This condition might represent the condition attainable during normal to dry years. **Steps required:** (a) A moderate level of effort would be required in Iraq to modernize its agriculture at local and national scales and to assure that adequate water is available for the marshlands. (b) The timing of water releases for agricultural irrigation would need to be coordinated with releases for marshlands agriculture. (c) Seasonal variation in water flow should be simulated through controlled releases.
Methodology: implementation of best practices in local agriculture, correct water management, limited infrastructure construction, and development of scheduled flow release plans to allow for optimum marshlands recovery. **Limitations:** Some areas will remain as seasonal marshlands while recovering, as hydraulic connectivity between marshes would not be fully achieved. It is recommended that some additional areas be inundated, as in the following scenario, to allow for full achievement of the benefits of marshland restoration.	



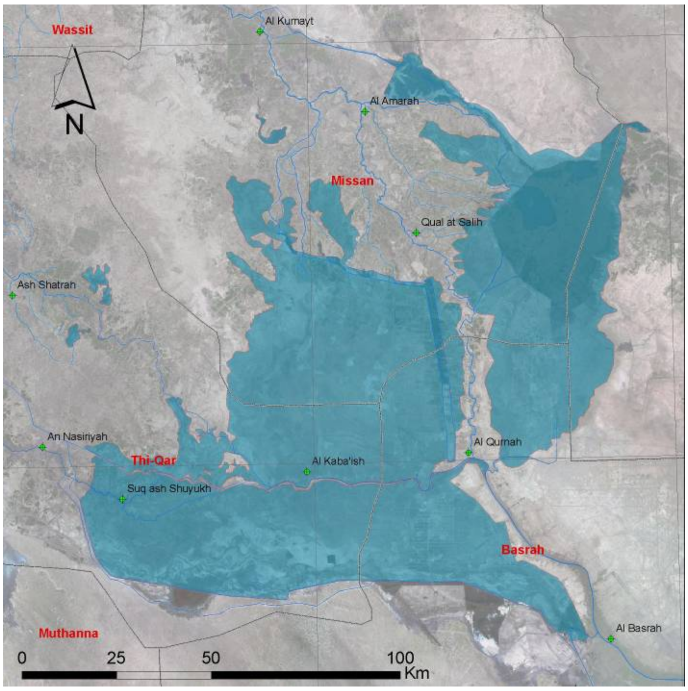
Recovery: 50%-75%

Area restored: the restored area would equal 1990 conditions. the total recovered area would range between 4,800 to 7,200 km². The full extent of this condition might be achievable only during wet and flood years.

Steps required: (a) Significant efforts would be required in Iraq to modernize its agriculture at local and national scale. (b) Timing of water releases to marshes to minimize water losses due to evaporation and optimize water use for agriculture. (c) Agreements must be made with neighboring countries for the necessary water allocations.

Methodology: implement best practices in local and national agriculture, correct water management, construction of significant infrastructure for water control, development of scheduled flow release plans to allow for optimum marshlands recovery.

Advantages: this condition represents the recommended level of marshlands recovery, as it would not interfere with other present and future land use utilization, it would allow for implementation of some agricultural development plans, and would remain flexible with respect to final selection of marsh restoration areas to maximize opportunities for productive field irrigation and for petroleum and other natural resource development.



Recovery: 75%-100%

Area recovered: the restored area would equal the 1970's conditions. The total recovered area would range between 7,200 to more then 10,000 km². This condition might only be achievable during extreme flood years.

Step required: (a) Major efforts would be required in Iraq to modernize its agriculture both at local and national scales. (b) Several locations currently used for field agriculture or petroleum development would be reconverted to marshes and agricultural development plans might have to be downscaled. (c) Agreements would have to be made with neighboring countries in order to provide the bulk of water required for the restoration.

Methodology: implement best practices in local and national agriculture, correct water management, construction of large infrastructure for water control, development of scheduled flow release plans to allow for best marshlands recovery, reclamation of large portion of land.

Limitations: this level of recovery (along with the first scenario of 25%) represents the least feasible level of restoration. Although the opportunity to achieve total restoration would enable the achievement of the most biodiverse wetlands, the presence of so large water and wetlands bodies might pose limitations to long-term national and local economical development. This scenario would meet with serious resistance from local farmers and from the nation as a whole inasmuch as Iraq's economy is strongly dependent upon its petroleum income.

The New Eden study recommends a relatively conservative scenario (50-75% restoration) that does not result in significant changes in the current land use (as of March 2006 the inundated marshland is at 58% restoration). Very limited areas would be converted into field agriculture, and no existing or planned agricultural land is proposed for marshland restoration. No areas that are currently used for petroleum production are proposed to be converted to marshland. This methodology will help to defuse any conflicts between proposed land uses and result in the best and wisest land use decisions for Iraq as a whole.

The following image represents a possible scenario for marshlands recovery in the short and medium term. Green areas represent marshes recovered today. Blue areas represent land proposed for further expansion of the existing wetlands. From the figure, it is worth pointing out that all the oil fields areas are left untouched as well as existing agriculture plan

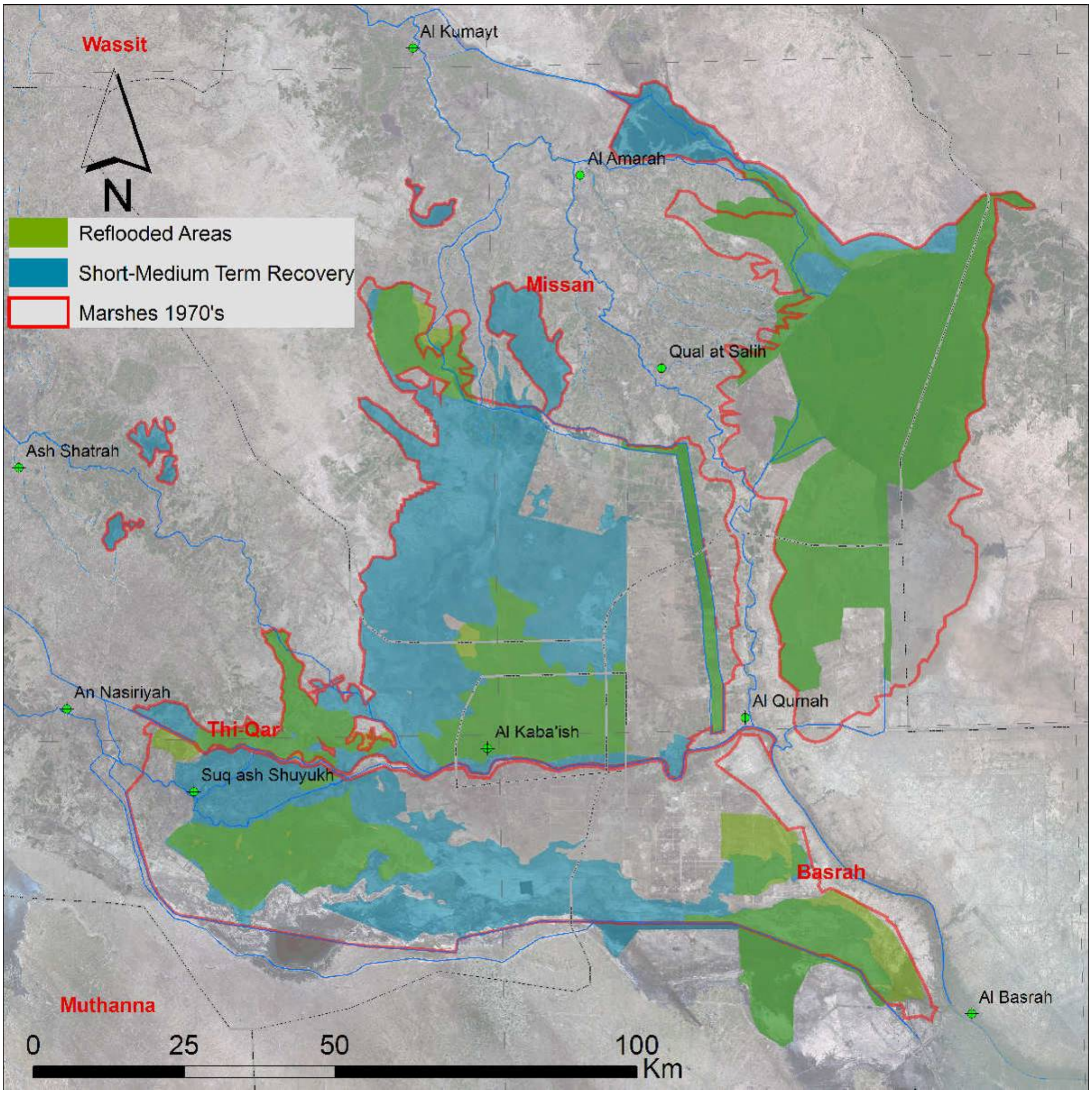


Figure 1: Areas proposed for marshlands restoration

METHODOLOGIES FOR BEST PRACTICES IN WATER UTILIZATION FOR THE MARSHES RESTORATION

INTRODUCTION

The present chapter aims at describing a possible alternative for implementing best practices in water control management for the marshlands. The overall strategy can be summarized in few points:

A Target Curve (TC), representing the desired rate of change in water level inside the marshes during time, must be chosen. Depending on the choice, water allocation for the marshes might considerably vary as large volumes of water are required to re-flood the marshes and bring the water level inside the marshes at the desired stage.

Water inflows and outflows in the marshes must be fully controlled to allow for water level to vary at the desired rate. By controlling the inlet and the outlets of the marshes it is possible to reduce water losses due to evaporation and optimize the water utilization.

The present chapter discusses in separate paragraphs the various element of the strategy.

WATER LEVEL VARIATION TARGETS

Water level variation during time is of paramount importance to guarantee the development of a healthy marshland system. By changing the water level, marshland dynamics meet the important requirements of maintaining flow movement and initiating wetting and drying processes. Identification of a specific Target Curve (TC) strongly influences water demand for large and complex marshlands such as those of southern Iraq. At the same time, identification of such a curve requires a lengthy stakeholder involvement process, aiming at finding the best compromise among parties which typically have conflicting goals and objectives.

Due to the fact that a participatory stakeholder process has not yet taken place for the marshes of southern Iraq, a tentative TC was selected based on the successful example set by the Al Azim (Iranian part of Hawizhe) Marshes. The following graph displays a multiyear water level variation record set measured inside the Iranian marshes. A slightly modified version of this curve was proposed as a target for water level variation for all the four wetlands inside southern Iraq.

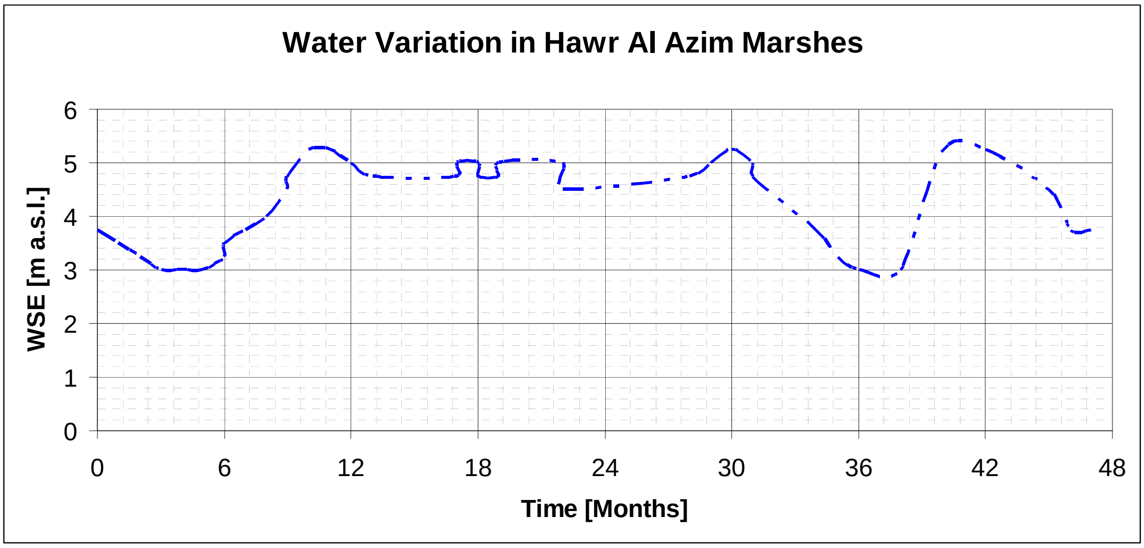


Figure 2: Water Surface Elevation [WSE] variability as recorded from June 2001 in Al Azim Marshes. The creation of a hydro period is of paramount importance for the management of the marshes.

It should be noted that many of the recommendations developed by the New Eden Hydrology Team remain valid regardless to the specific Target Curve which has been arbitrarily selected here. Moreover, the tools developed by the New Eden Hydrology Team are flexible enough to allow for a quick recalculation of the appropriate water requirements for marshlands management, should the TC be changed in the future.

The TC which was finally selected proposes a water fluctuation of almost 2 meters during the year. The Al Azim TC curve was slightly modified in order to create the opportunity to better distribute water for the marshes and for agriculture. In practice, water peaks proposed by the "natural" TC curve (the one recorder) were modified to enable to minimize water entering the marshes during summer time (when it is most needed in agriculture and it is most dispersed in the marshes due to the evapo-transpiration processes).

RE-FLOODING

Naturally the extension of the flooded areas is subject to variability during the year, according to the hydrological regime; dry years imply a reduction of the flooded areas, while wet years contribute to in increase in extent of the marshlands. It is very important to stress this situation to understand the entirety of the areas that can be re-flooded.

The re-flooding methodologies proposed herein reproduce the natural variation of the marshes extent, as far as is possible. The image below shows how the seasonal variation in the Central Marsh would work according to the proposed marshland's management strategy. The minimum extent occurs in August, while the maximum re-flooded area is measured during the months of April and May. It must be clear that the actual extent highly depends on the topographical characteristics of the re-flooded area: water tends to fill the channels in the marshes, before covering the floodplain.

It should also be noted that marshland's changes at a completely different rate then the re-flooding process and although re-flooded areas might greatly change during the year, a similar rate of change is not apparent on the extent of vegetation extension. A great deal of observation was made, to this extent, during the UNEP monitoring program. Some of the results are presented and discussed in Book 4, where a series of graphs clearly delineates these dynamics.

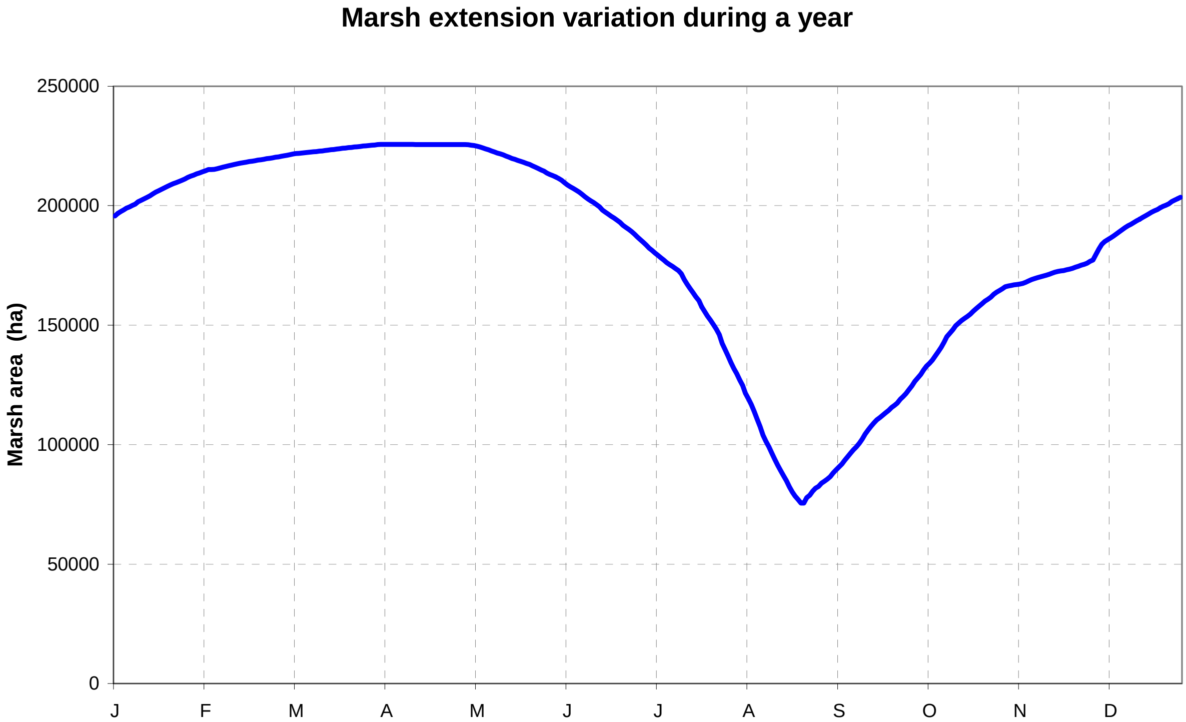


Figure 3: Marsh extension variation during one year for Central Marsh

INFLOW-OUTFLOW MANAGEMENT

"Natural" In-Out Management

The completely natural inflow-outflow system for the marshlands strongly depends on the presence of flood peaks and generally to the hydrological regime of the rivers that brings water in all the marshlands area. Before significant human impact on the hydraulic system, the area upstream of the marshlands was an inland delta that was periodically inundated during floods. On the other hand, during drought, the extent of the inundated areas decreased, causing an alternation in the behavior of the wetlands, and generally helping the development of biodiversity and optimizing environmental condition: the variation of the flood extension and of the water depth inside the marsh favor the ideal conditions for flora and fauna. For example, the most efficient nutrient cycling requires times of inundation and periodic drying; seed germination responds to changes in salinity with freshwater flooding. The hydraulic system integrated rivers and marshes as a whole, and the components were highly interconnected; basically the marshlands area represented, as a matter of fact, a system integrated with the channels of the delta. Moreover, man-made levees and embankments didn't exist; thus there was less physical limitation to the extent of inundation except for the natural levees and gradual changes in terrain elevation. An exchange of flows between flooded areas and rivers was constantly present in the hydrological regime; for example Central Marsh received water both from the Tigris and from the Euphrates and returned water to the same rivers. Large flow peaks were entering these wetlands, water was expanding and floods were naturally attenuated while water was expanding over the floodplain. Large volumes of water moving through the wetlands helped maintain a strong level of connectivity between the various marshes and rivers.

The next image shows a schematic of the marshes as a natural system.

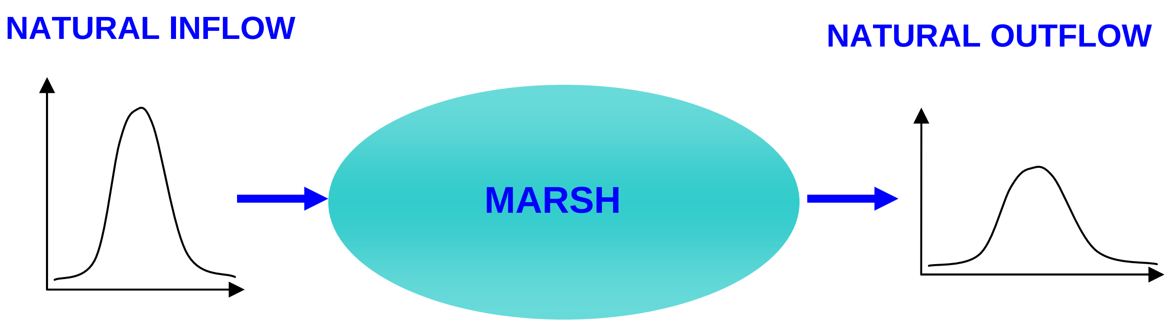


Figure 4: Natural In-Out management

"Semi-Natural" Management

Nowadays marshes are managed in a completely different way then in the past: the presence of dams, man-made levees and embankments allows for a full control of how water enters the marshes and where water is allowed to spread in southern Iraq. Dams and levees were built in order to enable and protect human activities. An immediate consequence of the construction of dams and reservoirs was the disappearance of peak flows from the rivers and the reduction of total available water for Southern Iraq. At the same time, the construction of an extensive levee system imposed physical constraints to the amount of land potentially available for marshlands development as well as to the connectivity between marshlands and rivers.

In today's conditions, marshes are no longer connected one to another, and if some connectivity still exists it is only because the local population has recently created breaches over the existing levees, or because a man-made canal brings water from one place to another.

In summary, the lack of peak flows and hydro-periods, the reduction in water availability, and the lack of hydrological connectivity are all factors contributing today to the existence of an unhealthy and unstable marshland system.

We will generally refer to this marshlands condition and flow management as "semi-natural": inflows to the marshes are fully controlled, whereas outflows are uncontrolled although modified. This marshlands management strategy is extensively applied today in southern Iraq. Unfortunately, it is a losing strategy, as large flows are not guaranteed anymore, and flow variation inside the marshes cannot be mimicked without an adequate artificial system.

The next image shows a schematic of the semi-natural management of the marshlands.

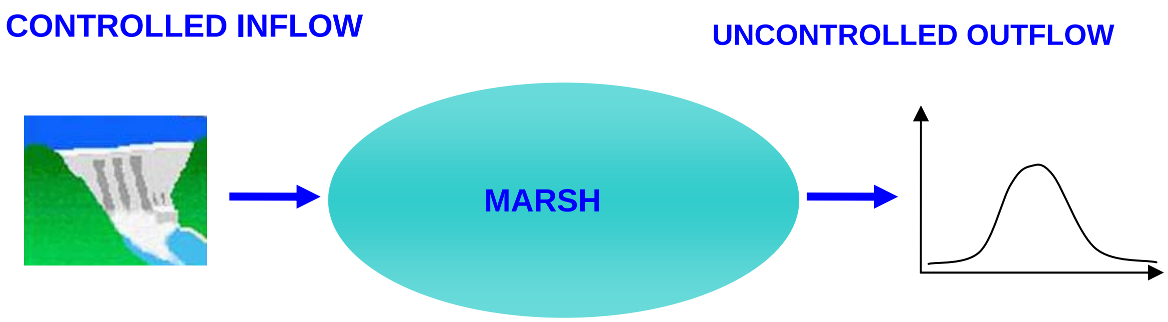


Figure 5: Semi natural In-Out management

"Controlled" Management

Recognizing that both "Natural In-Out" and "Semi-Natural" managements are no longer feasible or adequate in today's Iraq, a last alternative appears to be the most appealing. We will refer to this strategy as "Controlled" management, referring to a system where both inflows and outflows are fully controlled. "Controlled" management attempts to gain the necessary flow-through and water level variations required by the ecological system to thrive.

From a hydraulic standpoint, a "Controlled" management will operate the marshes as if they were tanks that must be filled and emptied through time. To do so, it is necessary to close or limit the outflows while the "tank" is filled and the water level is rising, and limit inflows and outflows when a drop in water elevation is required.

Although simple in principle, "Controlled" management is the hardest to operate: scheduled flows must be secured at the marshlands inflow's points and receiving water bodies must be ready when it is time to release water out of the marshes.

"Controlled" management is not only feasible but also the most water-saving efficient strategy and was selected by the New Eden team as the preferred solution for marshlands management. The following chapters will clarify the pros and cons of each different alternative, first considering possible inflow and then possible outflow strategies.

The next image shows a schematic of the controlled management of the marshlands.

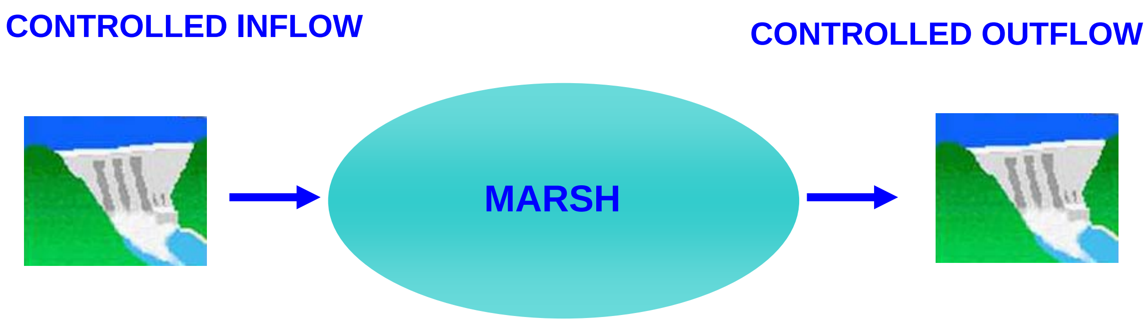


Figure 6: Controlled In-Out management

Upstream Water Control

The previous paragraphs discussed possible alternatives for overall marshlands management and indicated that a 'Controlled" strategy allows for a level of flow control which might make the recommended level of marshland restoration possible. The "Controlled" management requires that a system of water regulators exists both upstream and downstream of the marshes. Water control structures can be operated in different ways in order to meet the desired water flow-through and water level variation inside the wetlands. The following paragraphs present three alternatives for operation of the upstream water control structures.

Steady Inflow (SI)

A first option for upstream water control consists in using available hydraulic structures to maintain a constant inflow in the marsh. This operation is simple and leaves all the responsibility for changing water level inside the marsh to the outflow water control structures. We will from now on refer to this operation as "Steady Inflow" (SI).

The following figure explains the SI concept.

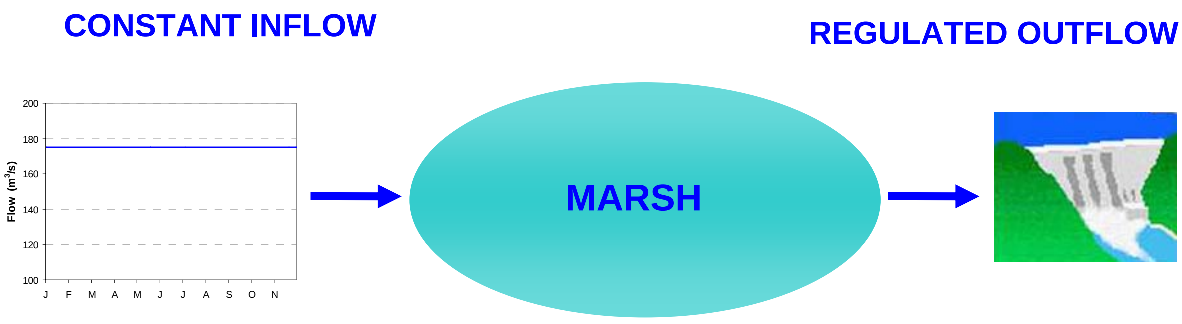


Figure 7: Inflow management: constant inflow

The overall goal of marshlands management is to have the water levels inside the marsh changing at the rate and magnitude defined by the Target Curve (TC). Steady Inflow is only partially responsible for the success of the operation, which is also affected by the size of the downstream water control structures and their operation strategies. On the other hand, SI is capable of ensuring that a target maximum water level is reached at the desired time of the year.

The following Figure 7 displays the results of the RES-SIM model wile attempting to operate Central Marshes according to the SI operation rules: the marsh well respond to the desired rising limb of the flood but hardly manages to follow TC during the decreasing phase. SI is clearly not an efficient strategy for marshlands management: water is constantly pumped into the marsh even during times when fitting of TC would require flooded areas inside the marsh to reduce their water level and extension.

At all times, RES-SIM is operating reasonably large downstream water control structure while attempting to meet the rules imposed by TC.

At this time, SI is a preferred way to operate water control structure is southern Iraq as it is difficult to gather flow discharge measurements in time to change operations schemes on a needed basis.

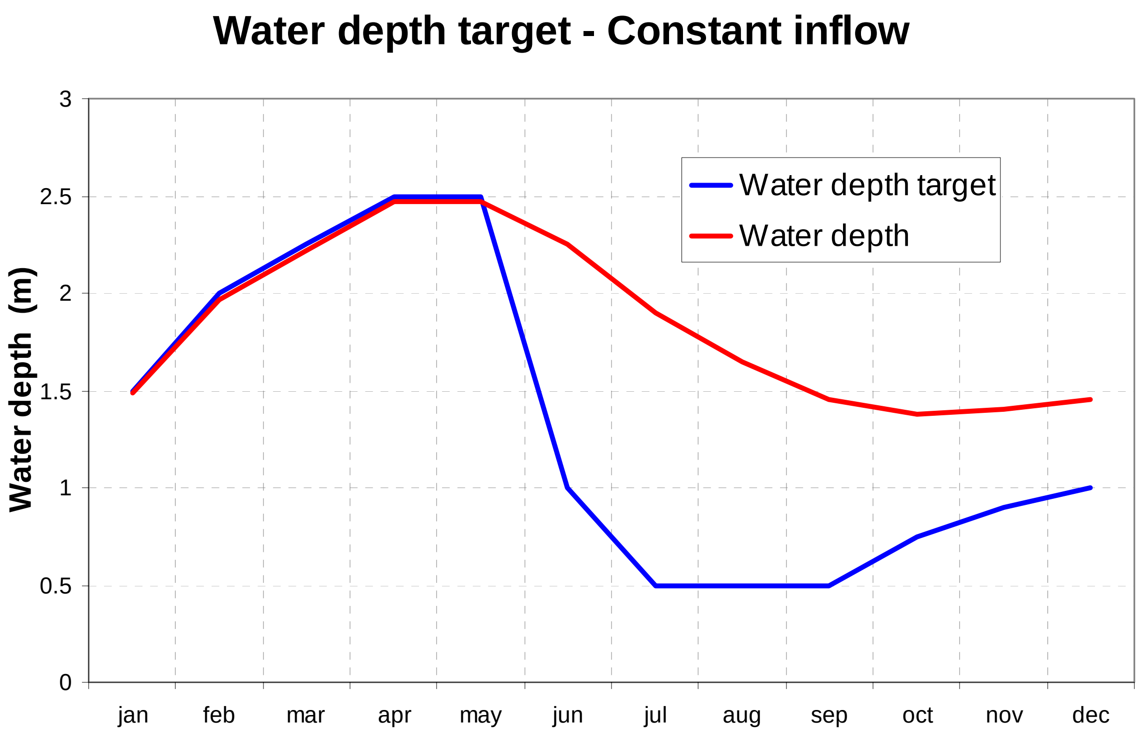


Figure 8: Constant inflow: fitting of the water depth target curve

Steady Inflow Optimized (On-Off)

The second option for the upstream control is to use a hydraulic structure to maintain either a constant inflow or no inflow at all according to the period of the year: basically the way of management is similar to the SI system, with the only difference that inflows are switched off when not needed. This On-Off system is still quite simple to implement with a hydraulic structure; the operations on the gate openings are not so frequent during the year. The figure below shows a schematic of the system.

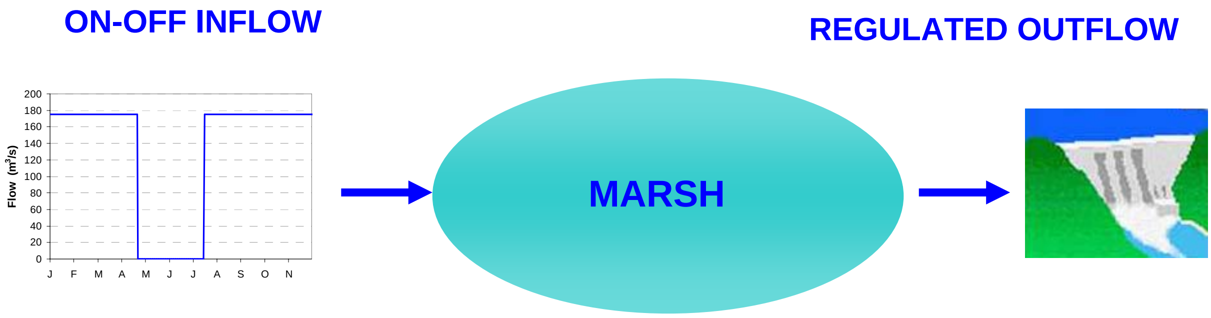


Figure 9: Inflow management: on-off inflow

The inflow discharge can be decided in order to obtain a good fitting with the target curve for the highest water level; during the period of time in which the water level has to decrease, the inflow must be switched off in order to avoid wasteful use of water and to gain a more accurate fitting of TC. Figure 10 illustrates an example of the water elevation variation obtained in the Central Marshes marsh considering the On-Off inflow: it is possible to see that during the rising limb of the flood, the fit of TC is not as good as for the SI system, but when the water elevation starts decreasing the On-Off inflow for the system tends to be more reactive to the TC requirements. On-Off operation rules are more water-saving efficient then SI and do allow the marshes a better fitting of the Target Curve: min and max water level changes are met at all times; the difference that can be noticed during the summer period is due to the discharge capacity of the outflow, which will be discussed in the following paragraphs.

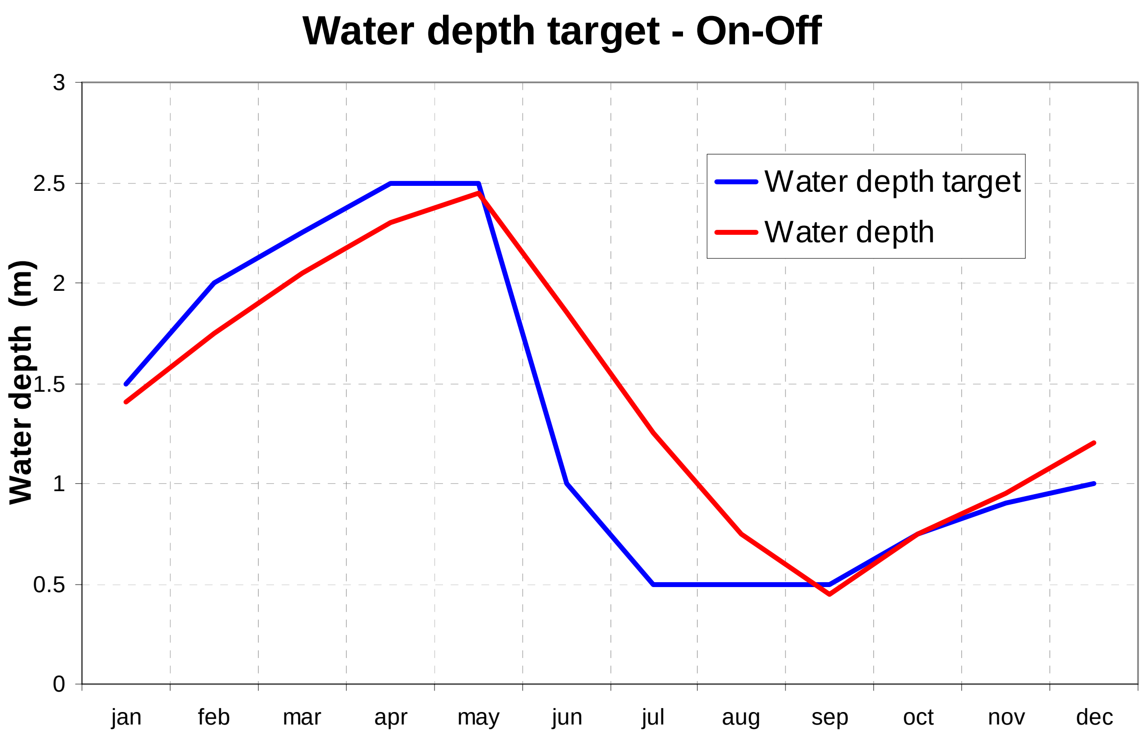


Figure 10: On-Off inflow: fitting of the water depth target curve

Optimized Inflow (OI)

A third option for operation of the upstream water control structures is to constantly optimize the inflow necessary to obtained the required water level changes inside the marshes. The OI system is clearly more complex to operate as an active management is required at all times; the operations on the gate's openings are quite frequent and changes must be made almost on a monthly basis. The figure below shows a schematic of the system.

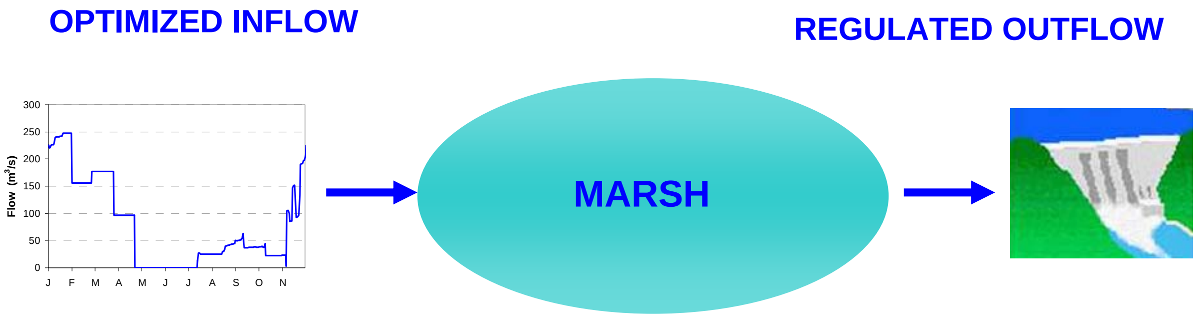


Figure 11: Inflow management: optimized inflow

RES-SIM simulations provide clues on the performances of the proposed operation strategy. Modeling results provides inflow discharge distributions which allow to best fitting TC wile using the least amount of water. In the OI system a minimum inflow of about 10-30 m³/s is guaranteed all year-round in order to stimulate flow movement inside the marsh at all times. Similarly an outflow of approximately 20 m³/s is kept flowing trough the outflow structures to allow for water movement, sanitary discharges into the receiving water bodies and simulate for the presence of small navigation passages trough the regulators.

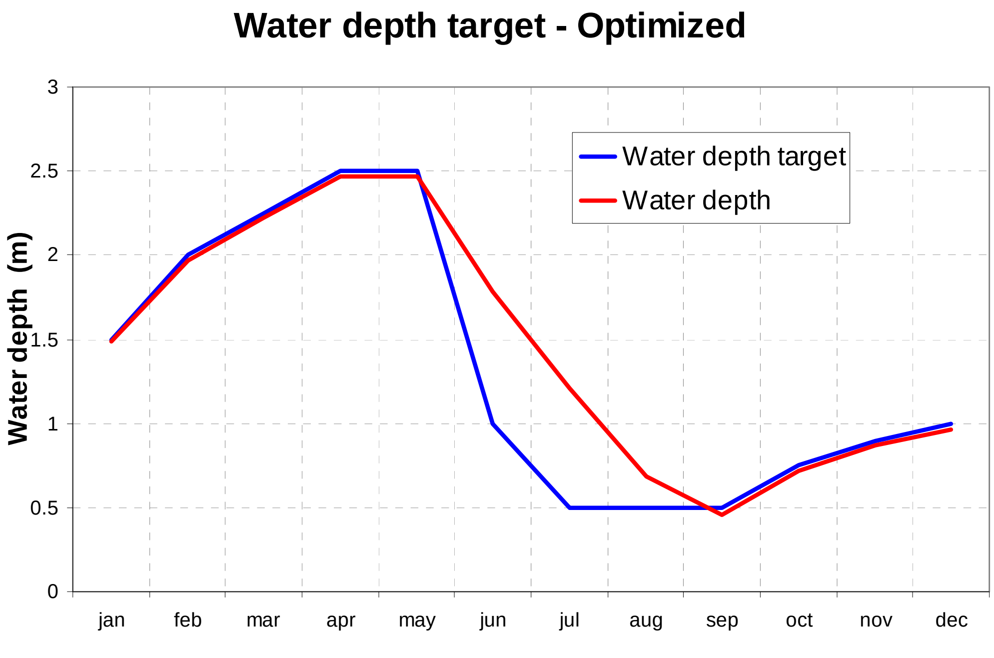


Figure 12: Optimized inflow: fitting of the water depth target curve

Figure 12 illustrates an example of the water elevation variation obtained in the Central Marshes according to the OI operation: it is possible to see that there is a good level of approximation with the target curve during all the year, except in summer, when the water depth variation spans from the minimum to the maximum requested level; the difference that can be noticed during the summer period is due to the discharge capacity of the outflow, which will be discussed in the following paragraphs. The OI upstream water control system doesn't waste water, and from this point of view it is the most efficient inflow system.

Water Volumes Comparison

Water for marshlands restoration can be managed in three basic ways. Q-constant or Steady Inflow (SI) implies that inflow is a constant value during the year: the available water in the rivers oscillates during time and it is necessary to regulate the flow entering the marsh in order to make it constant. Q-On-Off implies that inflows are switched off during those months when water is not required to enter the marshes. Q-optimized or Optimized Inflow (OI) implies that inflows are constantly regulated year-round at monthly bases.

Numerical models clearly show that the best management strategy for the marshes can be achieved by combining smaller (other then the historical ones) scheduled flow releases from upstream with a downstream water regulation. Scheduling of large flow releases from upstream (required if we attempt to mimic historical floods) is not possible in Iraq today. At the same time complete downstream water control with constant year-round upstream flows, would not represent a good solution either: large volumes of water would be wasted due to evaporation during the warmest months and water would be released to the marshes when they needed it the least.

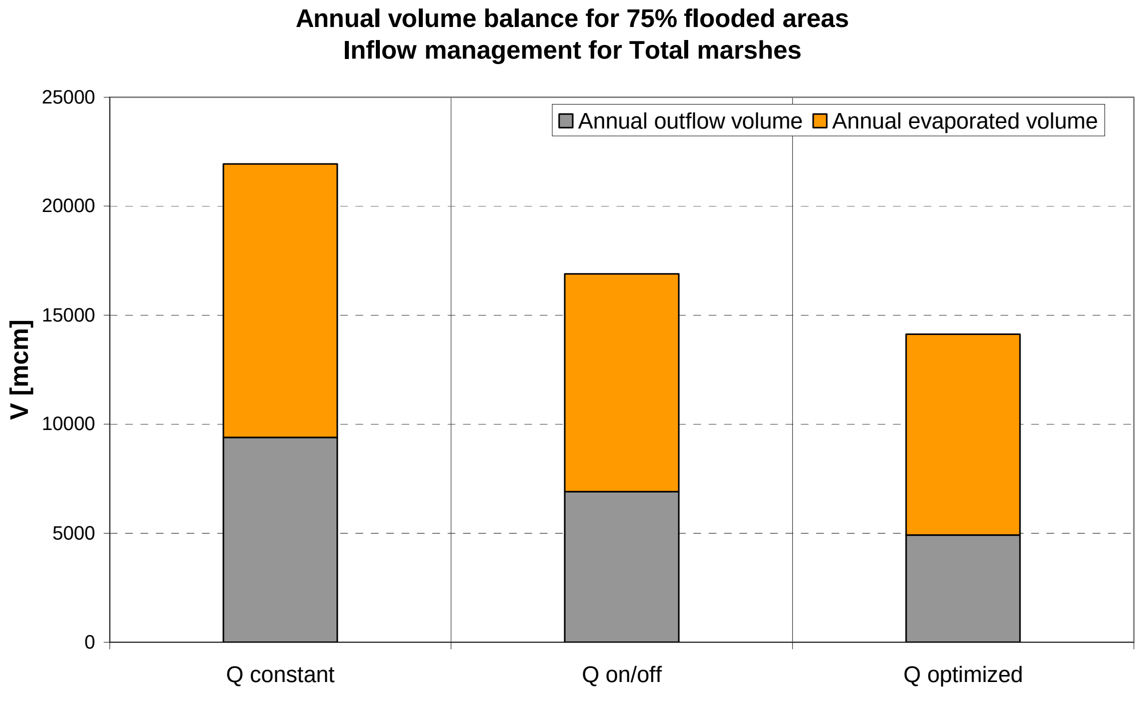


Figure 13: Annual volume balance for SI, On-Off, OI methods

Results from the modeling analysis are summarized in graphs like the one depicted in Figure 13. This graph shows how active management of the marshes (continuously changing inflow and outflow) could alone save up to ten billion cubic meters of water. In the graphs, each bar alone shows the total volume of inflow water required by the specific operation strategy. The gray part of the bar represents water leaving the marsh, whereas the orange portion is the water loss due to evaporation inside the marshes.

It should also be noted that all three methods (SI, On-Off, OI) more or less fit the Target Curve, but they do so utilizing different water volumes. It is reasonable to think that, in practice, marshlands should be managed with a set of operation rules which are somewhere in between On-Off and OI. After all, if it is true that OI is the most water conservative, it is also true that OI allows for the least water movement inside the marsh due to the smallest amount of flows.

Downstream Water Control

The opportunity to artificially operate the marshes from a downstream location is easily explained: head regulators effectively control water level in the upstream water bodies by opening and closing their gates. The design discharge capacity of each control structure influences the way the marsh might respond to the Target Curve: the larger the design discharge, the better the fitting of the target curve. This is clearly explained if we think that a large structure is capable of emptying the marshes in less time. A perfect fitting of the TC could be, in this sense, obtained with a structure having a design operation capacity equal to the 100-year flood event. For example, in Hammar Marsh, a perfect fitting of the Target Curve would be gained only by building a head regulator capable of operating up to 600 m^3/s (meaning that 600 m^3/s should go through the gates and not through emergency spillways). The concept is clearly explained in the two following graphs.

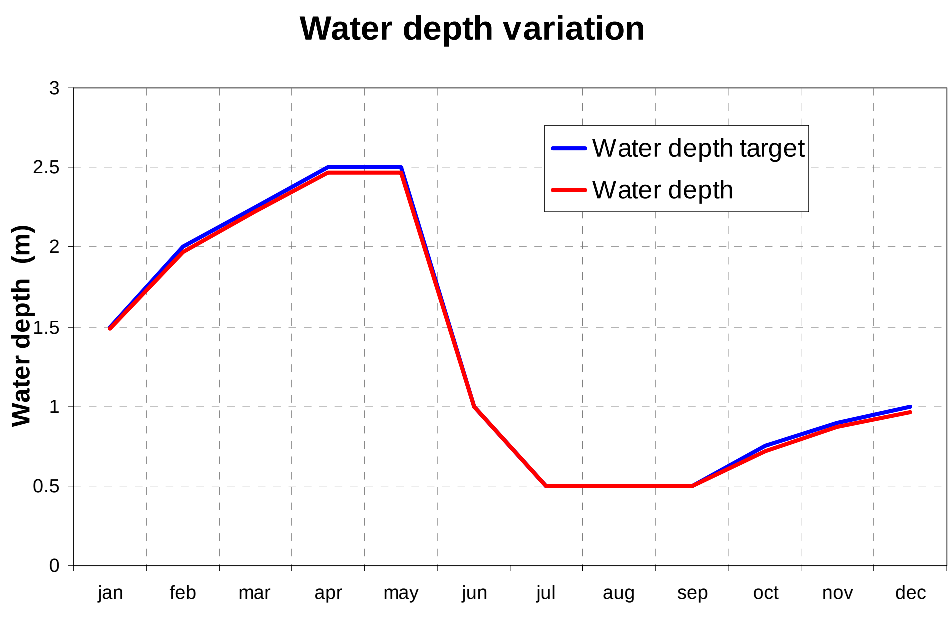


Figure 14: Maximum outflow: fitting of the water depth target curve

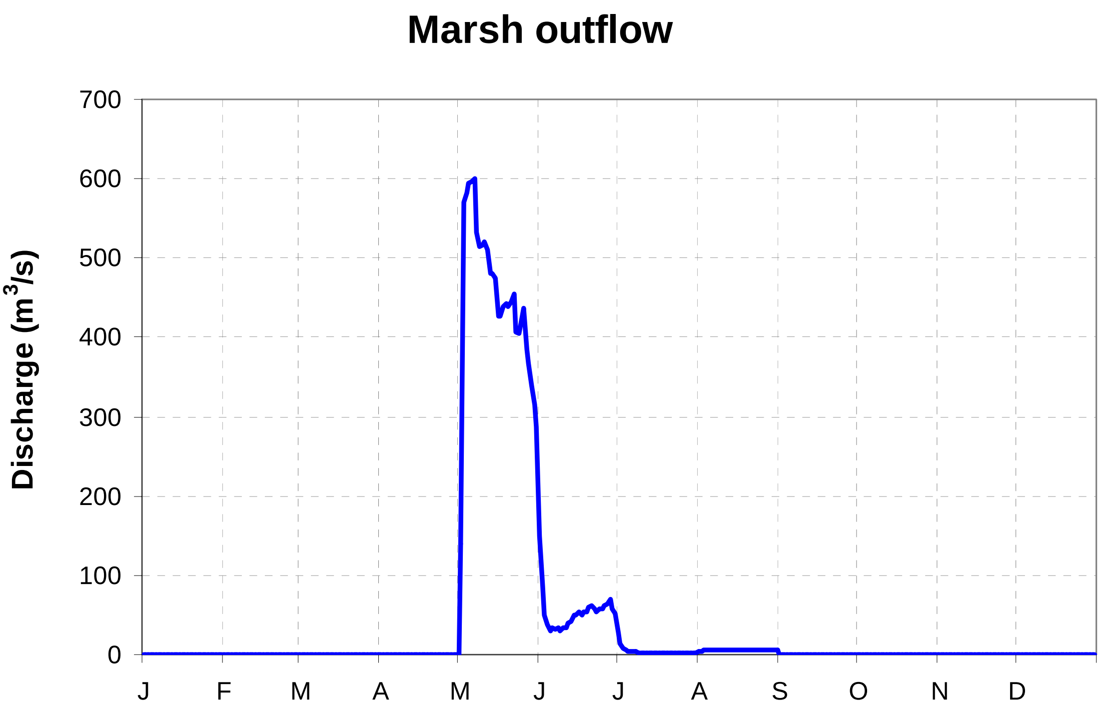


Figure 15: Required outflow for the best fitting of the target curve

Nevertheless it is not reasonable to build hydraulic structures that can handle such large discharges. Moreover the discharge peaks are due to the abrupt variation in water level from May to July, when water elevation decreases of 2 meters in two months; thus in order to follow that part of the curve the marsh system has to discharge a great amount of water in a short time.

Again, we should not forget that the Target Curve proposed here is just one of the many possibilities and that it might be changed in the future. Furthermore, is must be kept in mind that water level changes might not need to change in such a short amount of time and that water level changes are more important that the time required for that change to happen. This approach allows the possibility of considering hydraulic structures with lower discharge capacities, such as 50, 100, 150 and 200 m^3/s.

In this way, the outflow hydraulic structures are more acceptable from a design point of view, and the fitting of the target curve is approximate during the summer season. In the Figure 16 it is possible to see how the water depth changes according to the different maximum discharge capacities analyzed; the example shows what happens for Hammar Marshes when we operated downstream water control structures of respectively 100 m^3/s, 150 m^3/s and 200 m^3/s of design operation capacity.

It is important to noticing that the larger the outlet hydraulic structure, the less water is lost due to evaporation over the year (See Figure 17). The evaporation is higher in the case of hydraulic structures with lower discharge capacity rather than high discharge capacity. Considering Figure 17, the inflow for the 200 m^3/s discharge capacity scenario is nearly equivalent to the 50 m^3/s one, i.e. 3,550 m^3, versus 3,450 m^3; on the contrary the evaporation volume is quite different: in the first case it is 1,200 m³, while in the second it is 1,700 m³; the reason for the difference in evaporation is due to the fact that with low discharge capacity it takes much more time to empty the marsh, and so the surface area free to evaporate is greater; with respect to the outflow, in the first case it is about twice the second case, i.e. 1,400 m³ versus 700 m³.

Inflows as well as outflow flow requirements increase with the size of the structure. In practice, larger structures have higher construction and operation and maintenance costs but they do allow for an decrease in water losses due to evaporation and they do provide larger quantities of water to the receiving water bodies in a shorter amount of time. The direct benefit of having a larger and more expensive controlled outlet could be seen if downstream water is needed for navigation, or agriculture, or to feed a downstream marsh (as it might be the case of the Central and Abu Zirig Marshes.

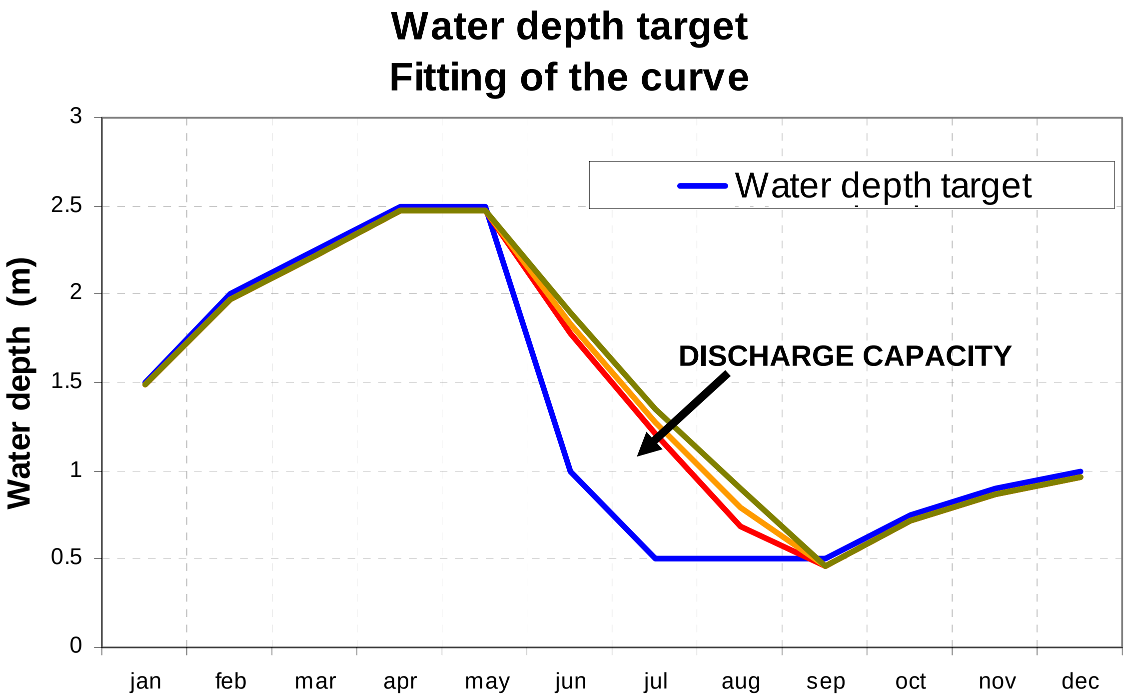


Figure 16: Fitting of the water depth target curve according to the discharge capacity

In summary, while choosing the most appropriate hydraulic structure, a designer should look at the cost and benefits aspects related to:

- the amount of water saved from evaporation;
- the cost for construction and O&M of the hydraulic structure;
- the socio-economic benefit deriving from having more or less water in the river network or in the marshes system.

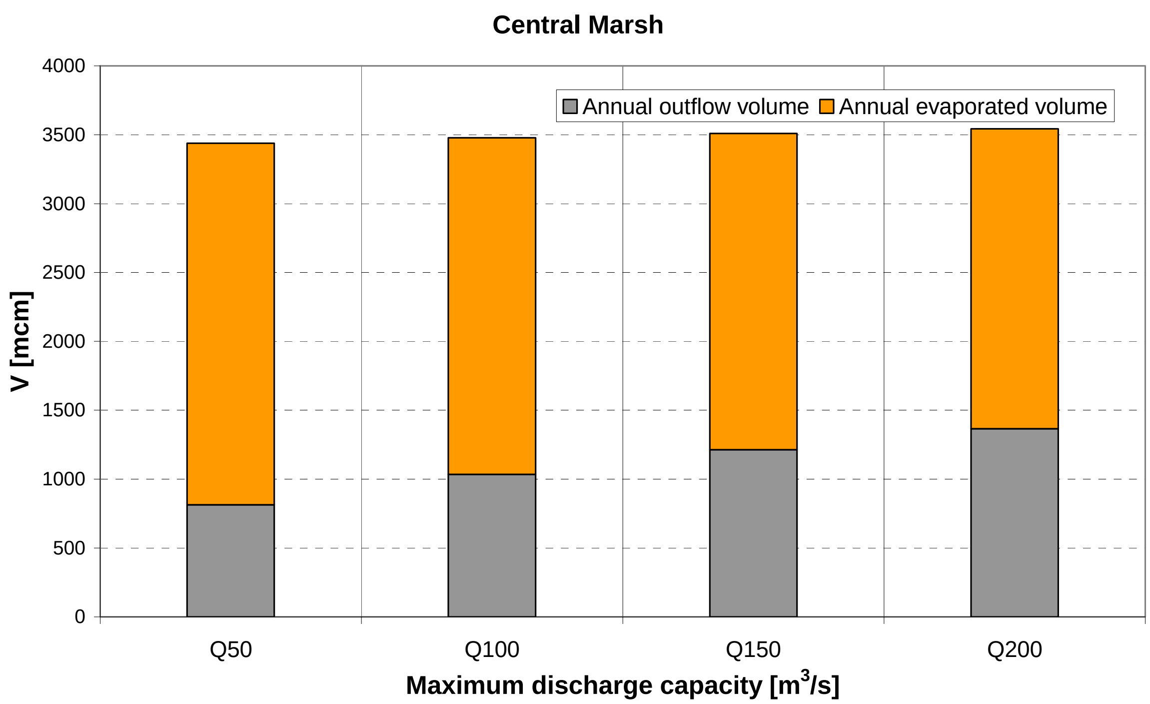


Figure 17: Annual volume balance for Central Marsh with different outlet discharge capacity

Water Control Structure Design Capacity

A standard engineering approach while designing civil structures is to size them so that they can withstand a design rare event. Such an event is typically an estimate based on an extrapolation made from historical records. Typically, in the case of the design of control structures, the design event is chosen to equal the 100-year flood events (a flood that has 1% of occurrence probability).

A general recommendation made by the Hydrology Group within the New Eden Team is that such standard practice should not be applied in southern Iraq as it would lead to a general over-design of the structures. The Tigris and Euphrates Rivers, as well as their tributaries, are today fully controlled by large reservoirs which alone could mange a 1000 and in some case even a 10000 year flood event. Water control structures for marshlands management should be sized to properly manage the flood events which each individual marshlands management plan would recommend.

Nevertheless, design events were defined for each canal and structure in southern Iraq. A reference map presented in Book 1 displays the individual discharge capacities. At the present time a review of these values is being conducted through the HEC-MoWR coordination project. Several steps are still required before the process is complete.

In the previous paragraph, some discussion was made about the opportunity to select the most appropriate size according to factors which involve not only the individual cost of the structure, but also its function and the benefit of being able to manage larger inflows and outflows.

A preliminary design of the water control structures required for the management of the marshes is discussed in greater detail in Book 8. It is standard procedure in Iraq to design control structures that are able to control 10 to 20% of the design capacity (the 100-year flood) leaving the opportunity to discharge larger flows trough emergency spillways.

Based on the results of the numerical models and the socio-economic evaluation, it is proposed that inflow structures should be able to control and operate for the following discharges:

For the Central Marshes up to 270 m^3/s

For the Hammar Marshes up to 330 m^3/s

For the Hawizhe Marshes up to 210 m^3/s

A detail discussion on the implication of such flows on the design of the water control structure for marshlands restoration is developed in Book 8.

WATER REQUIREMENTS FOR MARSHLANDS RE-FLOODING

INTRODUCTION

Based on the management methodologies discussed in the previous chapter, there is a need to clearly identify the total water volume required to re-flood different portions of the marshes. This chapter describes the results of the modeling application with respect to the water requirements for marshland re-flooding.

Significant modeling efforts were made to find the best water management conditions for each desired marshland restoration level. Graphics allowing for quick and precise estimates of the amount of water required to maintain the marshes re-flooded at the desired level were developed. The same graphs provide an indication of the average year-round flow (m^3/s) required to sustain the same chosen marshlands restoration level. By selecting a desired marshlands restoration level (% of 1970's conditions), one can evaluate the flow and volume of water required to manage the marsh under the best water management conditions.

The following graphs interpolate numerous modeling results. Each run evaluates the water required to best manage a different percentage of the marshes, from the smallest to the largest.

ABU ZIRIG

The Abu Zirig marshland was artificially divided in two parts because of the presence of an existing road on a levee that crosses it in its middle. The two basins (north and south) can have a different behaviour according to the seasonal variations of the water inflows. The two marshes are connected via two bridges on the road. In the future, it is planned that two control structures might be built to regulate flow from one marsh (north) to the other (south). Once construction is complete, then the two marshes will operate as separate water bodies and water levels might change inside each one of the marshes at different times.

For the sake of the analysis, it is assumed that a 25% of marshlands re-flooding will be met by managing approximately ½ of the North marsh, 50% recuperation will be achieved by re-flooding the entire North Abu Zirig, 75% by extending the marsh to ½ of the South Abu Zirig and 100% by filling the entire marsh inside the embankments.

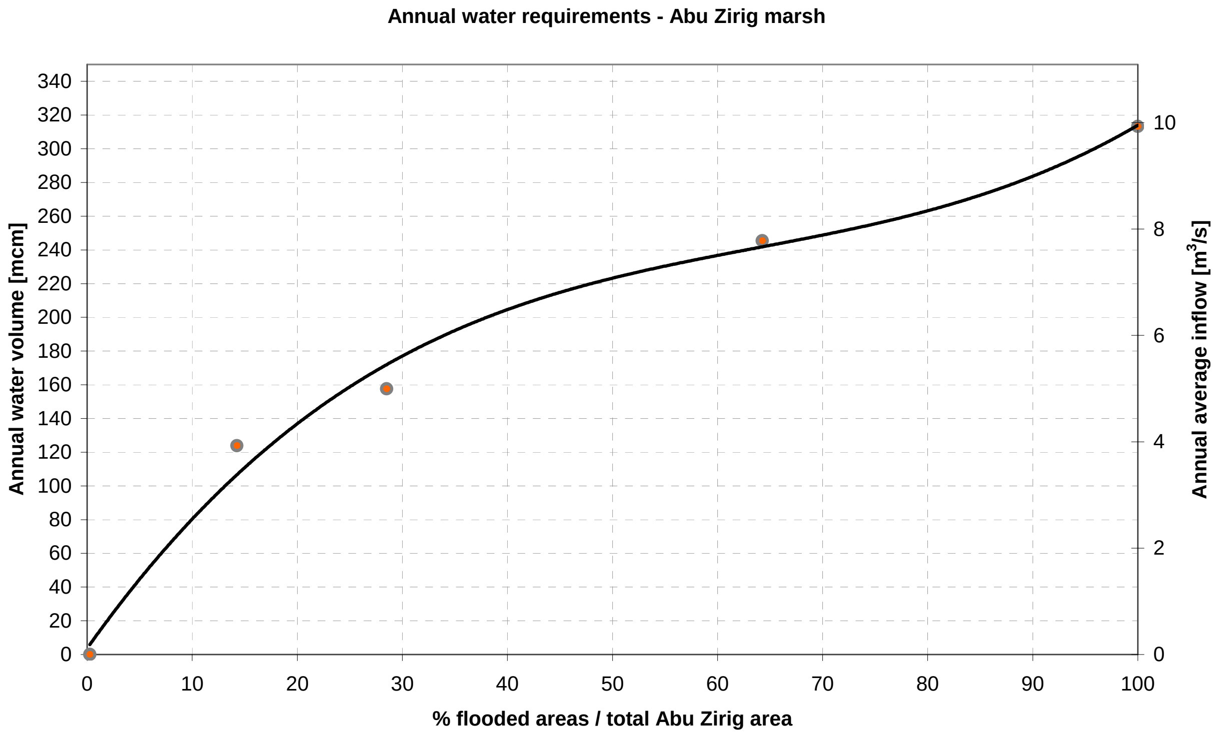


Figure 18: Annual water requirements for Abu Zirig

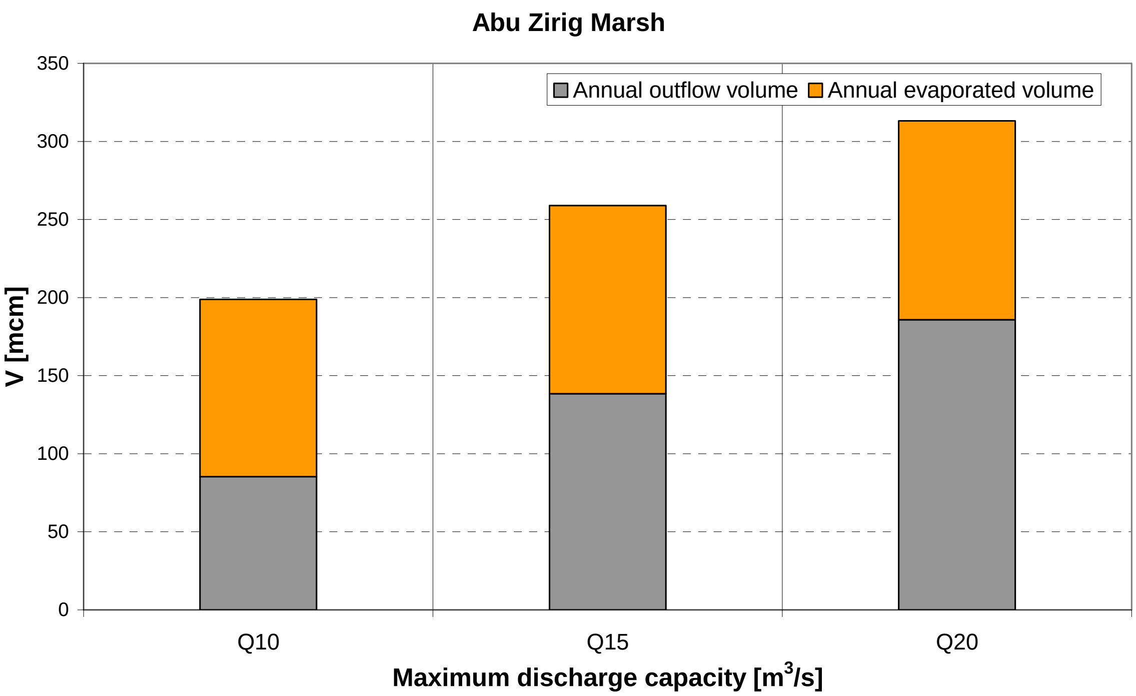


Figure 19: Annual volume balance for Abu Zirig Marsh with different outlet discharge capacity

The figure above shows that in order to re-flood 100% of Abu Zirig it is necessary to provide an average annual inflow of almost 315 MCM (equalling to a steady average inflow of 10 m^3/s for the entire year).

Abu Zirig marsh is today 100% recuperated. The New Eden Water & Energy Abu Zirig monitoring plan clearly shows that average flow in Abu Zirig is 15-20 m^3/s. The construction of the water control structures would allow for a more efficient utilization of the available water resources.

Central Marsh

The Central Marsh receives water from both the Tigris River to the north and the Euphrates River to the south. The Euphrates River is currently able to flood approximately 25% of the former 1970's conditions and large portions of the southernmost part of these wetlands are now covered by water and vegetation.

RES-SIM results are displayed in the next graph which provides indications of water volumes and average discharges required, on a yearly basis, to meet the desired marshlands restoration level. The general assumption is that, up to 25% of recovery could be achieved with only contributions from the Euphrates River. Recoveries higher then 25% are met with additional water from the Tigris River.

The figure below shows that in order to re-flood 75% of the Central Marshes it is necessary to provide an average annual inflow of about 3,600 MCM (which is equal to an instantaneous flow of 120 m^3/s).

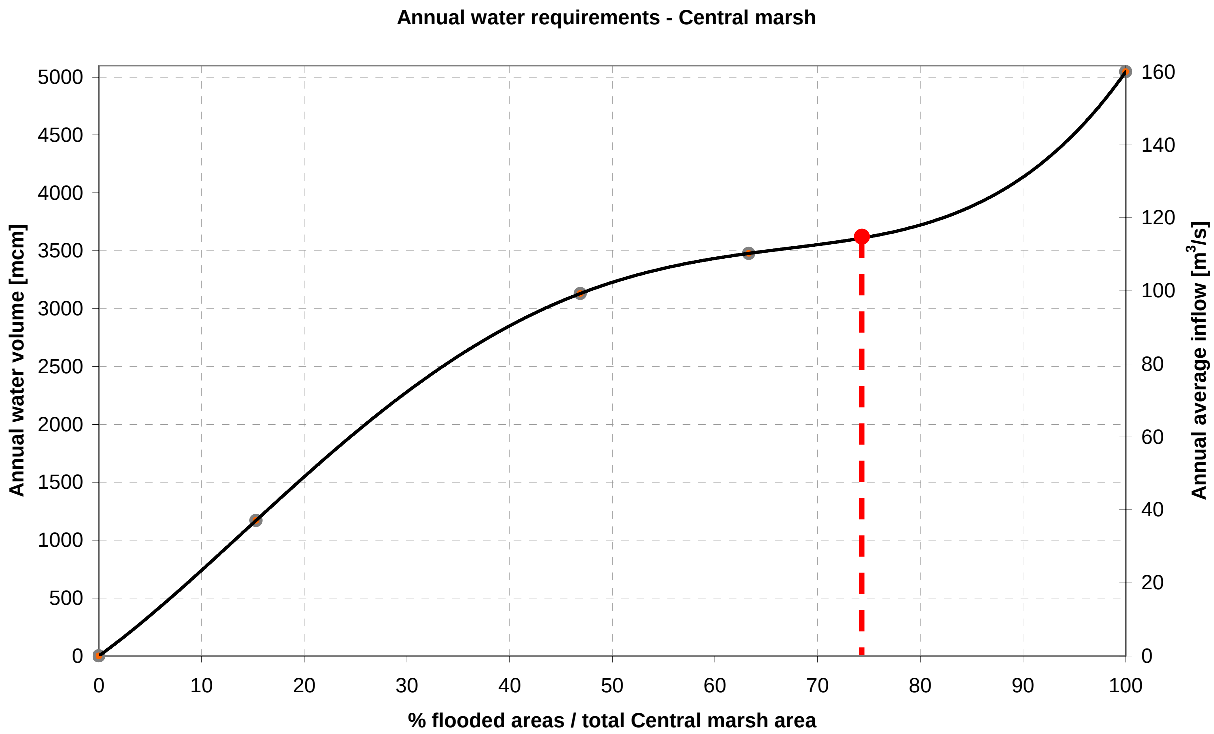


Figure 20: Annual water requirements for Central Marsh

At the same time, Figure 20 provides a comparative evaluation of water losses due to evaporation and outflow volumes for each one of the four different outflow structures taken into account considering managing a 75% re-flooding scenario. Figure 21, provides a guideline of the different flows which will have to be managed

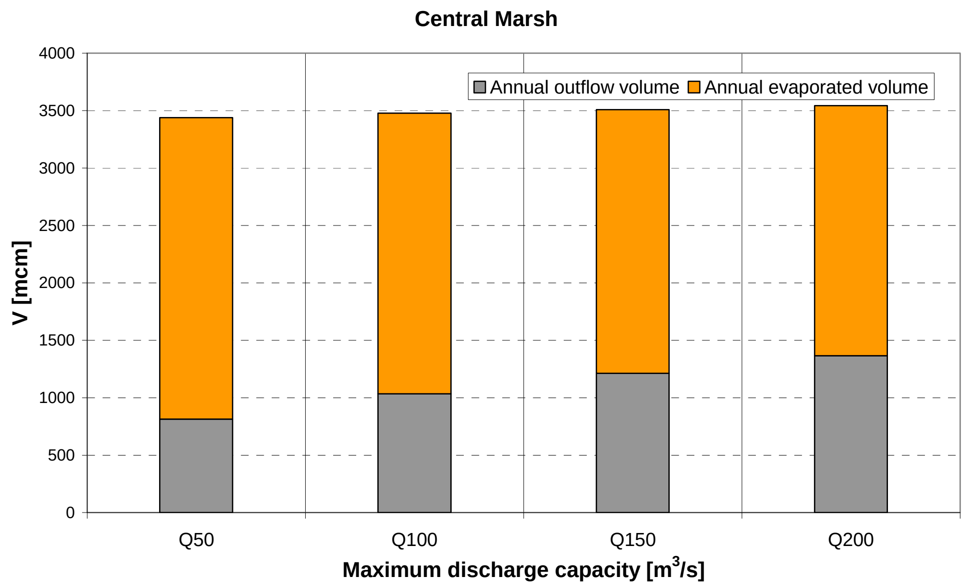


Figure 21: Annual volume balance for Central Marsh with different outlet discharge capacity

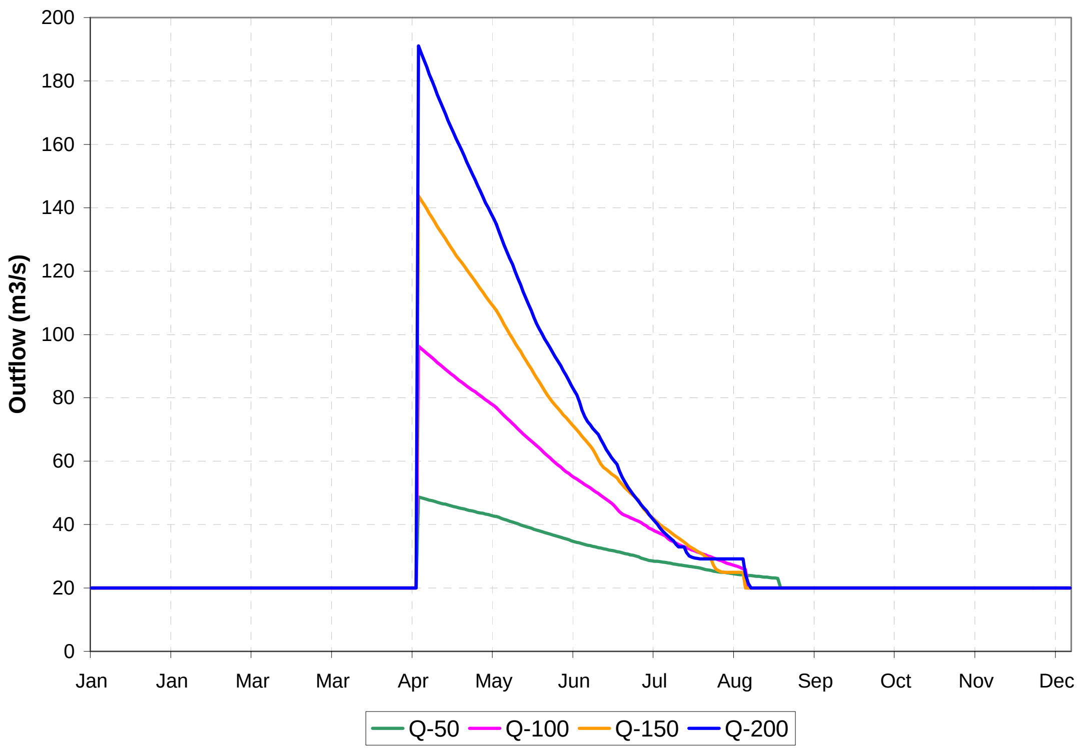


Figure 22: Outflows operations for outlets with different discharge capacity for Central Marshes

The following maps (Figure 23 and Figure 24) illustrate the minimum and maximum inundated area during the year in the Central Marsh. The outflow condition is the one that preserve the connectivity of the water flux.

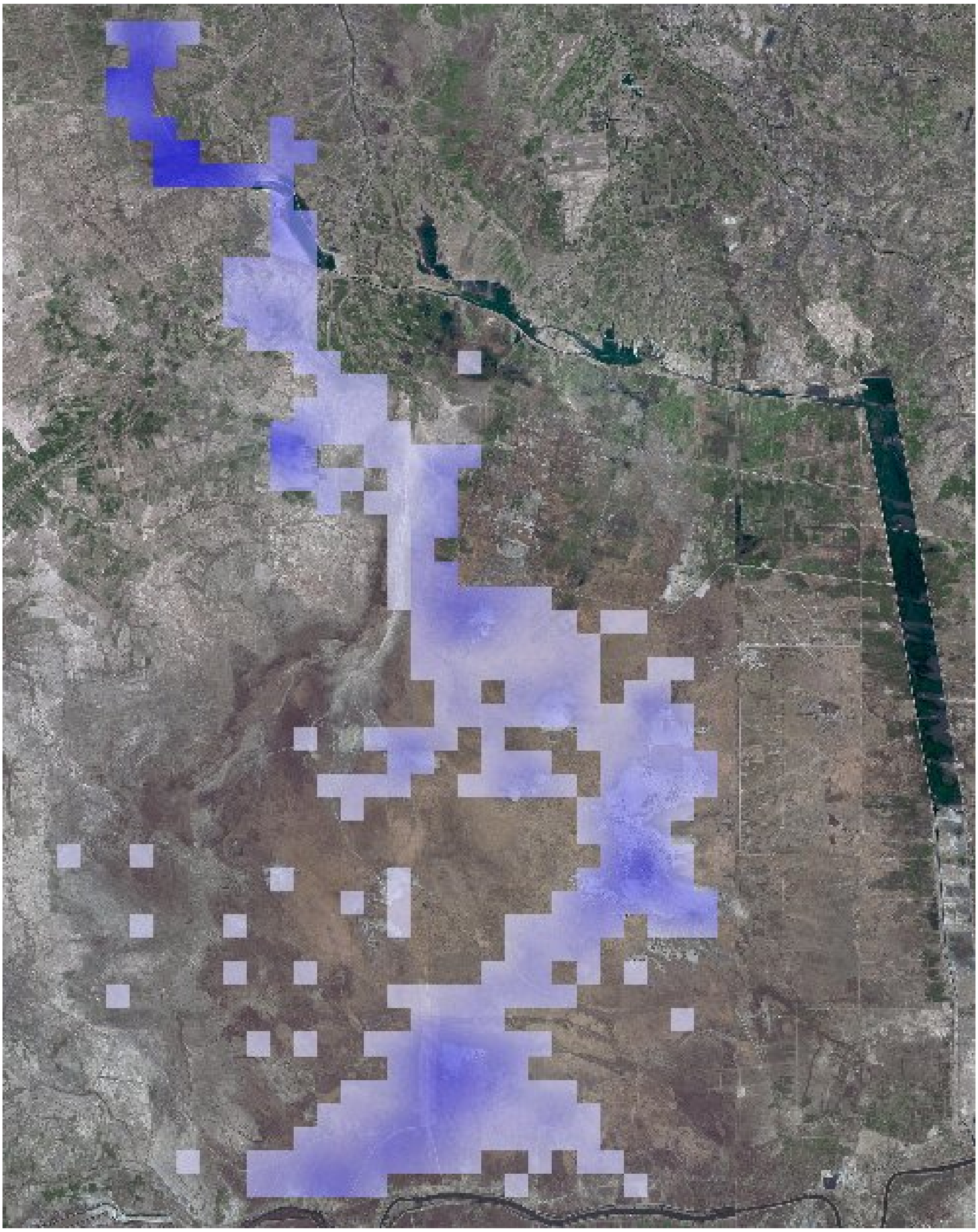


Figure 23: Re-flooding map – minimum extension for Central Marsh

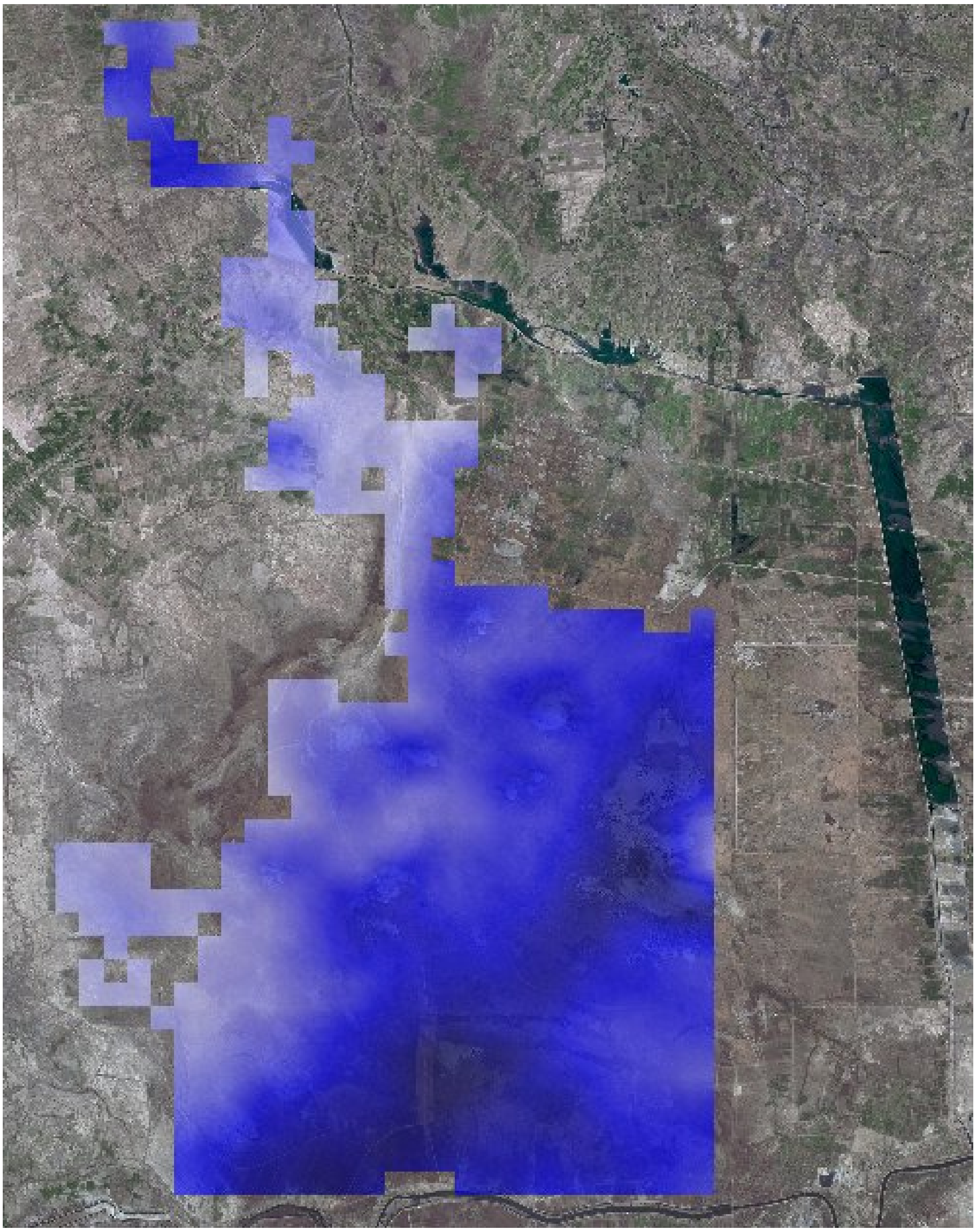


Figure 24: Re-flooding map – maximum extension for Central Marsh

Hammar Marsh

Hammar Marsh receives water both from the Euphrates upstream and from the Shatt Al Arab downstream. The area influenced by the Shatt Al Arab is the zone downstream of the Oil Bridge, that is flooded due to the tidal effect of the river. Nevertheless the analysis didn't consider that part of the Hammar Lake, in order to account just for the inflow coming from the Euphrates.

The figure below shows that in order to re-flood the 75% scenario, it is necessary to achieve an average annual inflow of about 5000 MCM (160 m³/s).

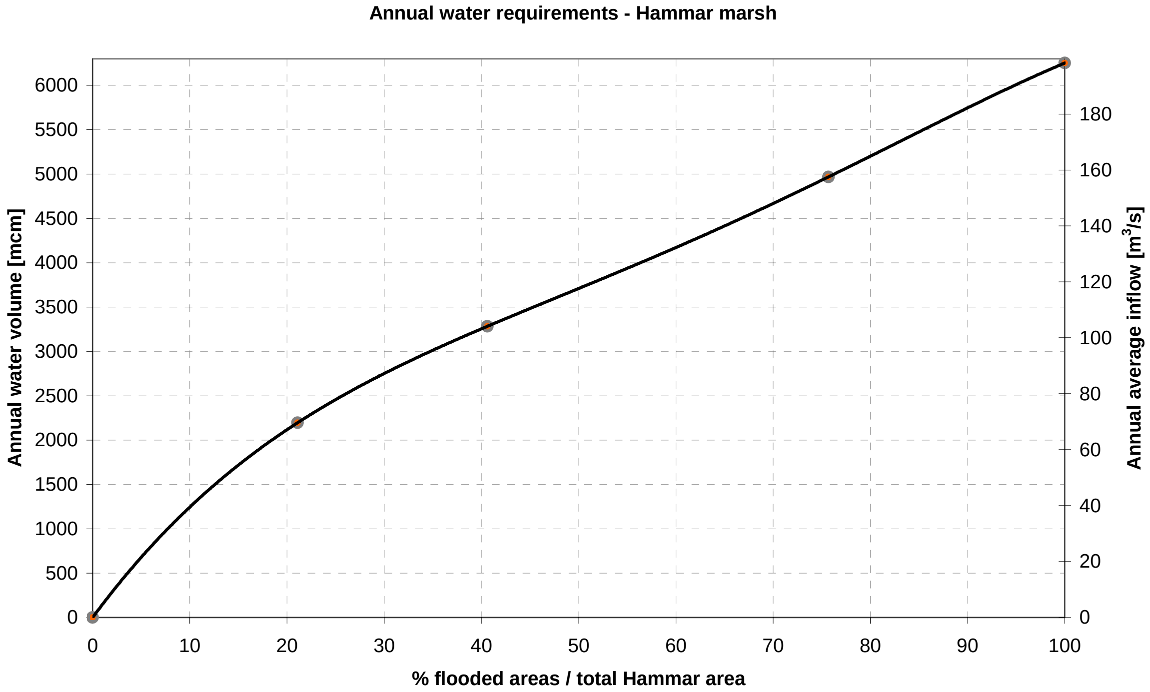


Figure 25: Annual water requirements for Hammar Marsh

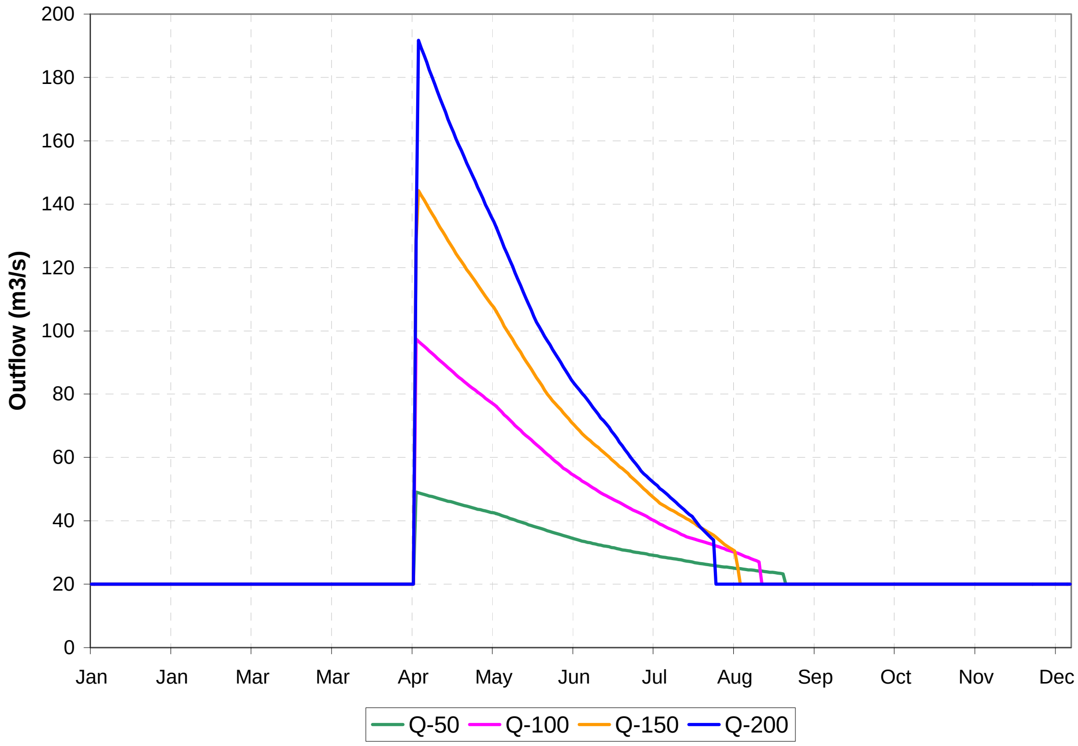


Figure 26: Outflows based on different water control structures dimensions

The following maps (Figure 27, Figure 28) illustrate the minimum and maximum inundated areas during the year in the Hammar Marsh. The outflow condition is the one that preserves the connectivity of the water flux.

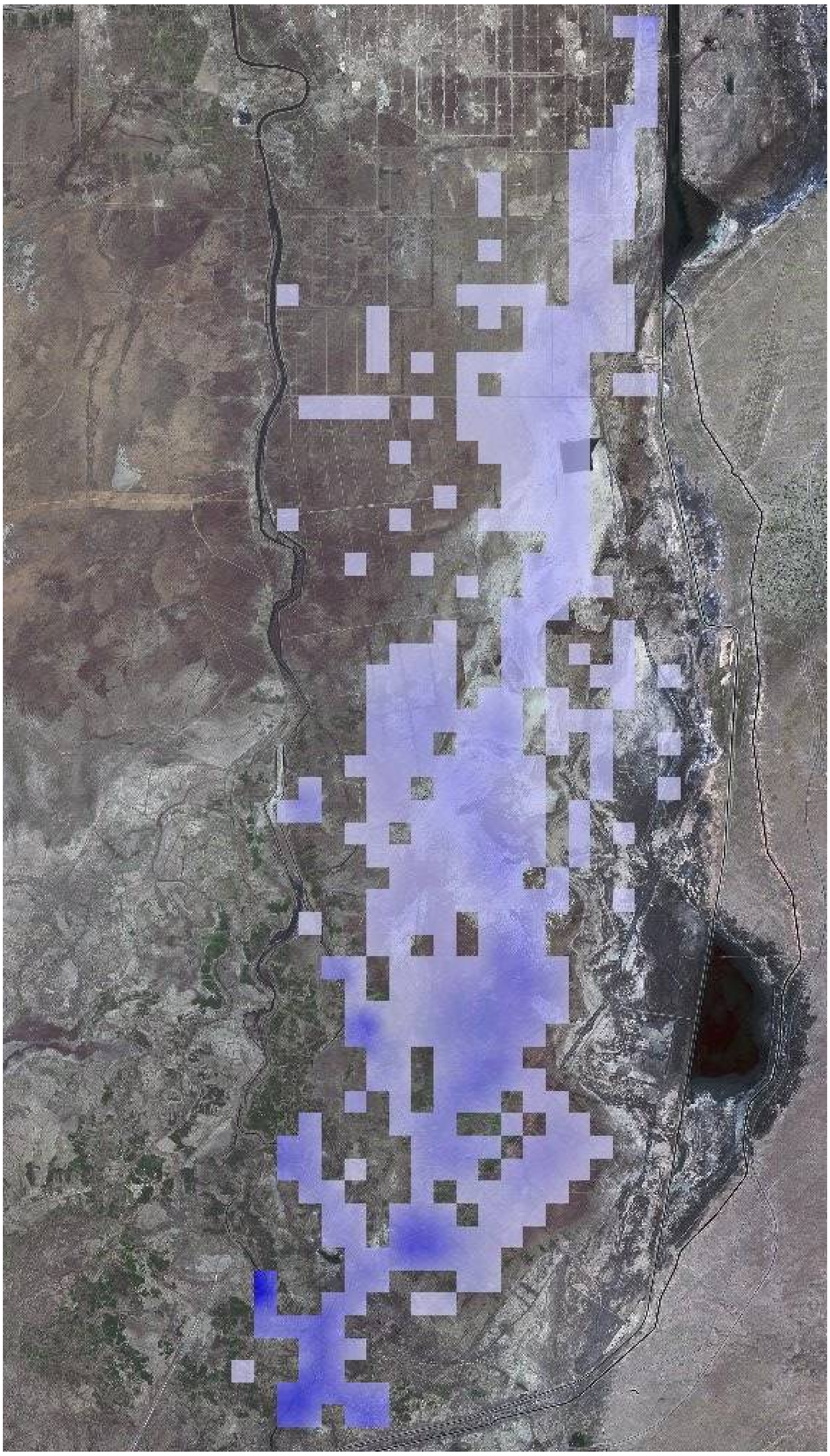


Figure 27: Re-flooding map – minimum extension for Hammar Marsh

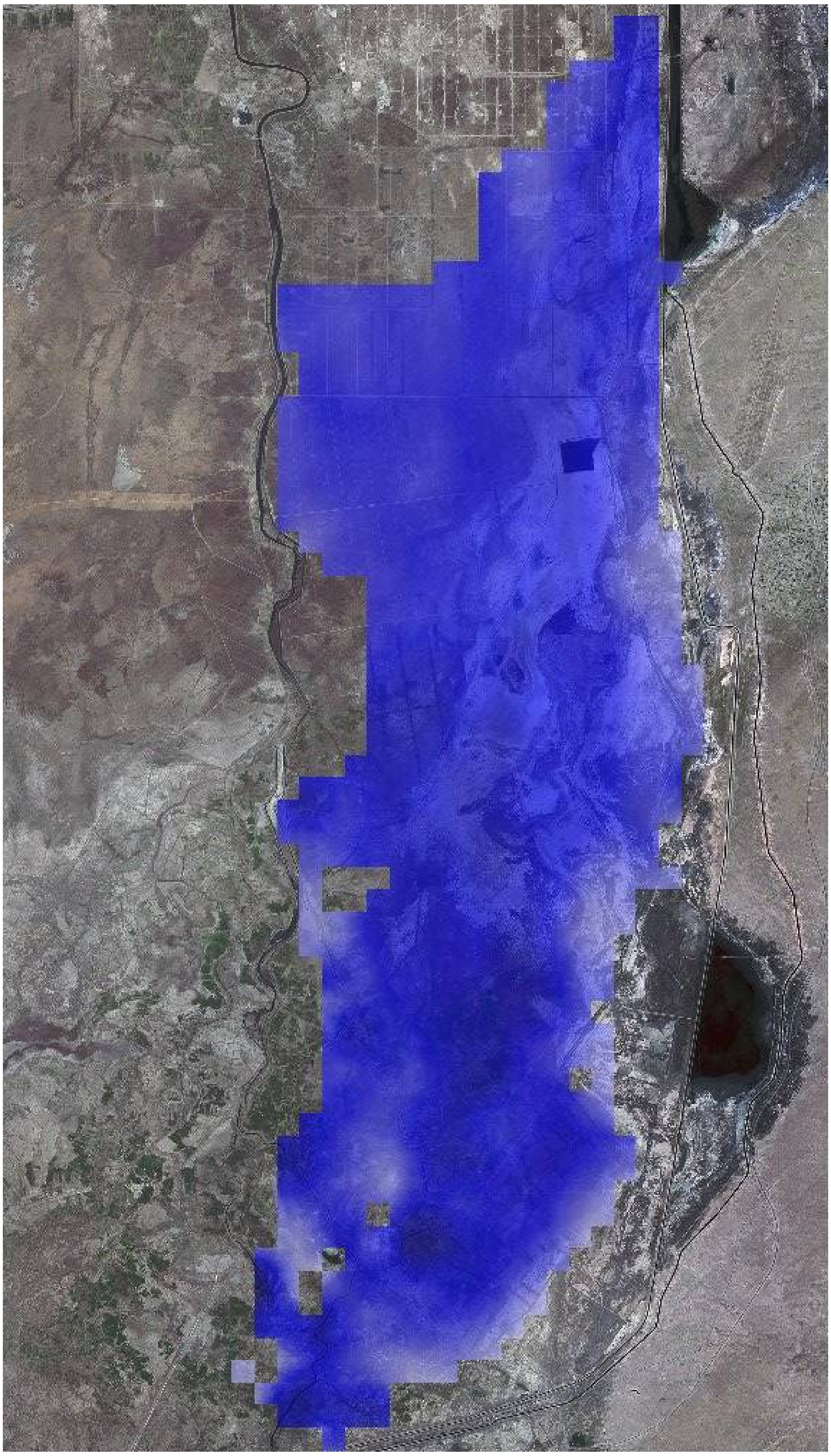


Figure 28: Re-flooding map – maximum extension for Hammar Marsh

HAWIZHE MARSHES

Hawizhe Marsh receives water from the Tigris River, and, from the Iranian side, from the Karkheh River. During the period in which the marshes had their minimum extent, Hawizhe was maintained due to the water inflow from the Iranian side. However, even if the Karkheh inflow were enough to reflood Hawizhe, it would be better to have an Iraqi inflow for the health and stability of the marsh, and for establishing environmental conditions as natural as possible: the only Karkheh inflow would cause an asymmetry in the flow distribution inside the wetland. The Karkheh inflow data comes directly from the Iranian study "Azadegan Environmental Baseline Study", January 2004, Iran.

Irrigation developments in the Karkheh River Project in the Azadegan Plain, as well as plains in the upstream reaches, would affect both quality, quantity, timing and distribution of the water supplied to the marsh. Regulators in the Karkheh Storage Dam, and releases according to the irrigation requirements, would change the natural regime of the river flow. The future inflows from the Karkheh River into the marsh with the irrigation developments were estimated in the study; these values were considered in the Hawizhe model.

With respect to the outlets, there are two points where the flow comes out of the system: Kassarah river and Swaib river, the first is in the central part of the marsh and the second in the southern part of the marsh.

The figure below shows the Iraqi water requirement from the Tigris River system; in order to reflood the 75% scenario it is necessary to achieve an average annual inflow of about 2400 MCM (75 m^3/s).

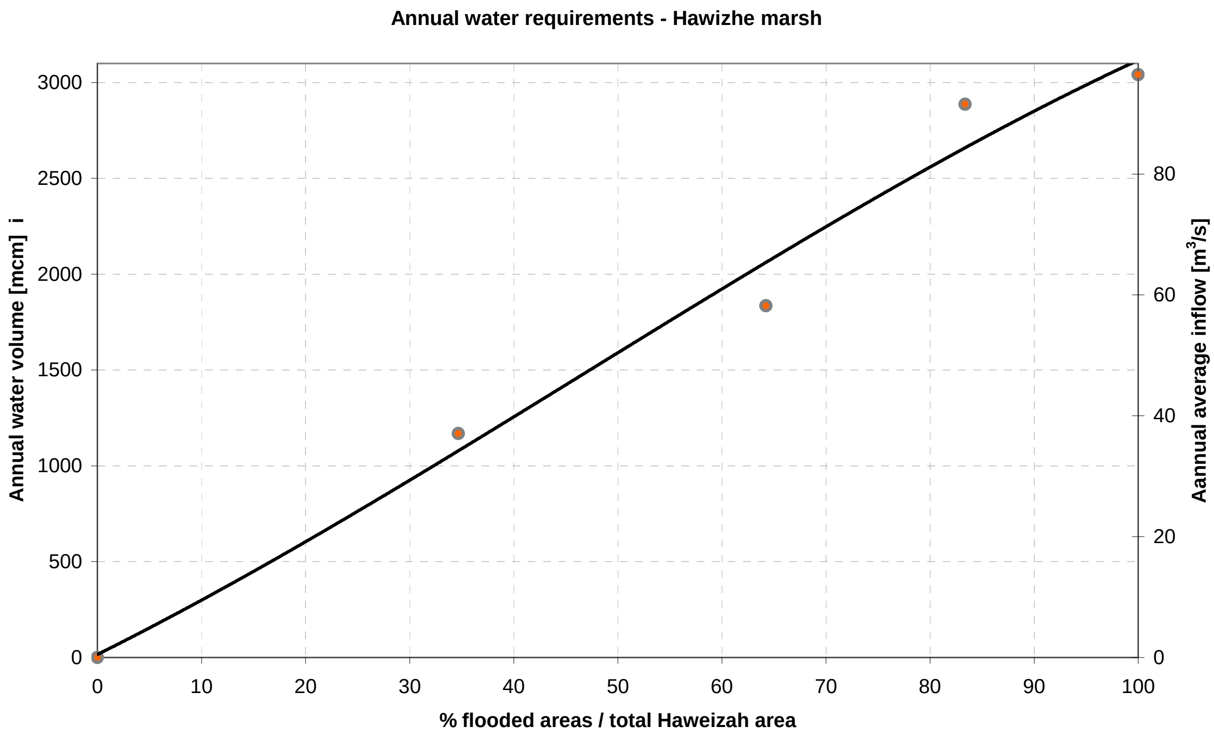


Figure 29: Annual water requirements for Hawizhe Marshes

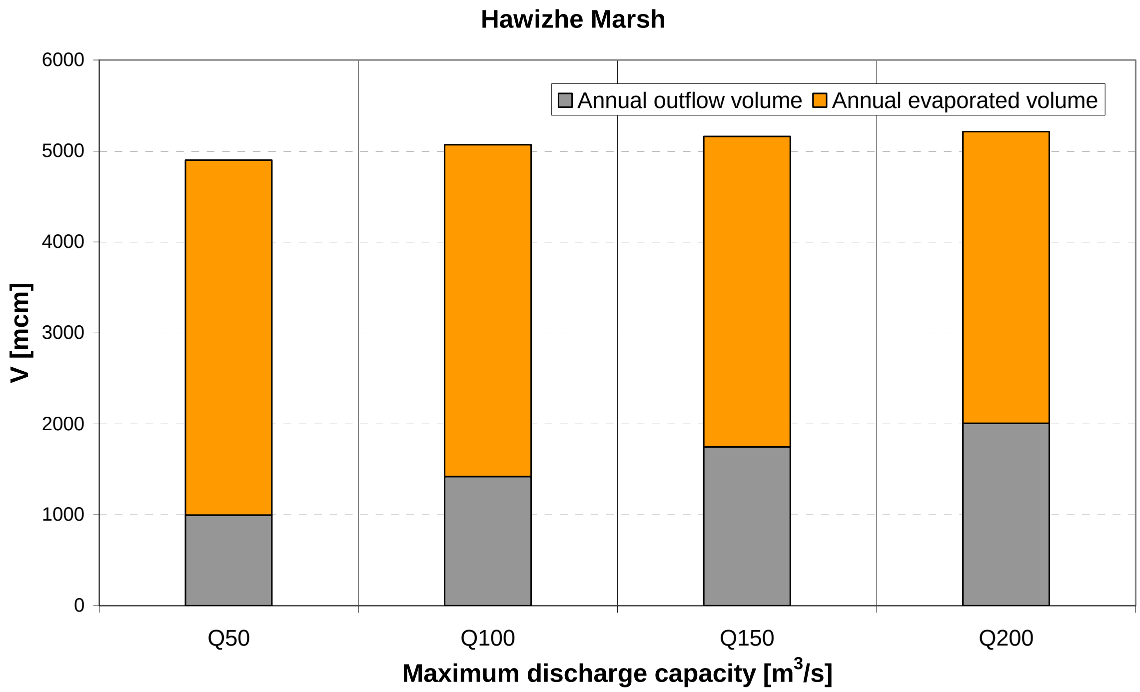


Figure 30: Annual volume balance for Hawizhe Marsh with different outlet discharge capacity

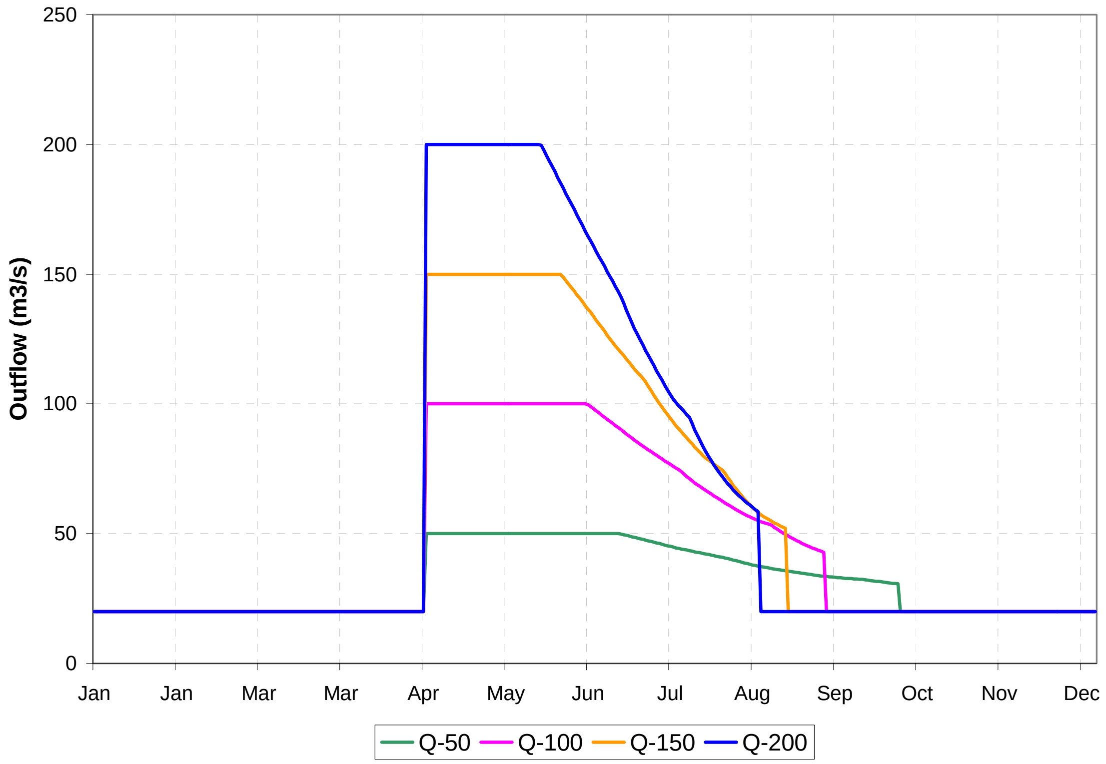


Figure 31: Outflows operations for outlets with different discharge capacity for Hawizhe Marshes

The following maps (Figure 32 and Figure 33) illustrate the minimum and maximum inundated areas during the year in the Central Marsh.

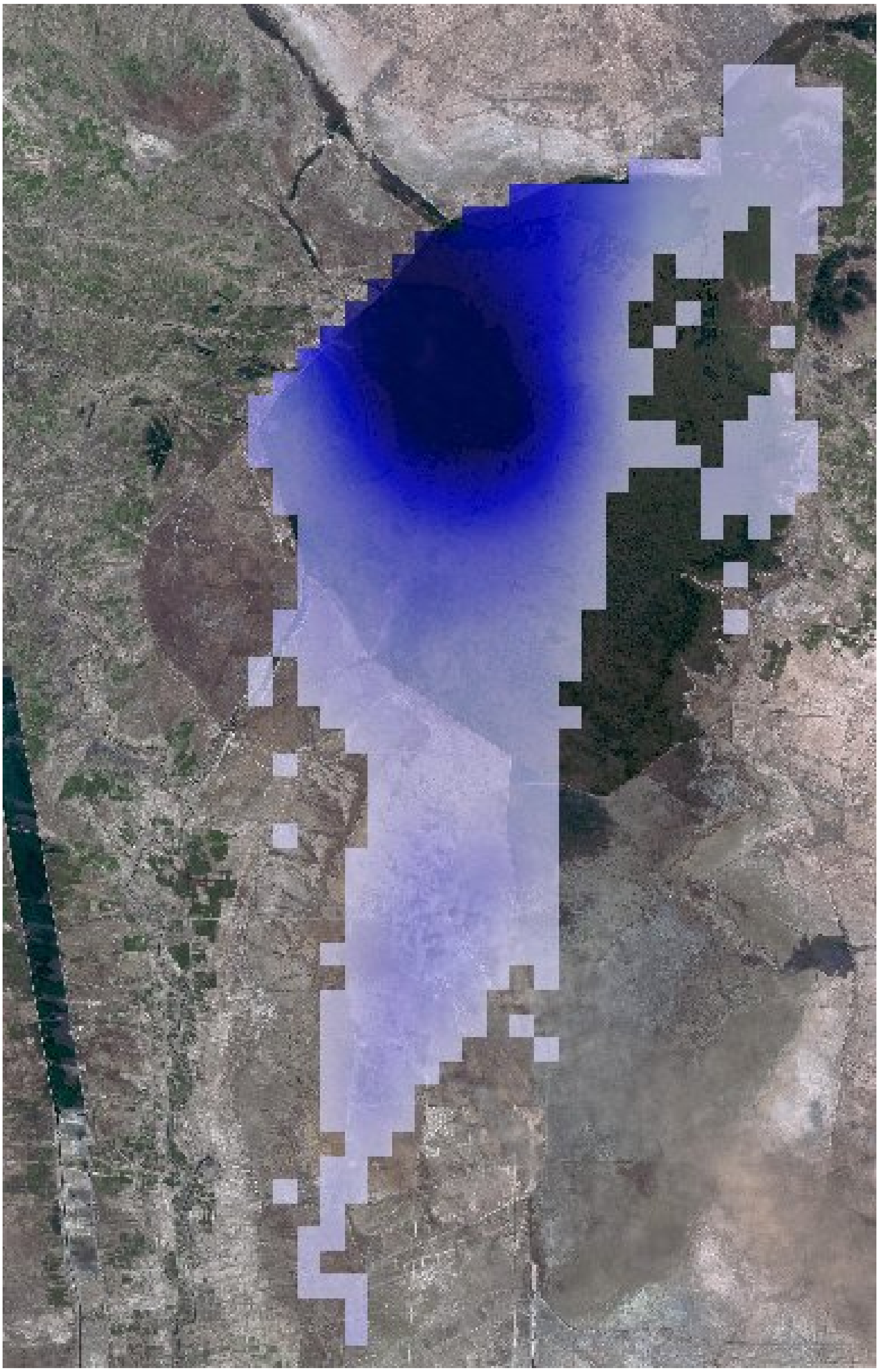


Figure 32: Re-flooding map – minimum extension for Hawizhe Marshes

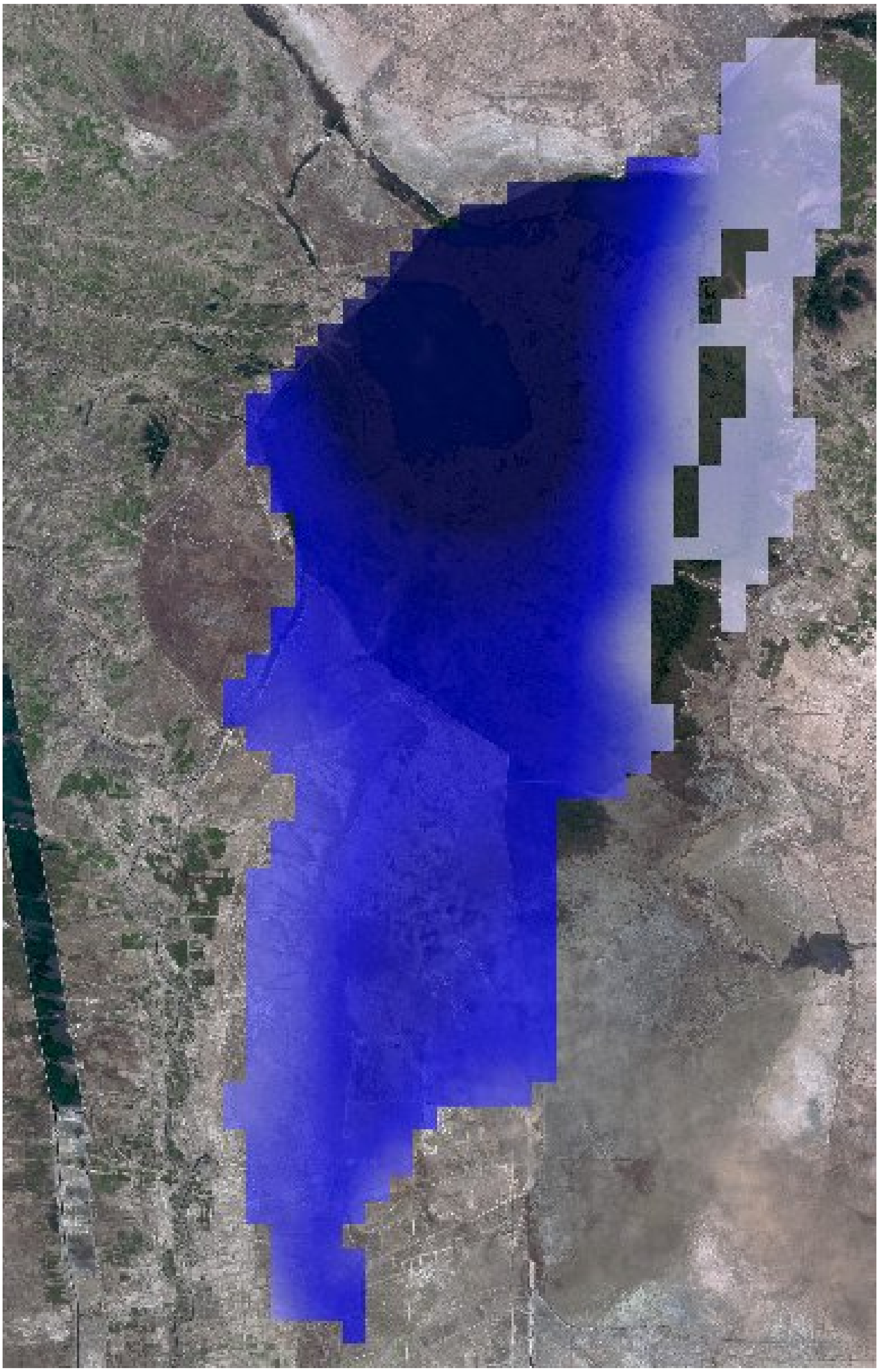


Figure 33: Re-flooding map – maximum extension for Hawizhe Marsh

CONCLUSIONS

Global re-flooding percentages can be obtained considering a many combinations given by different restoration scenarios per each marsh. The choice of one percentage or another depends on the physical and socio-economic constraints of the areas. Complete (100%) re-flooding can be obtained only by re-flooding 100% of every single marsh; to the contrary, achieving 75% total re-flooding can be obtained considering, for example, re-flooding 100% of the Hammar plus 85% of Hawizhe plus 50% of Abu Zirig and 40% of Central Marsh; or as another example 100% of Hammar, 35% of Hawizhe, 100% of Abu Zirig, and 100% of Central Marsh, and so on.

The image below, which provides an indication of the annual water requirements for all the marshes and for all possible re-flooding lever, was obtained by performing a considerable number of numerical simulations each one providing a different combination of marshland restoration level (the result of each simulation is represented by a dot in the graph).

The result is an easily-utilized plot (Figure 34) that provides an indication of the average year-round flow (m^3/s) and volume (MCM) required to sustain the chosen level of marshlands restoration. The estimation is average as it represents yearly water allocation values. Ultimately, water diverted to the marshes will have to be changed almost on a monthly bases: some months high flows will be required whereas, during some other months, flow might have to be reduced to almost zero.

ANNEX I presents all these results organized per marsh and per month. In fact, in order to obtain the 75% re-flooding scenario, it would be necessary to achieve an average annual inflow of about 11,000 MCM (350 m^3/s); that's an average value, and some months requires much more water, some much less. Thus the chose of the re-flooding scenario must be aware of what happens during each month, in order to check the actual necessary peak inflow.

During winter months, the requirements are much higher than in summer months. Figure 35 and Figure 36 show the water requirements for winter and summer. Under the hydrological point of view, winter is considered to cover the period from December to May, while summer is considered to cover the period from June to November.

The plots show that winter requirements are about five times higher than summer requirements.

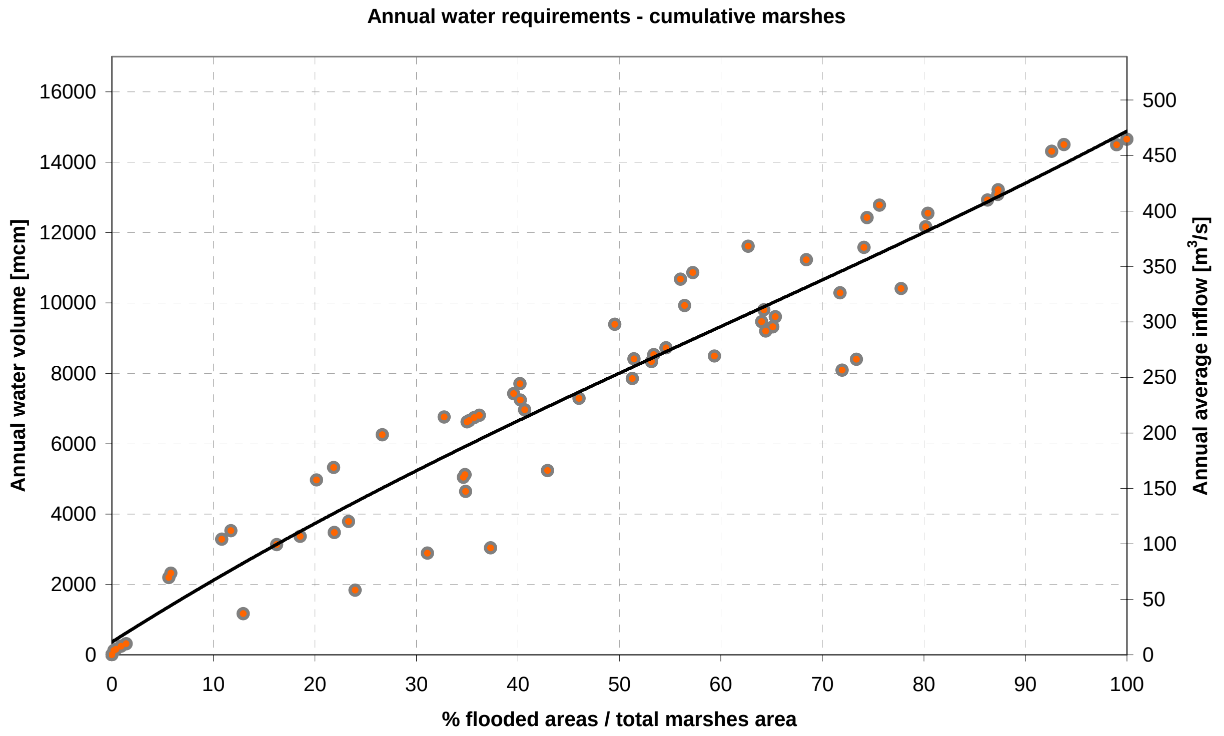


Figure 34: Annual water requirements for all marshes

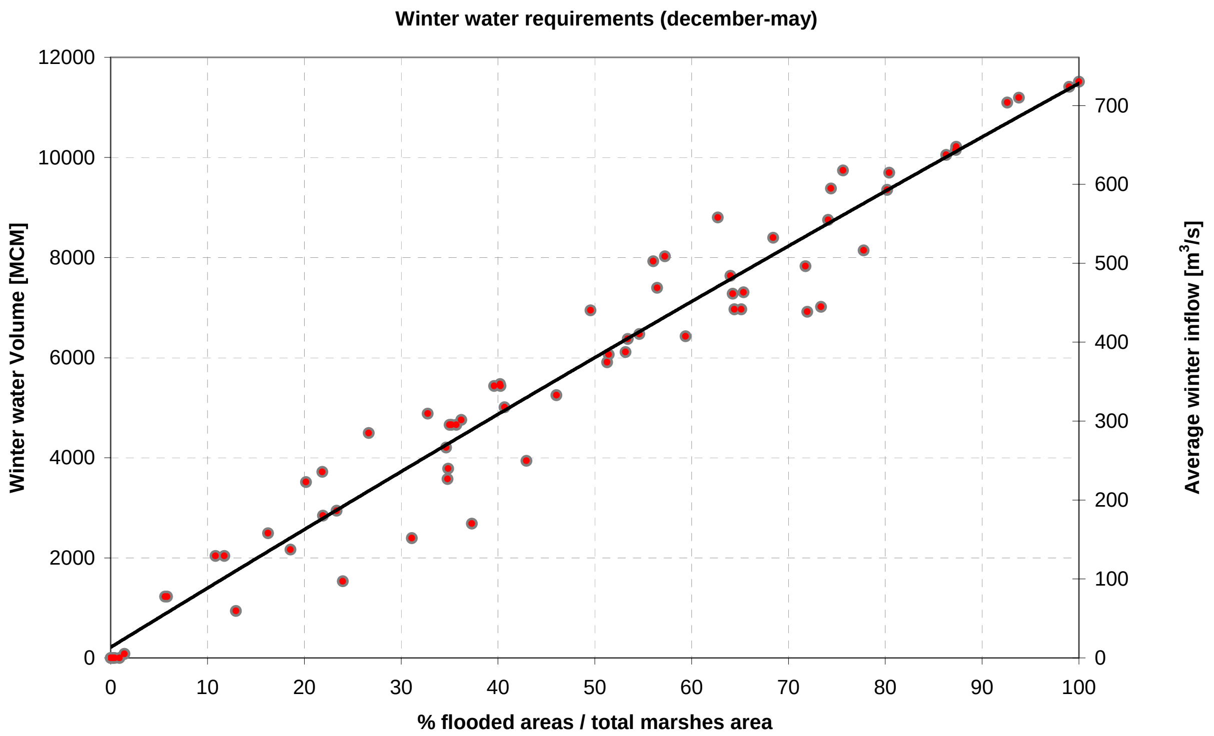


Figure 35: Winter water requirements for all marshes

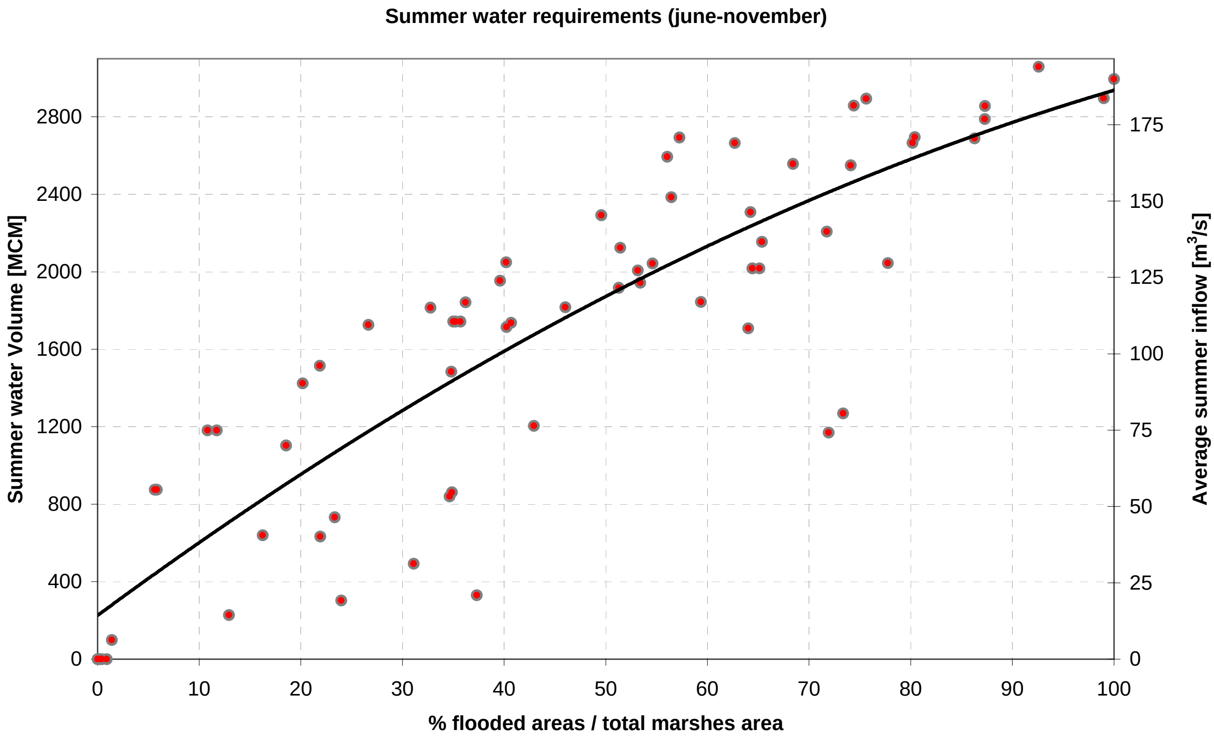


Figure 36: Summer water requirements for all marshes

It is interesting to compare the calculated annual water requirements with the average flow available in the main rivers of the basin (Figure 37, Figure 38, Figure 39).

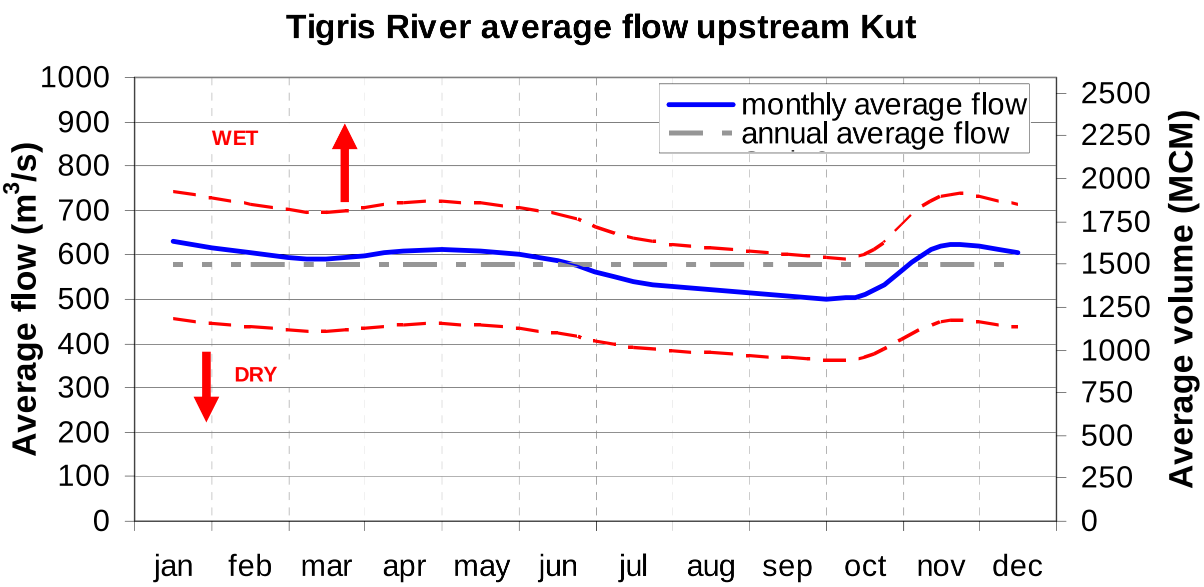


Figure 37: Tigris average flow

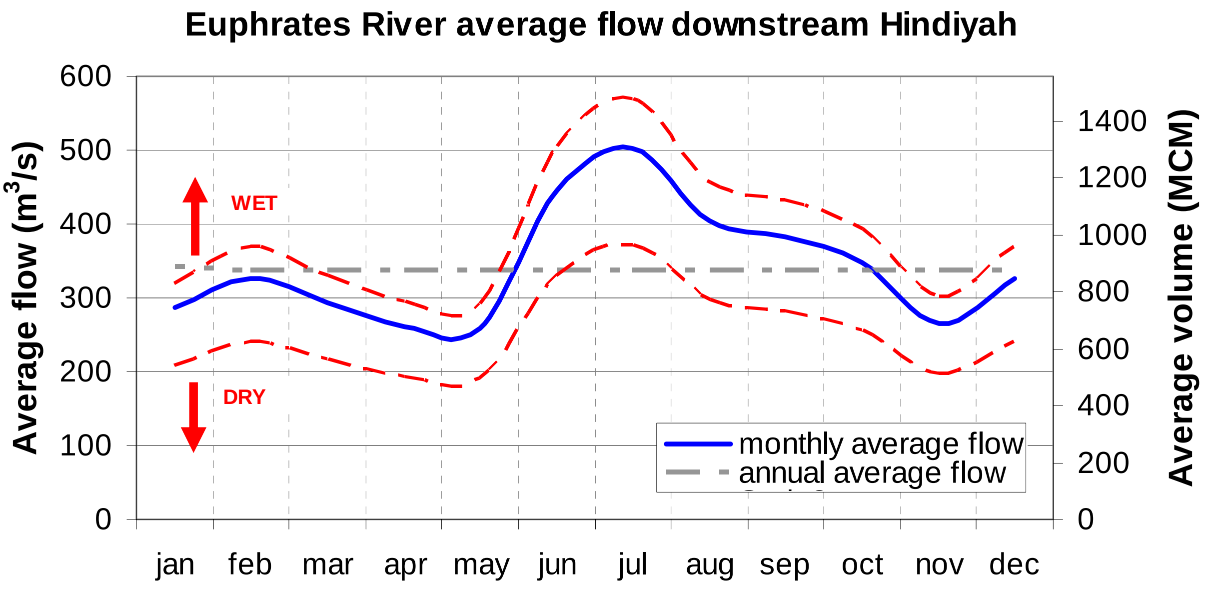


Figure 38: Euphrates average flow

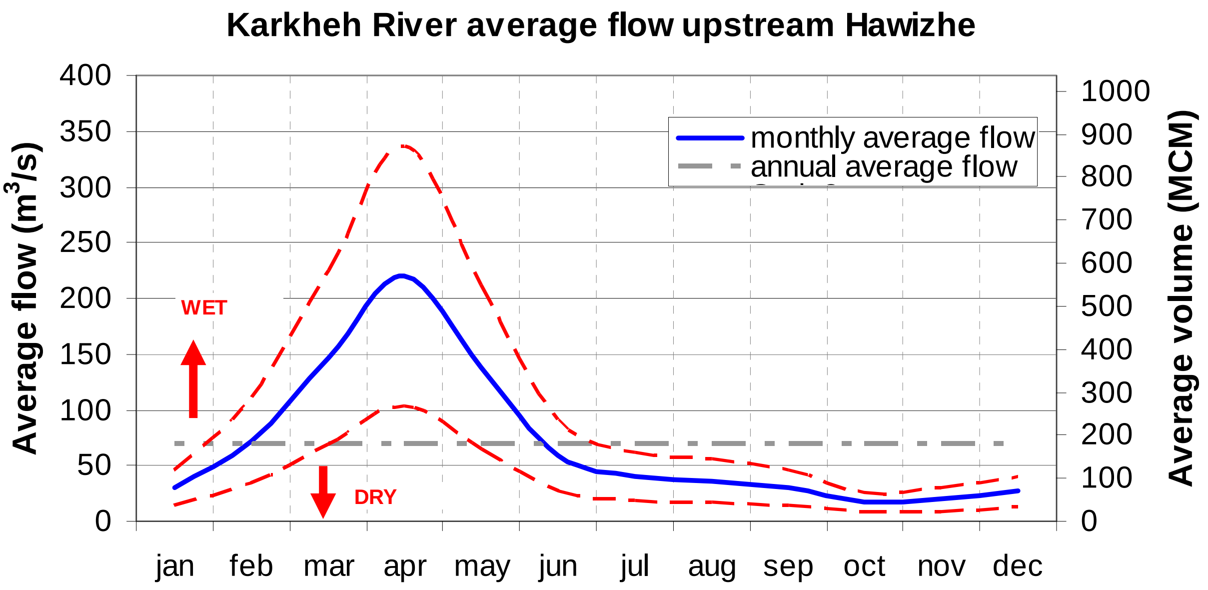


Figure 39: Karkheh average flow

The images illustrate the monthly average flow, the annual average flow, and the monthly average flow for typical wet and dry years.

Tigris flow refers to Kut and Euphrates to Hindiyah; as a consequence the flow in the images doesn't represent available water for marshes, bur it still keeps into account water for irrigation projects and for other purposes. Karkheh flow, on the contrary, is the flow directly entering Hawizhe, and it is water available for that marsh.

Starting from this base point, if we sum up the average flow for the three rivers we obtain about 950 m^3/s, that is almost twice the required flow necessary for the 100% re-flooding scenario. Again, it is not very consistent considering the annual average flow; but if we look at the sum of dry year average flow we obtain about 700 m^3/s, that is still twice the required flow for the 75%.

It is very difficult to verify the real feasibility of the proposed water allocation layout; it is highly linked to the purpose of the water resources and to the priorities in the socio-economic scenario. There is a conflict between marshes, agriculture and navigational uses of water, that can be solved partly with socio-economic evaluation and partly with political decisions.

It must be stressed that the system developed to to study the water requirements for marshlands re-flooding is strictly based on the target curve that describes the ideal water depth variation during one year. That curve was obtained starting from Hawizhe measurements, and slightly modified in order to consider water availability and evaporation time restrictions. It must be considered as an example of possible target curve, and for this reason the important aspect is the 2 meters change in water depth rather than the variation during all the year; that is to say that the re-flooding of the marshes doesn't imply that the water depth variation follows exactly the target curve.

It is interesting to notice that a marsh filled with water with no outflow gets emptied in about one year, or near to the minimum water depth, just by evaporation.

These considerations lead to the fact that during one year, the management of the marshes must not be absolutely related to the target curve. The water depth in the marsh can keep staying high or low for long periods of time, depending on the available flow: if there is a flood it is necessary to store as much water as possible in the marshes; on the contrary if there is a drought, the marshes can be fed just by the available water. Under this point of view the marshlands management must be done according to the hydrological regime.

Definitely the target curve gives an indication of at least one possible management method that can be modified or adjusted in relation to the available water and to the actual marshland environmental conditions.

EXAMPLES OF APPLICATION OF THE NEW EDEN TOOL

INTRODUCTION

Most of the information described in the New Eden Master Plan provides background data to decision makers while developing their strategies for marshlands management. Book 1 describes key information to assess available water resources in the marshlands area, Book 3 summarizes the water demand for agriculture according to present as well as past development plans, Book 5 presents the various mathematical models available for the study. Most of the information provided within this Book (Book 6) is meant to define the best strategy for marshlands management. The information such in Books 2 and 4 allow for a more comprehensive delineation of the context in which best practices in marshlands management should be developed.

Overall, the system of information and numerical models defined within the New Eden Master Plan created a basis for decision makers to which we generally refer as to the "New Eden Tool" (NET).

The application of the concepts and methodologies of the NET are not by any means a straightforward exercise, and in several other places in these books it was clearly stated that the NET does not provide solutions but methodologies: final results will greatly depend on the set of assumptions that only the Iraqi decision makers and stakeholders will ultimately define. These assumptions, on the other hand, are subject to change and the application of NET and the delineation of new solutions will always be an interactive and open process.

Nevertheless, many of the assumptions made while developing NET are based on solid scientific evidences. As a consequence, it is possible to apply NET on some test case scenarios which are useful not only because they provide example as to the application of various methodologies and tools, but also because they provide some guidelines which we hope might be helpful to decision makers at the present time.

In the following pages, four case studies are presented. Each case starts by making an assumption as to what extent agriculture and navigation should be developed in the south of Iraq. Once these figures are selected, the application of the socio-economic model provides two basic answers:

1. In the first place the model provides a clear indication of the percentage of marshlands that can be restored.

2. Once agriculture, navigation, and marshlands restoration levels are clearly identified, then the model allows for a simple comparison between the relative benefits associated to each one of the three main water sectors (Agriculture, Navigation, Marshlands) at any given time of the hydrological cycle in Southern Mesopotamia (summer and winter season for both "wet", "normal" and "dry" years). The comparison is simplified as all benefits are presented in the form of a monetary value.

The socio-economic model is a tool that, in the absence of constraint will typically allocate the maximum benefit to that water sector that provides maximum socio-economic return. The model will do that without questioning the sustainability of the proposed solution. Technical speaking, this process is called "unconstrained maximization".

In the specific case of southern Iraq, the unconstrained maximization of the overall net benefits suggests for example that no water should be allocated to agriculture during droughts seasons and all water should go first to sustain navigation first and marshlands second. The result of the model is evident if we acknowledge that in today's conditions, agriculture in southern Iraq provides almost no market profit and requires strong intervention at a national level in order to supply products of primary dietary importance from elsewhere. Nevertheless, it is clear that a constraint should be applied to the socio-economic model as it is not sustainable that agriculture disappears during droughts, or millions of people in southern Iraq will end up without a job during periods of water shortages.

Four case studies

Based on the above observation, the following four case studies discuss the various opportunities for best water resources allocation in southern Iraq, assuming that agriculture must exist regardless of the contingent climatic conditions. The four case studies are developed as follows:

1. The long-run navigation project as a possible objective and a minimum allocation of water to agriculture as a constraint, assumed to be at least 25% of the water required to implement its plan;
2. The short-run navigation project as a possible objective and a minimum allocation of water to agriculture as a constraint, assumed to be at least 25% of the water required to implement its plan;
3. The long-run navigation project as a possible objective and a minimum allocation of water to agriculture as a constraint, assumed to be at least 37.50% of the water required to implement its plan;
4. No navigation project as a possible objective and a minimum allocation of water to agriculture as a constraint, assumed to be at least 25% of the water required to implement its plan;

It should be noted that most of the assumptions made while developing these study cases are clearly defined elsewhere in the New Eden Master Plan and we strongly encourage the reader to review relevant chapters in both Books 1, 3 and 5.

At this time it might be helpful to recall that:

- "Short" and "Long Term Navigation Projects" refers to the investments which will be required if commercial navigation is developed along the Euphrates River. "Short" term investment will enable the desired navigation development if a flow of 250 m^3/s is guaranteed 95% of the time of the year along the Euphrates River. On the other hand, "Long" term investment would enable the same navigation output with only 100 m^3/s of flow guaranteed 95% of the time along the River. Navigation along the Tigris is considered to have a smaller impact on the economy. Shatt al Arab navigational development is not considered as it is not directly related to the marshlands.
- Although a clear relation between past-planned agriculture and today's output does not exists, several indicators seem to suggest that today's agro-production is approximately one fourth of the one which was planned in 1980's whereas water utilization is three-to-four times higher then expected (i.e. southern Iraq utilizes today most of the water which was planned to produce four times more crop's yield then the one which is declared today). For all these reasons and for the sake of simplification of the analysis, it is assumed that an agro-production of 25% of the one proposed in the Russian Master Plan will be roughly equals today's yields. At the same time, 25% of agricultural development is assumed to be the minimum required to sustain employment in southern Iraq. Furthermore it is assumed that, whatever level of agriculture will be developed in southern Iraq, such a goal will be met by employing clear Water Utilization Efficiency (WUE) strategies (see Book 3 for more details).
- A minimum sanitary flow along the Shatt Al Arab is assumed to be equal to 150 m^3/s (4,730 million of cubic meter per year). Such flow is always ensured if "long term" navigation is developed and/or if more then 50% of marshlands recovery is achieved.

Following the above mentioned assumptions, it is possible to simplify the four case studies as follows:

- CASE 1 - Long-run navigation / Agriculture at its status quo
- CASE 2 - Short-run navigation / Agriculture at its status quo
- CASE 3 - Long-run navigation / Agriculture 150%ts status quo
- CASE 4 - No navigation / Agriculture at its status quo

It should be noted that in all cases results will be biased in favor of agriculture. Indeed, first we did not consider production costs in agriculture, although these are likely to be negligible, due to its subsistence nature: hence, considering revenues, rather than profits, will over-value the benefits arising from the water allocated to agriculture. Second, we used an average per capita income for city inhabitants of 0.947 MIQD obtained with a microeconomic approach, while its assessment with a macroeconomic approach is around 5.1 MIQD: hence, the water allocated to marshlands, depending also on the willingness to pay for its restoration by Iraqi people, here represented by city inhabitants, will be under-valued, with respect to water allocated to agriculture. Third, we considered not only structural costs, but also management costs from now on, for both marshland extension and navigation projects: hence, subtracting these costs from current returns will under-value the benefits arising from the water allocated to marshlands and navigation.

CASE 1 - LONG-RUN NAVIGATION / AGRICULTURE AT ITS STATUS QUO

Generalities

The case study attempts an evaluation of the benefits associated with a water allocation strategy where:

- Navigation on the Euphrates River is met by making long term investments which will radically change the infrastructure along the river and will be able to minimize water requirements for navigation. Infrastructures and investments follow the 1986 SOGREA Navigation Project. Cost and benefits associated with the project have been year marketed.
- Agricultural production is kept at a minimum of at least 25% (i.e. agriculture yield with equal today's conditions, water allocation for agriculture will reduced at one fourth) of the Past-planned yields. Water consumption for agriculture is assumed to not exceed the past-planned irrigation efficiency.

Socio-Economic Evaluations

Based on the water allocation assumptions, the socio-economic model provided the following results:

	WINTER			SUMMER		
	Agriculture	Marshland	Navigation	Agriculture	Marshland	Navigation
DRY YEARS						
Water allocated to(MCM)	1,589	3,484	1,577	3,226	1,821	1,577
Total values (MIQD)	107,160	-1,408,350	70,759,383	63,339	1,400,250	70,759,383
Marshland extension (%)		**23.7%**			**68.6%**	
Agriculture extension (%)	**25.0%**			**25.0%**		
NORMAL YEARS						
Water allocated to (MCM)	1,589	10,640	1,577	7,917	2,461	1,577
Total values (MIQD)	107,160	1,754,480	70,759,383	291,982	3,362,700	70,759,383
Marshland extension (%)		**74.3%**			**100.0%**	
Direct value		220,663			297,030	
Water quality		987			1,328	
Flood abatement		111			149	
Storm buffering		887			1,193	
Carbon sequestration		26,849			36,141	
Willingness To Pay		1,969,980			3,491,860	
Total costs		465,000			465,000	
Agriculture extension (%)	**25.0%**			**61.4%**		
Average yield (MIQD/Ha)	1.027			1.583		
WET YEARS						
Water allocated to (MCM)	6,358	14,135	1,577	12,904	2,461	1,577
Total values (MIQD)	885,436	3,363,950	70,759,383	522,942	3,362,700	70,759,383
Marshland extension (%)		**100.0%**			**100.0%**	
Agriculture extension (%)	**100.0%**			**100.0%**		

Table 2 – Economical benefits associated with CASE 1

While reading the results from the socio-economic model it should be kept in mind that:

- In the case of a reduction of the marshland extent to size smaller then 41% (which represents the average size of the marshes at the time this report is published), then the Iraqi population, should be compensated for the loss of the marsh.
- The amount of water allocated to marshlands during the summer season aims to maintain them while balancing water losses due to evaporation and seepage.
- Transportation of freight through navigation used to be a very popular approach in the 1970's and 80's. Nowadays, although numbers clearly show its relative importance if compared to other water utilizations, the Government of Iraq, as many other government around the world have done, might decide to play down its role.
- The considerable high net value associated with navigation might be largely affected by two factors: (1) the 1986 studies overestimated the socio-economic development of southern Iraq for the year 2000, thus making the proposed investments less worthy then anticipated, and (2) the net benefit for navigation might be largely affected by the factor which was chosen for the Iraqi currency actualization (1 ID (1980's) = 5, 000 ID (in 2006)). This value was the average proposed by the World Bank and United Nation but it might well be lower.
- The general willingness of the population of the three governorates of Missan, Thi-Quar and Basrah to pay for restoration of the marshlands, is a benefit of an order of magnitude larger than any other one associated with the restoration of the marshes

The marshland's recovery which best represents the result for each case study is the one we might obtain during the winter season of a "normal" year. A "Normal" year is indeed the most frequent one whereas flood and drought represents somehow "extreme" events which do not influence the everyday management of the marshes. Moreover, the winter season is the time when marshes can efficiently augment their size. This second interpretation of the result must be carefully addressed. Indeed, it should be noted that the socio-economic model is just a first step in the NET approach and provides only a mathematical interpretation of the various physical conditions. The socio-economic model "does not know" the strategy for best water management in the marshes, a step which NET approach provides in a subsequent phase. Such a strategy clearly defines the mechanisms for best marshland management in such a way that less water is routed into the marshes during the warmest months. All the socio-economic model sees is that water is available during summer and for that reason attempts to use all of it within the marshes. The alternative should be to store that water upstream and make a better use of it during winter/spring time.

The numerical results from the socio-economic model allow the following conclusions to be drawn:

- Water allocated to agriculture has the least worth, due to the current irrigation systems (affecting the water use per Hectare) and the current production systems (affecting the crop yields per Hectare)
- Water allocated to navigation has the most worth
- Water allocated to marshlands is less worth than navigation and more than agriculture

- Water availability does not represent a constraint in wet years

Hydrological Sustainability

The socio-economic model provides guidelines for water utilization strategies. The subsequent step in the NET approach must verify the sustainability of the proposed water allocation scenarios. This step is easily achieved by referring to a series of tables and graphs developed within this Master Plan and described early in other sections of this book as well as Book 1 and Book 3.

Table 2, shows that for CASE 1 and with the water resources available in the marshlands region, it is possible to sustain today's agriculture outputs as well as "long run" navigation objectives and, at the same time, recuperate ~75% of the 1970's marshland's extension. During "wet" seasons, marshes could expand to their 1970's conditions whereas, during extended period of draughts, they would recede back to 24% of the 1970's figures. Clearly, marshes would be able to expand beyond 75% only if embankments, roads, agriculture and oil fields were removed.

The graph depicted in Figure 40 (already proposed and discussed in Figure 34 in this book), allows for moving the first step out of the socio-economical model: the red line shows the proposed solution. Approximately 11 billion cubic meters of water would be required, on an average year, to sustain the marshes. The average flow would be 350 m³/s. From this point on it is clear that several alternative exists on how to re-flood 75% of marshes: we could, for example, attempt to recover 65% of Hawizhe, 80% of Hammar and 80% of the Central Marshes and 100% of Abu Zirig but any other such combination would be possibly equally sustainable.

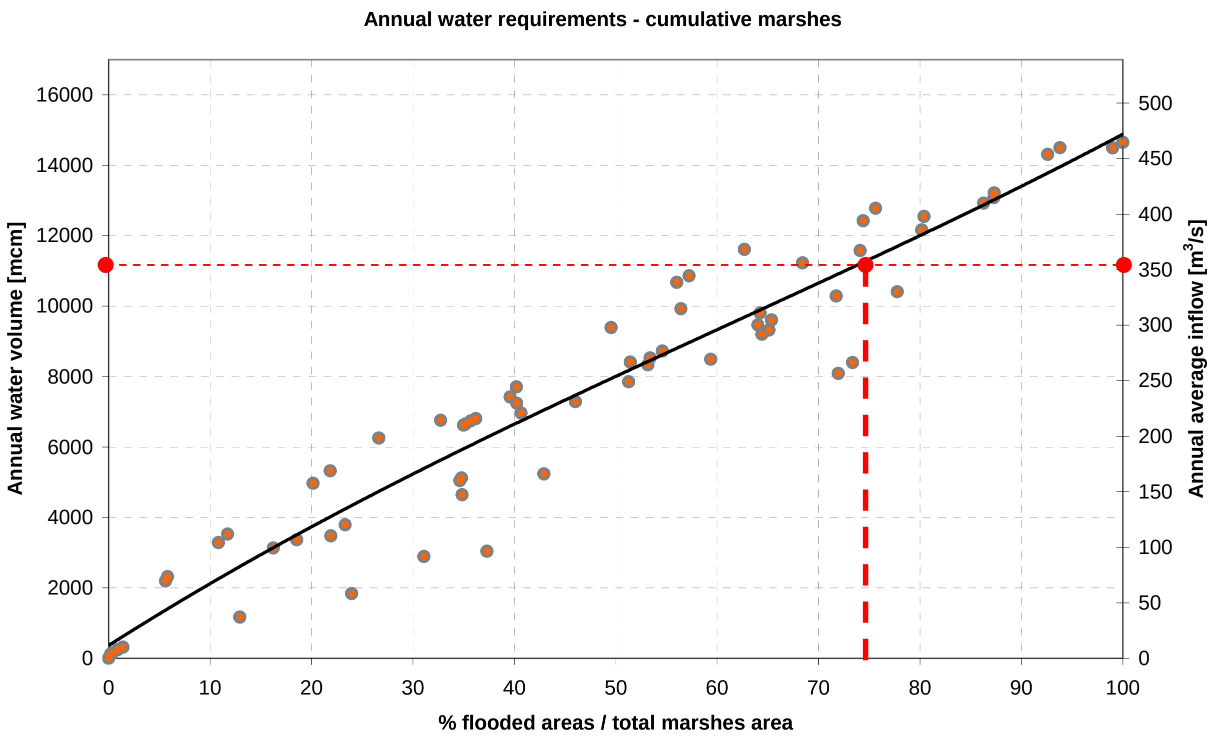


Figure 40: Annual water requirements for all marshes

At the end of December 2005, according to the UNEP survey, marshes covered 3,774 km² of land, accounting for more then 42% of recovery of the 1973 baseline (8,926 km² inside Iraq). Hammar covering 1,368 km² (2,729 km² being the 1973-76 condition), Hawizhe 1,640 km² (3,076 km² being the 1973-76 extent) and Qurna Marshes 766 km² (3,121 km² being the 1973-76 extent) including approximately 100 km² of Abu Zirig marshes.

For the sake of this example, it is assumed that Iraq might decide to target the 75% average recovery level according to the distribution proposed in the following Table 3

	1973-76 conditions	Dec-05	Today's % of 1973 Conditions	Proposed	
	Kmq	Kmq	%	%	Kmq
Qurna	3,021	666	22%	80%	2,417
Azu Zirig	100	100	100%	100%	100
Hawizhe	3,076	1,640	53%	65%	1,999
Hammar	2,729	1,368	50%	80%	2,183
TOTAL	8,926	3,774	42.28%	75%	6,699

Table 3: Proposed recovery to achieve the CASE 1 recommendations

In order to do so, it will be necessary that, during normal years, the maximum extent of Hammar Marshes in winter should cover 80% of its former area. To achieve this result, inflow varies according to the best practice approaches proposed by NET models. In the example, the peak inflow for Hammar Marshes is reached in January. Graphs like the following one are presented for each month of the year for each one of the four marshes. To estimate the peak flow requirements in January, it is necessary to specify the desired marsh's recovery level (80% in this case). The peak flow discharge is automatically provided and it equals 350 m³/s.

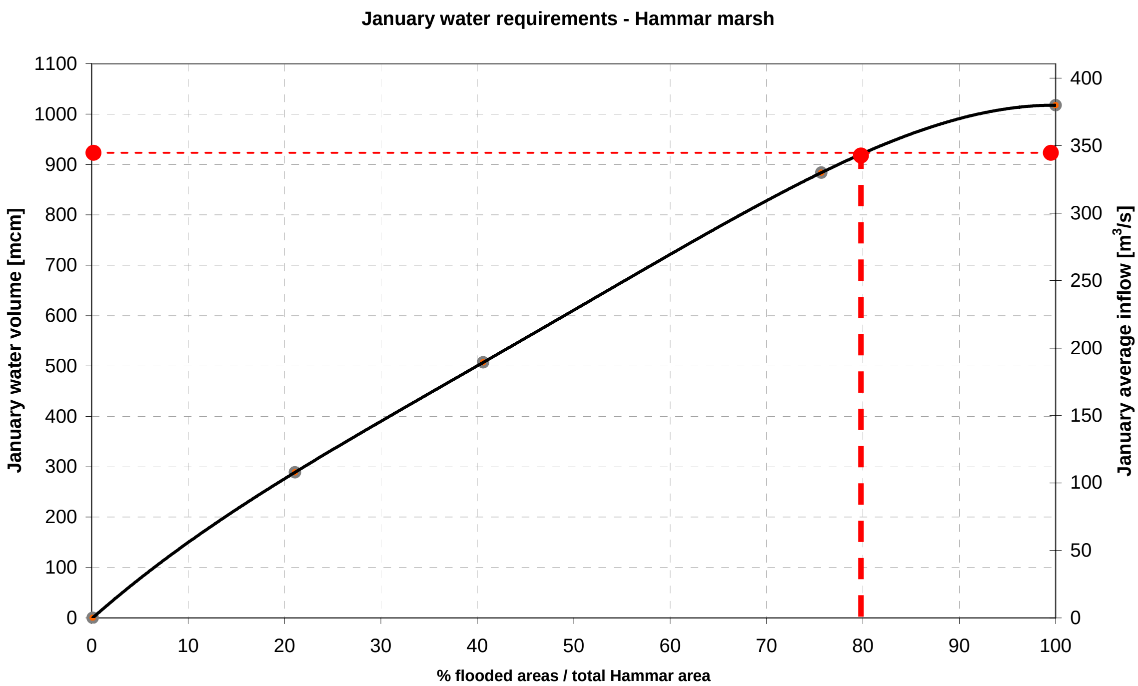


Figure 41: March water requirements for Hammar Marsh

Finally, it is necessary to evaluate if the appropriate design conditions exist to provide and discharge such a flow into the marshes. Nowadays, water into Hammar Marshes is mostly provided by the Euphrates River.

Graphs such as the one reported in Figure 38 and hereafter repeated in Figure 42, allows the quick estimation of the hydrological sustainability of the required flow. In this case, it is clear that a peak flow of 350 m^3/s in January is not available in today's conditions: the following graphs shows average flows measured in the past 15 year downstream Hindiyah barrage, a location way upstream of the Hammar Marshes. From the control point at Hindiyah to Hammar Marsh's inlets there are several large agriculture fields. Consequently, the available peak flows depicted in the following graph are significantly reduced prior to reaching the marshes.

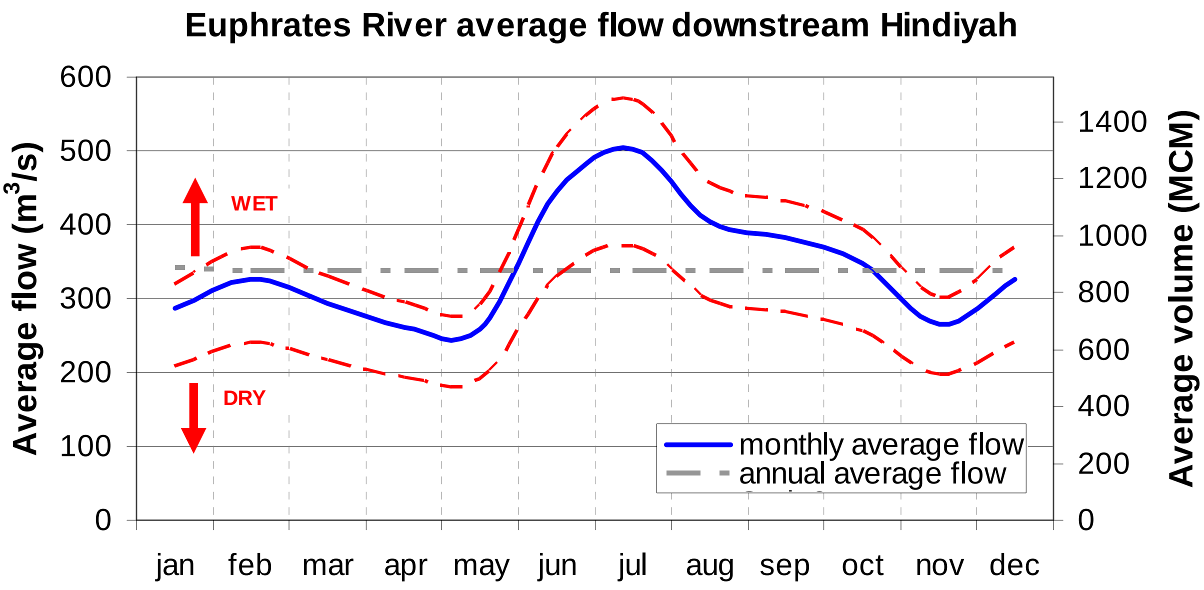


Figure 42: Euphrates average flow

Nevertheless, it is important to notice that adequate volumes of water are indeed available to sustain each recommendation made in CASE 1: the only problem is that, in today's conditions, they are not adequately distributed during the year.

Based on the water allocation requirements expressed in CASE study 1, and counting only on the water available today in southern Iraq, it is possible to conclude that:

- An average 75% of marshlands recovery would be sustainable most of the time. Marshes would be significantly reduced during summer time and during droughts. During wet years, marshes could reach 100% of the target recovery. In order to achieve this (if desired), the government of Iraq would need to significantly change the land use of many locations in the south.
- In order to meet the 75% recovery, water release strategies would need to be redefined and reservoirs upstream of the marshes must be operated differently.

- Total year water allocation would not be changed.
- Adequate water control structures would need to be built and operated at the inlets and outlets of each marsh.
- Summer crops would be able to expand far beyond the proposed 25% recovery scenario discussed in this example.

CASE 2 - SHORT-RUN NAVIGATION / AGRICULTURE AT ITS STATUS QUO

Generalities

The case study attempts an evaluation of the benefit associated with a water allocation strategy where:

- Navigation on the Euphrates River is met by making short term investments that will only partially change the infrastructure along the river. If short-term investment are made, then it is necessary that larger volumes of water be secured all year around inside the River in order to maintain navigation going (this is because a more robust, a consequently more expensive, system of infrastructure allows for a more efficient use of water for navigation; see book 1 for more details). Infrastructure and investments follow the 1986 SOGREA Navigation Project. Cost and benefits have been year marketed so that estimates made twenty years ago can be compared with today's costs.
- Agriculture production is kept at a minimum of at least 25% of the past-planned yields. Water consumption for agriculture is assumed to not exceed the past-planned irrigation efficiency.

Socio-Economic Evaluation

Based on the water allocation assumptions, the socio-economic model provided the following results:

	WINTER			SUMMER		
	Agriculture	Marshland	Navigation	Agriculture	Marshland	Navigation
DRY YEARS						
Water allocated to (MCM)	1,589	1,994	3,067	3,226	331	3,067
Total values (MIQD)	107,160	-2,044,420	5,225,140	63,338	-2,078,410	5,225,140
Marshland extension (%)		**13.6%**			**13.0%**	
Agriculture extension (%)	**25.0%**			**25.0%**		
NORMAL YEARS						
Water allocated to (MCM)	1,589	8,275	3,942	5,551	2,461	3,942
Total values (MIQD)	107,160	689,184	7,555,685	165,756	3,362,700	7,555,685
Marshland extension (%)		**57.2%**			**100.0%**	
Agriculture extension (%)	**25.0%**			**43.0%**		
WET YEARS						
Water allocated to (MCM)	6,068	14,135	3,942	12,904	2,461	3,942
Total values (MIQD)	852,496	3,363,950	7,555,685	522,942	3,362,700	7,555,685
Marshland extension (%)		**100.0%**			**100.0%**	
Agriculture extension (%)	**95.4%**			**100.0%**		

(orange) Smaller than the minimum water requirment
(yellow) Water alwais always floing into Hawr Al Azim marshes

Table 4 – Economical benefits associated with CASE 2

CASE study 2 presents similar results with respect to the previous one, except that for this case, water availability represents a constraint also during "wet" years. It should be noted that in "normal" years the total value for marshlands restoration is negative, although its extent is greater then 41%. Indeed, most of the direct and indirect values of marshlands restoration are positive, but structural and management costs exceed benefits arising from the marshland extension.

It should be also noted that in "dry" years the water allocated to navigation is smaller than the minimum required (-22%), while marshlands in summer are reduced to the bottom extension ensured by the water coming from the Karkheh river: the short-run project does not seem to be sustainable in this scenario.

This basic example demonstrates that it would be fundamentally counterproductive to promote navigation along the Euphrates River without making long term investment: although navigation might be important for Iraq, both agriculture and marshes would end up suffering for this choice. This is because, short run investment in navigation will require that at least 250 m^3/s of water will have to flow along the lower course of the Euphrates River for at least 95% of the time of the year and in all hydrological conditions. Consequently, significantly less water will available for agriculture and marshes (long run investment in navigation would allow to achieve the same results, but only 100 m^3/s of water will be required all year round).

Hydrological Sustainability

Table 4 shows that, with "short-run" investments on navigation, CASE 2 would provide limited water to sustain today's agriculture outputs and small expansion of the marshes during winter time. Navigation will result not sustainable during droughts as much as marshlands restoration. Agriculture will be left at today's level during winter time, and will be able to expand during summer time. During "wet" seasons there will be enough water to sustain agriculture, marshes and "short-run" navigation. The basic result of CASE study 2 is that marshes will be sustainable at a 57.2% level. According to the following graph, approximately 9 billion cubic meters of water would be required, on an average year, to sustain this level of marshlands restoration. The average total flow would be 290 m^3/s.

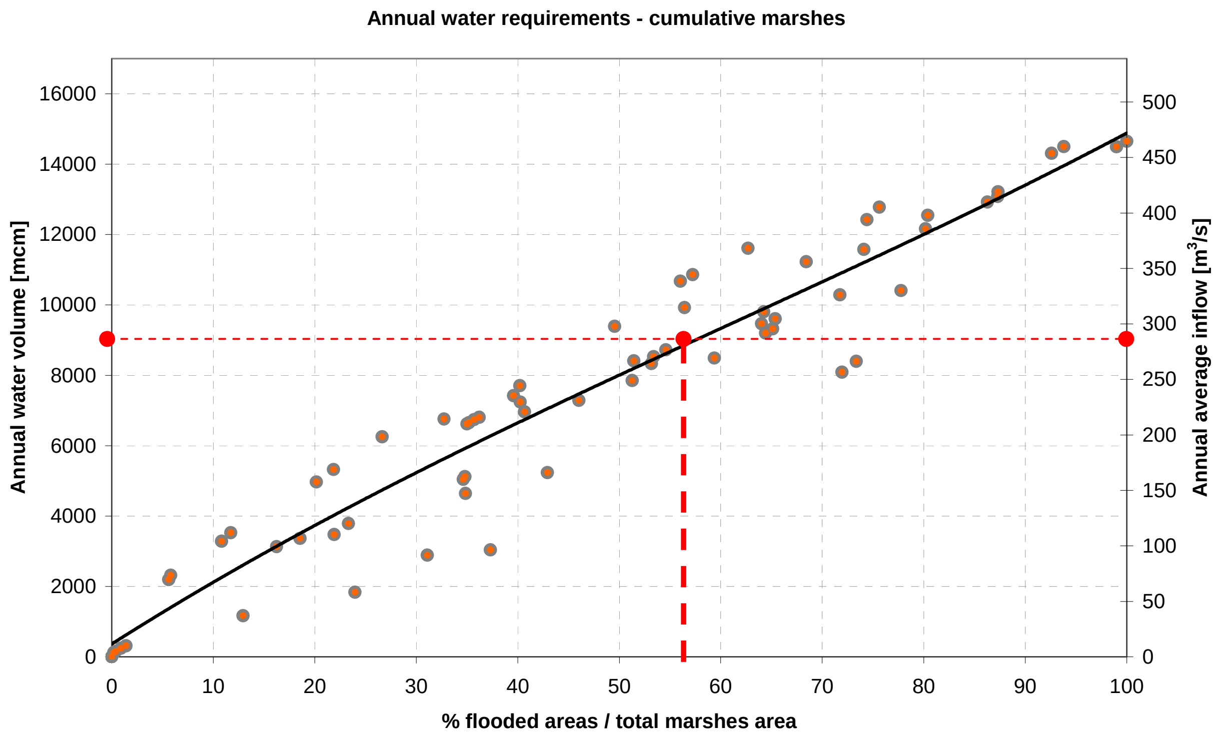


Figure 43: Annual water requirements for all marshes

A possible configuration of marshlands restoration for this case study is proposed in the following Table 5.

	1973-76 conditions	Dec-05	Today's % of 1973 Conditions	Proposed	
	Kmq	Kmq	%	%	Kmq
Qurna	3,021	666	22%	60%	1,813
Azu Zirig	100	100	100%	100%	100
Hawizhe	3,076	1,640	53%	53%	1,630
Hammar	2,729	1,368	50%	55%	1,501
TOTAL	**8,926**	**3,774**	**42.28%**	**57%**	**5,044**

Table 5: Proposed recovery to achieve the CASE 2 recommendations

To achieve this result it will be necessary to triple the Central Marshes, expand of an additional 5% Hammar Marshes. Hawizhe Marshes and Abu Zirig will remain at the level they are today. In conclusion, large efforts will be required in order to move more water from the Tigris in the Central Marshes.

Water allocations and infrastructure operation rules are defined with similar steps discussed for CASE 1.

CASE 3 - LONG-RUN NAVIGATION / AGRICULTURE 150% ITS STATUS QUO

Generalities

The study case attempts to evaluate the benefits associated with a water allocation strategy where:

- Navigation on the Euphrates River is met by making long-term investments which will radically change the infrastructure along the river and will be able to minimize water requirements. Infrastructure and investments follow the 1986 SOGREA Navigation Project. Cost and benefits have been year marketed.
- Agricultural production is double that of today, in order to reach a minimum of at least 50% of the Past-planned yields. Water consumption for agriculture is assumed to not exceed the past-planned irrigation efficiency. By doubling agricultural output, we intended to mimic the possible effects of a medium-term development plan in agriculture.

Socio-Economic Evaluation

Based on the water allocation assumptions, the socio-economic model provided the following results:

	WINTER			SUMMER		
	Agriculture	**Marshland**	**Navigation**	**Agriculture**	**Marshland**	**Navigation**
DRY YEARS						
Water allocated to (MCM)	2,384	2,813	1,454	4,839	331	1,454
Total values (MIQD)	221,678	-1,696,080	62,696,000	131,017	-2,078,410	62,696,000
Marshland extension (%)		**19.1%**			**13.0%**	
Agriculture extension (%)	**37.5%**			**37.5%**		
NORMAL YEARS						
Water allocated to (MCM)	2,384	9,846	1,577	7,917	2,461	1,577
Total values (MIQD)	221,678	1,394,380	70,759,383	291,982	3,362,700	70,759,383
Marshland extension (%)		**68.5%**			**100.0%**	
Agriculture extension (%)	**37.5%**			**61.4%**		
WET YEARS						
Water allocated to (MCM)	6,358	14,135	1,577	12,904	2,461	1,577
Total values (MIQD)	885,436	3,363,950	70,759,383	522,942	3,362,700	70,759,383
Marshland extension (%)		**100.0%**			**100.0%**	
Agriculture extension (%)	**100.0%**			**100.0%**		

Smaller than the minimum water requirment
Water alwais always floing into Hawr Al Azim marshes

Table 6: Economical benefits associated with CASE 3

Results from this case study are mostly similar to those of the two previous one. If long-term investments are secured for navigation, then it is possible to double the agricultural production and slightly increase the actual marshlands extent compared to present. During wet years, water would be sufficient to enlarge the wetlands to their maximum extent. It should be also noted that in "dry" years the water allocated to navigation is smaller than the minimum required (-8%), while marshlands in summer are reduced to the bottom extension ensured by the water coming from the Karkheh river: the agriculture at one and a half its status quo might not be sustainable in this scenario.

Hydrological Sustainability

Table 6 shows that, with "short-run" investments on navigation, CASE 2 would provide limited water to sustain today's agriculture outputs and small expansion of the marshes during winter time. Navigation will result not sustainable during droughts as much as marshlands restoration. Agriculture will be left at today's level during winter time, and will be able to expand during summer time. During "wet" seasons there will be enough water to sustain agriculture, marshes and "short-run" navigation. The basic result of CASE study 2 is that marshes will be sustainable at a 68.5% level. According to the following graph, approximately 10 billion cubic meters of water would be required, on an average year, to sustain this level of marshlands restoration. The average total flow would be 330 m³/s.

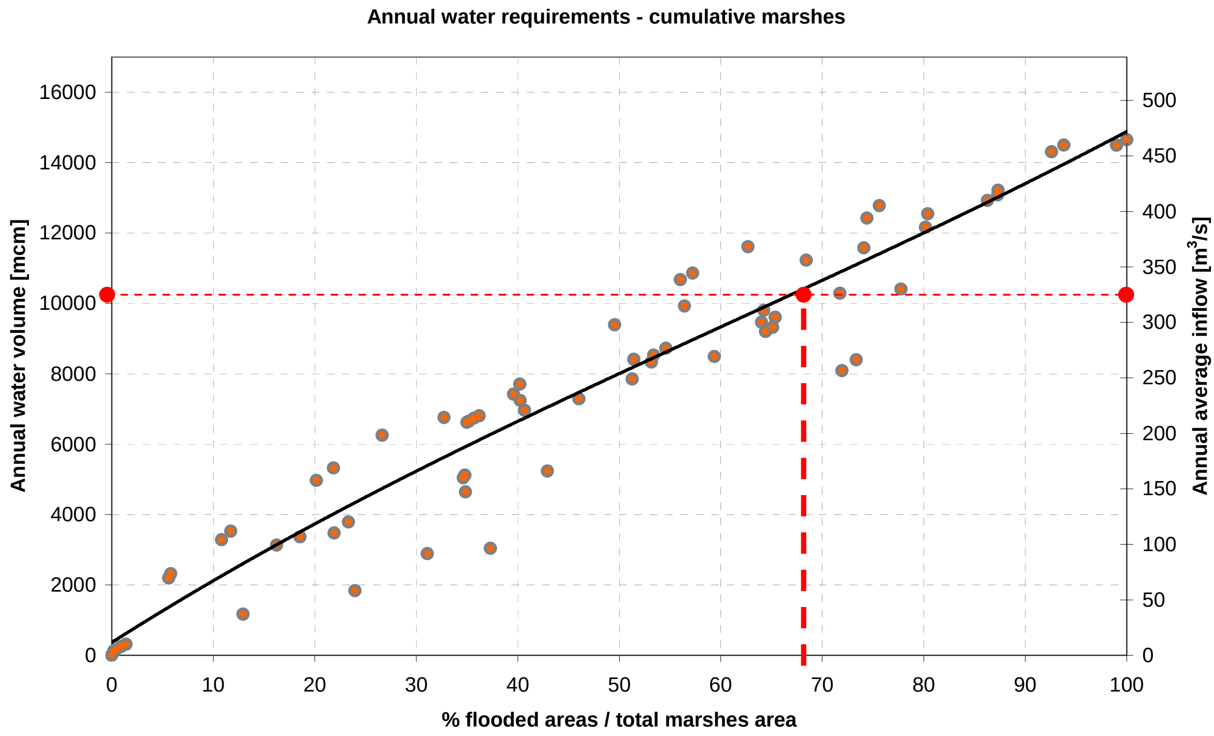


Figure 44: Annual water requirements for all marshes

A possible configuration of marshlands restoration for this case study is proposed in the following Table 7.

	1973-76 conditions	Dec-05	Today's % of 1973 Conditions	Proposed	
	Kmq	Kmq	%	%	Kmq
Qurna	3,021	666	22%	65%	1,964
Azu Zirig	100	100	100%	100%	100
Hawizhe	3,076	1,640	53%	60%	1,846
Hammar	2,729	1,368	50%	80%	2,183
TOTAL	**8,926**	**3,774**	**42.28%**	**68%**	**6,092**

Table 7: Proposed recovery to achieve the CASE 2 recommendations

To achieve this result it will be necessary to more then triple the Central Marshes, almost double Hammar Marshes and slightly increase Hawizhe Marshes. Abu Zirig will remain at the level it is today. In conclusion, large efforts will be required in order to move more water from the Tigris in the Central Marshes.

Water allocations and infrastructure operation rules are defined with similar steps discussed for CASE 1.

CASE 4 - NO NAVIGATION / AGRICULTURE AT ITS STATUS QUO

Generalities

The study case attempts an evaluation of the benefits associated with a water allocation strategy where:

- Navigation will not be a priority for the development of the south and thus no water will be secured for this use. Still, minimum sanitary flows will be secured along both the Tigris and Euphrates River. Such flows will partially derive from outflows of the marshes themselves.
- Agricultural production is kept at a minimum of at least 25% of the Past-planned yields. Water consumption for agriculture is assumed to not exceed the past-planned irrigation efficiency.

Socio-Economic Evaluation

Based on the water allocation assumptions, the socio-economic model provided the following results:

	WINTER			SUMMER		
	Agriculture	Marshland	Navigation	Agriculture	Marshland	Navigation
DRY YEARS						
Water allocated to (MCM)	1,589	5,061		4,163	2,461	
Total values (MIQD)	107,160	-726,704		100,534	3,362,700	
Marshland extension (%)		**34.6%**			**100.0%**	
Agriculture extension (%)	**25.0%**			**32.3%**		
NORMAL YEARS						
Water allocated to (MCM)	1,589	12,217		9,494	2,461	
Total values (MIQD)	107,160	2,475,520		376,625	3,362,700	
Marshland extension (%)		**85.8%**			**100.0%**	
Agriculture extension (%)	**25.0%**			**73.6%**		
WET YEARS						
Water allocated to (MCM)	6,358	14,135		12,736	2,461	
Total values (MIQD)	885,436	3,363,950		517,695	3,362,700	
Marshland extension (%)		**100.0%**			**100.0%**	
Agriculture extension (%)	**100.0%**			**98.7%**		

Table 8: Economical benefits associated with CASE 4

Results from this case study demonstrate that water currently flowing to southern Iraq will be sufficient to keep the present agriculture outputs (if WUE strategies are adopted) and maximize marshlands extent during both normal and wet years. To meet this result, Iraq would have to give up navigation development plans along the lower course of the Euphrates River, for the reach between Nassiryah and Qurna.

It should be also noted that with no navigation, agriculture is almost sustainable at double its status quo in this scenario: indeed, marshlands in summer reduced to the bottom extension ensured by the water coming from the Karkheh river would allow to meet 97% of water requirements by agriculture.

Hydrological Sustainability

Table 8 shows that, with "short-run" investments on navigation, CASE 2 would provide limited water to sustain today's agriculture outputs and small expansion of the marshes during winter time.

Navigation will result not sustainable during droughts as much as marshlands restoration. Agriculture will be left at today's level during winter time, and will be able to expand during summer time. During "wet" seasons there will be enough water to sustain agriculture, marshes and "short-run" navigation. The basic result of CASE study 2 is that marshes will be sustainable at a 85.8% level. According to the following graph, approximately 12 billion cubic meters of water would be required, on an average year, to sustain this level of marshlands restoration. The average total flow would be 400 m^3/s.

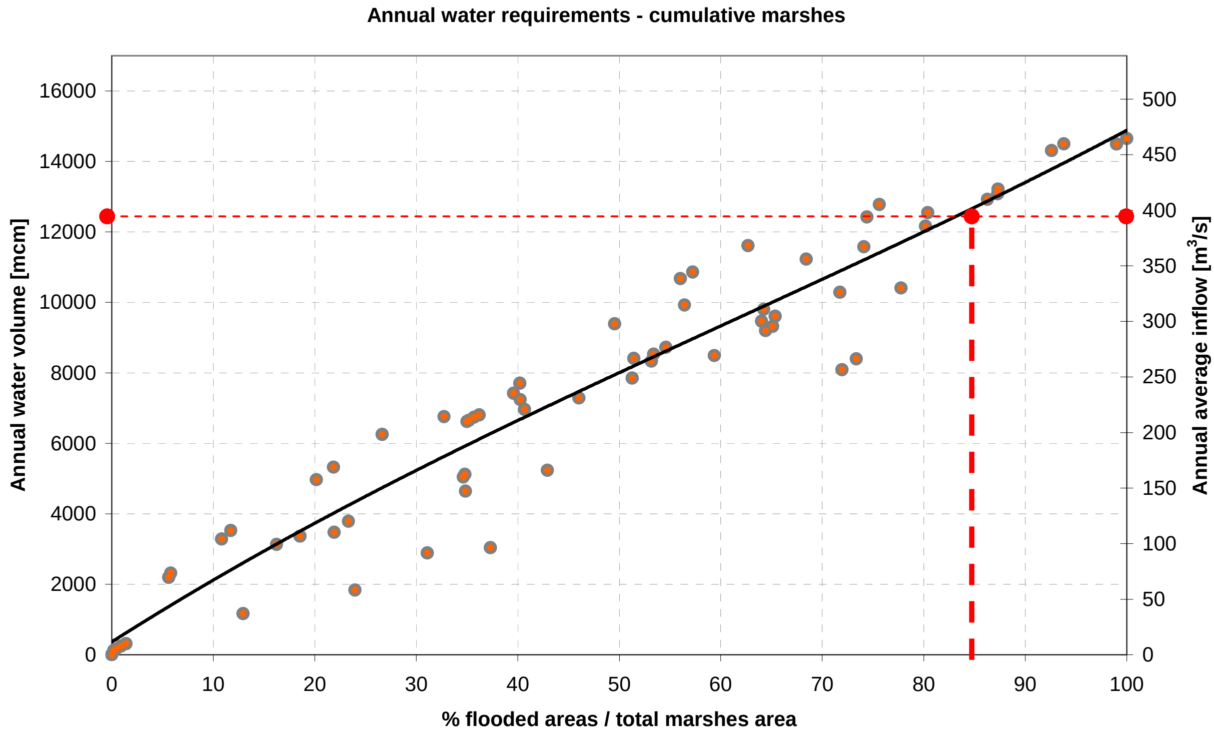


Figure 45: Annual water requirements for all marshes

A possible configuration of marshlands restoration for this case study is proposed in the following Table 7.

	1973-76 conditions	Dec-05	Today's % of 1973 Conditions	Proposed	
	Kmq	Kmq	%	%	Kmq
Qurna	3,021	666	22%	95%	2,870
Azu Zirig	100	100	100%	100%	100
Hawizhe	3,076	1,640	53%	70%	2,153
Hammar	2,729	1,368	50%	90%	2,456
TOTAL	**8,926**	**3,774**	**42.28%**	**85%**	**7,579**

Table 9: Proposed recovery to achieve the CASE 2 recommendations

To achieve this result it will be necessary to greatly expand the Central and Hammar Marshes and slightly increase Hawizhe Marshes. Abu Zirig will remain at the level it is today. Central and Hammar

Marshes will both benefict from additional water flowing along the Euphrates. In conclusion, large efforts will be required in order to move more water from the Tigris in the Central Marshes.

Water allocations and infrastructure operation rules are defined with similar steps discussed for CASE 1.

CONCLUSIONS

The purpose of this study was to provide a decision making algorithm, that would embody the highest possible level of analytical details of the essential features characterizing the Southern Iraqi ecosystem, and which would be suitable for use by the Ministry of Water Resources in deciding whether, and under which conditions, to restore marshlands *in order to maximise the social welfare of the Iraqi population at a national level.* Numerical results performed above show that this goal has been achieved.

However, numerical experiments discussed above also show that no final decision is suggested. Additional analyses from hydrological and ecological studies are required, in order to identify which scenarios are feasible: indeed, a reduction of marshlands in dry years from 41% to 23.72% (I scenario) or to 34.62% (IV scenario) might be sustainable, while a reduction to 13.55% (II scenario) or to 19.12% (III scenario) might not be sustainable. Next, additional information from decision makers is required in order to address the competition for water between agriculture, navigation and marshlands: indeed, the scenario with no navigation projects is patently the worst (its total value is 3970033), with the scenario with the short-run navigation project at around 4 times this value, but both scenarios with the long-run navigation project, either with agriculture at its status quo and marshlands at +33%, or with agriculture at double its status quo and marshlands at +27%, show similar total values at around 25 times the scenario without navigation projects.

We stressed the importance of communication and bridging between local residents and users, on one hand, and scientists, conservationists and decision-makers, on the other hand.

Next, we highlighted that scientific analysis is not enough, but local knowledge and stakeholder's desires must also be taken into account.

MARSHLAND MANAGEMENT

This section discusses the historical methods used to manage the marshlands and a proposed method for developing a Sustainable Restoration and Development Plan that would be part of the Sustainable Development Strategy for the region. An annotated listing of organizations involved in the marshlands (including governmental, scientific, and conservation-oriented groups) is also provided. Finally, there is an annotated listing of international environmental treaties to which Iraq is a signatory, and other treaties which Iraq may consider joining in order to increase protection of its valuable environment.

HISTORICAL MANAGEMENT OF THE MARSHLANDS

The historical management of the wetlands of Iraq has been summarized by Scott (1995) and this paragraph has been excerpted from his work. Prior to the war in 2003, responsibility for management of the natural environment lay with the Ministry of Agriculture and Irrigation (the ministry was later divided into two ministries; Agriculture and Water Resources), but no major conservation plans were developed or implemented, and no protected areas were established in the wetlands. In 1977, the precursor of the General Directorate of Horticulture and Forestry in the Ministry of Agriculture and Irrigation (later divided into Agriculture and Water Resources Ministries) became responsible for wildlife protection, and established two small protected areas for the captive breeding of gazelles, one near Baghdad and the other at Rutba near the Jordanian border. In 1995, both of these were reported to be closed down due to loss of funding. Some "National Parks" have been previously designated in Iraq, but these are mainly state-owned areas for public recreation, with no specific management for wildlife. No special measures had been taken by the Iraqi Government to conserve wetlands; in fact to the contrary, there was a national policy to drain the southern marshes and wetlands. There has been no national conservation strategy in Iraq, and no legal protection has been given to any part of the wetlands. Legislation was introduced to prohibit fishing during the spawning season, but no serious steps were taken to implement this, and the seasonal prohibition on fishing has been widely disregarded (it was enforced at the whim of the local police and their desire to collect bribes). The environmental wildlife law of 1981 is presumed to legislate for wildlife preserves including those in existence before that date (IUCN, 1992). In the late 1970s, the Government introduced legislation banning all hunting in Iraq in order to conserve wildlife, particularly terrestrial game which had been heavily harvested in the past. These and later hunting restrictions have not been implemented or enforced.

Since 2003, natural resource protection is now primarily the responsibility of the new Ministry of Environment. The former Ministry of Irrigation has been renamed the Ministry of Water Resources to reflect a more conservation-oriented role. Both of these ministries, along with the Ministry of Municipalities and Public Works, and the Ministry of Planning, will be intimately involved in managing the environment, infrastructure, water regime, and socioeconomics of the marshlands. The National Assembly of Iraq has created a special committee on Marshlands in southern Iraq and another on Water Resources. These committees will focus on development and infrastructure needs. They will identify and work to obtain funds from donor countries, international organizations, and the Iraqi government budget itself to create development projects in these sectors. More information on the Iraqi governmental agencies is provided later.

For decades, there had been no community organizations advocating environmental protection. In 2005, Nature Iraq was formed with a mission to build civil society networks to protect the environment of Iraq and develop capacity within Iraq, both in private and publicly-owned industries, to help clean and protect the environment. In addition, there are dozens of smaller NGOs which are involved with environmental protection and human welfare in the marshlands, which should also be included in the participatory process of developing the marshland management plan and sustainable development strategy. More information on these groups, along with involved international and regional conservation groups, is provided below.

In May 2003, re-flooding of the marshlands was initiated by local inhabitants, in some places through their direct actions (breaching dykes and levees) and in other areas through petition to the local irrigation district to redirect or increase water flow to desiccated areas. These actions, although not centrally planned, have succeeded in re-flooding approximately 38% (in summer) and 58% (during winter) of the former marshland areas; about half of the re-flooded areas have experienced good recovery of the natural vegetative cover. However, their restoration is not sustainable over the long-term unless hydrological controls, such as achieving greater inter-connection amongst the marshlands, and increasing the natural seasonality of flow, are implemented. These actions do require coordinated planning and subsequent management.

Over 100,000 people have returned to these areas, with little socioeconomic or human welfare support. The areas that have been re-flooded through the actions or requests of the local inhabitants are recovering well in an ecological sense, however not in a socioeconomic sense.

RECOMMENDED TREATIES

There are several international treaties and conventions that are presented for consideration for Iraq to enter into as a signatory party. The purpose of entering into these treaties is to obtain access to technical and financial resources and to assist Iraq in maintaining a focus on environmental conservation and sustainable development. These treaties, as described briefly below, include the Treaty on the Convention of Wetlands of International Importance (Ramsar Convention), the Convention on Biodiversity, the Bonn Convention (Migratory Animals) and Agenda 21 (Sustainable Development). It is our understanding that the government of Iraq is interested in entering the

Ramsar Convention and has started the process of designating the entire footprint of the Huweizeh Marsh as a Ramsar site.

Treaty on Convention on Wetlands of Int'l Importance Especially as Waterfowl Habitat (Ramsar)

The Convention on Wetlands is an intergovernmental treaty adopted in 1971 in the Iranian city of Ramsar. The "Ramsar Convention" is the first of the modern global intergovernmental treaties on conservation and wise use of natural resources, but, compared with more recent ones, its provisions are relatively straightforward and general. Over the years, the Conference of the Contracting Parties (the main decision-making body of the Convention, composed of delegates from all the Member States) has further developed and interpreted the basic tenets of the treaty text. The Convention's mission is the conservation and wise use of all wetlands through local, regional and national actions and international cooperation, as a contribution towards achieving sustainable development throughout the world

Membership in the Ramsar Convention:

- entails an endorsement of the principles that the Convention represents, facilitating the development at national level of policies and actions, including legislation that helps nations to make the best possible use of their wetland resources in their quest for sustainable development;
- presents an opportunity for a country to make its voice heard in the principal intergovernmental forum on the conservation and wise use of wetlands;
- brings increased publicity and prestige for the wetlands designated for the List of Wetlands of International Importance, and hence increased possibility of support for conservation and wise use measures;
- brings access to the latest information and advice on application of the Convention's internationally-accepted standards, such as criteria for identifying wetlands of international importance, guidelines on application of the wise use concept, and guidelines on management planning in wetlands;
- brings access to expert advice on national and site-related problems of wetland conservation and management through contacts with Ramsar Bureau personnel and consultants and through application of the Ramsar Advisory Mission mechanism when appropriate; and
- encourages international cooperation on wetland issues and brings the possibility of support for wetland projects, either through the Convention's own Small Grants Fund or through the Convention's contacts with multilateral and bilateral external support agencies.

When countries join the Convention, they are enlisting in an international effort to ensure the conservation and wise use of wetlands. The treaty includes four main commitments that the Contracting Parties have agreed to by joining.

1. Listed sites. The first obligation under the Convention is to designate at least one wetland for inclusion in the List of Wetlands of International Importance (the "Ramsar List") and to promote its conservation, including, where appropriate, its wise use. Selection for the Ramsar List should be based on the wetland's significance in terms of ecology, botany, zoology, limnology, or hydrology. The Contracting Parties have adopted specific criteria and guidelines for identifying sites that qualify for inclusion in the List of Wetlands of International Importance.

2. Wise use. Under the Convention there is a general obligation for the Contracting Parties to include wetland conservation considerations in their national land-use planning. They have undertaken to formulate and implement this planning so as to promote, as far as possible, "the wise use of wetlands in their territory." The Conference of the Contracting Parties has approved guidelines and additional guidance on how to achieve "wise use," which has been interpreted as being synonymous with "sustainable use."

3. Reserves and training. Contracting Parties have also undertaken to establish nature reserves in wetlands, whether or not they are included in the Ramsar List, and they are also expected to promote training in the fields of wetland research, management and wardening.

4. International cooperation. Contracting Parties have also agreed to consult with other Contracting Parties about implementation of the Convention, especially in regard to transfrontier wetlands, shared water systems, and shared species.

Over the years, the Conference of the Contracting Parties has interpreted and elaborated upon these four major obligations included within the text of the treaty, and it has developed guidelines for assisting the Parties in their implementation. Contracting Parties report on the progress in implementing their commitments under the Convention by submitting triennial National Reports to the Conference of the Contracting Parties. These National Reports become part of the public record.

Convention on Biological Diversity

The Convention on Biological Diversity was signed at the "Earth Summit" in 1992 in Rio de Janerio, Brazil. Over 150 governments signed the document at the Rio conference, and since then more than 187 countries have ratified the agreement.

The Convention has three main goals:

1. The conservation of biodiversity,

2. Sustainable use of the components of biodiversity, and

3. Sharing the benefits arising from the commercial and other utilization of genetic resources in a fair and equitable way

The Convention is legally binding; countries that join it are obliged to implement its provisions. The Convention reminds decision-makers that natural resources are not infinite and sets out a new philosophy for the 21st century, that of sustainable use. While past conservation efforts were aimed at protecting particular species and habitats, the Convention recognizes that ecosystems, species and genes must be used for the benefit of humans. However, this should be done in a way and at a rate that does not lead to the long-term decline of biological diversity.

Some of the many issues dealt with under the Convention include:

- Measures and incentives for the conservation and sustainable use of biological diversity.
- Regulated access to genetic resources.
- Access to and transfer of technology, including biotechnology.
- Technical and scientific cooperation.
- Impact assessment.
- Education and public awareness.
- Provision of financial resources.
- National reporting on efforts to implement treaty commitments.

Private companies, landowners, fishermen, and farmers take most of the actions that affect biodiversity. Governments need to provide the critical role of leadership, particularly by setting rules that guide the use of natural resources, and by protecting biodiversity where they have direct control over the land and water. Under the Convention, governments undertake to conserve and sustainably use biodiversity. They are required to develop national biodiversity strategies and action plans, and to integrate these into broader national plans for environment and development. This is particularly important for such sectors as forestry, agriculture, fisheries, energy, transportation and urban planning.

Other treaty commitments include:

- Identifying and monitoring the important components of biological diversity that need to be conserved and used sustainably.
- Establishing protected areas to conserve biological diversity while promoting environmentally sound development around these areas.
- Rehabilitating and restoring degraded ecosystems and promoting the recovery of threatened species in collaboration with local residents.
- Respecting, preserving and maintaining traditional knowledge of the sustainable use of biological diversity with the involvement of indigenous peoples and local communities.
- Preventing the introduction of, controlling, and eradicating alien species that could threaten ecosystems, habitats or species.
- Controlling the risks posed by organisms modified by biotechnology.
- Promoting public participation, particularly when it comes to assessing the environmental impacts of development projects that threaten biological diversity.

- Educating people and raising awareness about the importance of biological diversity and the need to conserve it.
- Reporting on how each country is meeting its biodiversity goals.

One of the first steps towards a successful national biodiversity strategy is to conduct surveys to find out what biodiversity exists, its value and importance, and what is endangered. On the basis of these survey results, governments can set measurable targets for conservation and sustainable use. National strategies and programs need to be developed or adapted to meet these targets.

The conservation of each country's biological diversity can be achieved in various ways. "In-situ" conservation - the primary means of conservation - focuses on conserving genes, species, and ecosystems in their natural surroundings, for example by establishing protected areas, rehabilitating degraded ecosystems, and adopting legislation to protect threatened species. "Ex-situ" conservation uses zoos, botanical gardens and gene banks to conserve species.

Promoting the sustainable use of biodiversity will be of growing importance for maintaining biodiversity in the years and decades to come. Under the Convention, the "ecosystem approach to the conservation and sustainable use of biodiversity" is being used as a framework for action, in which all the goods and services provided by the biodiversity in ecosystems are considered. The Convention is promoting activities to ensure that everyone benefits from such goods and services in an equitable way.

Each government that joins the Convention is to report on what it has done to implement the accord, and how effective this is in meeting the objectives of the Convention. These reports are submitted to the Conference of the Parties (COP) - the governing body that brings together all countries that have ratified the Convention. The reports can be viewed by the citizens of all nations. The Convention secretariat works with national governments to help strengthen reporting and to make the reports of various countries more consistent and comparable, so that the world community can get a clearer picture of the big trends. Part of that work involves developing indicators for measuring trends in biodiversity, particularly the effects of human actions and decisions on the conservation and sustainable use of biodiversity. The national reports, particularly when seen together, are one of the key tools for tracking progress in meeting the Convention's objectives.

One of the most important benefits of becoming a signatory to the CBD is that the country is then eligible for funding of biodiversity projects under the Global Environmental Facility (GEF). GEF is an independent financial organization that provides grants to developing countries for projects that benefit the global environment and promote sustainable livelihoods in local communities.

GEF funds are contributed by donor countries. Since 1991, the GEF has provided $4.5 billion in grants and generated $14.5 billion in co-financing from other partners for projects in developing countries and countries with economies in transition. In 2002, 32 donor countries pledged $3 billion to fund operations between 2002 and 2006. Since 1991, GEF has provided grants for more than 1,300 projects in 140 countries.

Each Member Country has a GEF representative know as a "Focal Point." Nongovernmental Organizations (NGOs) participate in the GEF activities and assist in the design, execution, and monitoring of projects. GEF biodiversity project ideas are proposed directly to UNEP and executed and monitored in close coordination with UNEP.

As the financial mechanism for implementing the Convention on Biological Diversity (CBD), GEF also collaborates closely with other treaties and agreements. Any eligible individual or group may propose a project, which must meet two key criteria: It must reflect national or regional priorities and have the support of the country or countries involved, and it must improve the global environment or advance the prospect of reducing risks to it.

Country eligibility to receive funding is determined in two ways. Developing countries that have ratified the relevant treaty are eligible to propose biodiversity and climate change projects. Other countries, primarily those with economies in transition, are eligible if the country is a party to the appropriate treaty and is eligible to borrow from the World Bank or receive technical assistance grants from UNDP.

Agenda 21 (Sustainable Development)

Sustainable development has three principal dimensions: economic growth, social equity and protection of the environment. At the heart of sustainable development is the challenge of evaluating and managing the complex interrelationships between economic, social and environmental objectives. Agenda 21 is a comprehensive plan of action to be taken globally, nationally and locally by organizations of the United Nations System, Governments, and major groups in every area in which human impact the environment. Agenda 21 was revealed at the 1992 United Nations Conference on Environment and Development (the "Earth Summit"), where 179 governments voted to adopt the program.

The Commission on Sustainable Development acts as a high level forum on sustainable development and has acted as preparatory committee for summits and sessions on the implementation of Agenda 21. The United Nations Division for Sustainable Development acts as the secretariat to the Commission and works 'within the context of Agenda 21

Agenda 21 covers a comprehensive set of issues including the following:

- International cooperation.
- Alleviating poverty.
- Changing consumption patterns.
- Demographic dynamics and sustainability.
- Protection and promotion of human health.
- Promoting sustainable human settlement development.
- Integrating environment and development in decision making.
- Protection of the atmosphere.

- Integrated approach to the planning and management of land resources.
- Combating deforestation.
- Managing fragile ecosystems.
- Sustainable mountain development.
- Promoting sustainable agriculture and rural development.
- Conservation of biological diversity.
- Environmentally sound management of biotechnology.
- Protection of oceans and seas.
- Protection of the quality and supply of freshwater resources:
- Environmentally sound management of toxic chemicals.
- Environmentally sound management of hazardous wastes
- Environmentally sound management of solid waste and sewage.
- Safe and environmentally sound management of radioactive wastes
- Global action for women towards sustainable and equitable development
- Children and youth in sustainable development
- Recognizing and strengthening the role of indigenous people and their communities
- Strengthening the role of workers and their trade unions
- Strengthening the role of business and industry

Implementation by member states remains essentially voluntary. Countries implement Agenda 21 through the development of National Sustainable Development Strategies (NSDSs). An NSDS is a coordinated, participatory and iterative process of thoughts and actions to achieve economic, environmental and social objectives in a balanced and integrated manner. It is a tool for informed decision-making that provides a framework for systematic thought across sectors and territory. It also helps to institutionalize processes for consultation, negotiation, mediation and consensus building on priority societal issues where interests differ.

Partnerships are voluntary multi-stakeholder initiatives which contribute to the implementation of inter-governmental commitments in Agenda 21. They can improve the quality of implementation by involving those relevant stakeholders whose activities have direct impact on sustainable development. Partnerships are governed by partner organizations through a variety of mutually agreed mechanisms. Partnerships are self-governing bodies with their own accountability mechanisms

The 1st International Forum on Partnerships for Sustainable Development, also known as the Rome Forum was held in Rome, Italy, from 4-6 March 2004. The meeting was organized by the Italian Ministry for the Environment and Territory in cooperation with the UN Department of Economic and Social Affairs (UN/DESA). The purpose of the Forum was to enhance the contribution of partnerships towards the implementation of sustainable development goals and objectives.

Convention on the Conservation of Migratory Species of Wild Animals (Bonn Convention)

The Convention on the Conservation of Migratory Species of Wild Animals (also known as CMS or the Bonn Convention) aims to conserve terrestrial, marine and avian migratory species throughout their range. It is an intergovernmental treaty, concluded under the aegis of the United Nations Environment Program, concerned with the conservation of wildlife and habitats on a global scale. Since the Convention's entry into force, its membership has grown steadily to include 95 (as of 1December 2005) parties from Africa, Central and South America, Asia, Europe and Oceania.

Migratory species threatened with extinction are listed in Appendix I of the Convention. CMS Parties strive towards strictly protecting these animals, conserving or restoring the places where they live, mitigating obstacles to migration and controlling other factors that might endanger them. Besides establishing obligations for each State joining the Convention, CMS promotes concerted action among the Range States of many of these species.

CMS acts as a framework Convention. The agreements may range from legally binding treaties (called Agreements) to less formal instruments, such as Memoranda of Understanding, and can be adapted to the requirements of particular regions. The development of models tailored according to the conservation needs throughout the migratory range is a unique capacity to CMS.

The largest Agreement developed so far under CMS auspices, the Africa-Eurasia Migratory Waterfowl (AEWA), focuses on migratory waterbirds. It was concluded on 16 June 1995 in The Hague, the Netherlands, and entered into force on 1 November 1999. The Secretariat is located in Bonn, Germany. AEWA's flyway approach to waterbird conservation is unique. Being a regional agreement, AEWA focuses on 235 waterbird species ecologically dependent on wetlands for at least part of their annual cycle including many species of pelicans, storks, flamingos, ducks, waders, terns, gulls and geese.

The AEWA Agreement area covers 117 Range States in Africa, Europe including parts of Canada, Central Asia and the Middle East. The geographic area stretches from the northern reaches of Canada and the Russian Federation to the southernmost tip of Africa.

Parties to the Agreement are called upon to engage in a wide range of conservation actions which are described in a comprehensive Action Plan (2003-2005). This detailed plan addresses such key issues as: species and habitat conservation, management of human activities, research and monitoring, education and information, and implementation.

In 2003, the Global Environmental Facility (GEF) agreed to finance a US$12 million project within the AEWA Agreement area. The African-Eurasian Flyway GEF project aims to enhance and coordinate catalytic strategic measures to conserve a network of critical wetland areas that migratory waterbirds depend upon to complete their annual cycle. There are three linked components to the project: establishing a network of sites, enhancing technical capacity and improving communication and coordination. Project activities includes development of the network of sites through surveys, training and knowledge base development; a training and awareness raising program; demonstration projects for best practices, which aimed at showing practitioners how to manage sites in a sustainable manner; and communications, including web-based resources, a project newsletter and publications. The project started in the second half of 2004 and will last approximately 5 years.

Other Appropriate International Treaties

The most important and valuable international treaties are named above. Additional treaties and conventions which may be considered by Iraq include:

- Convention for Combating Desertificaiton
- Convention on International Trade in Endangered Species (CITES)
- Montreal Protocol on Substances that Deplete the Ozone Layer (Montreal Protocol)

UN Framework Convention on Climate Change (Kyoto)

INTERNATIONAL ENVIRONMENTAL TREATIES

Iraq is a party to or signatory of the following international treaties regarding the environment:

- Articles of Agreement of the International Development Association (Washington, 1960)
- Constitution of the Food and Agriculture Organization of the United Nations (Quebec, 1945)
- Constitution of the United Nations Educational, Scientific and Cultural Organization (London, 1945)
- Constitution of the World Health Organization (New York, 1946)
- Convention of the World Meteorological Organization (Washington, 1947)
- Convention concerning the Protection of the World Cultural and Natural Heritage (Paris, 1972) Entry into Force: 05/03/74
- Statutes of the International Centre for the Study of the Preservation and Restoration of Cultural Property (New Delhi, 1956)
- Agreement for the Establishment of the Arab Centre for the Studies of Dry and Barren Land (Strasbourg, 1968)
- Protocol Concerning Regional Co-operation in Combating Pollution by Oil and other Harmful Substances in Cases of Emergency (Kuwait, 1978)
- International Plant Protection Convention (Rome, 1951) Entry into Force: 12.01.1954
- Kuwait Regional Convention for Co-operation on the Protection of the Marine Environment from Pollution (Kuwait, 1978)
- Protocol for the Protection of the Marine Environment against Pollution from Land-Based Sources (Kuwait, 1990)

NEXT STEPS

The "**New Eden Master Plan for Integrated Water Resource Development in Southern Iraq"** has focused on providing the technical information and decision-making tools to enable development of a restoration and development plan for the study area. The vital critical elements related to environmental restoration and water allocation are provided within this book. However, the New Eden Team cannot actually write the development plan itself; beyond the process of technical analysis is required a political and participatory decision-making process. Only the Iraqi government decision-makers can implement this process.

The New Eden Team recommends that the restoration and development plan be drafted using the procedures and guidelines provided in the United Nation's Sustainable Development process. The Sustainable Development process provides a tested and internationally-accepted way of determining appropriate development plans that sustainably use the country's natural resources. The Sustainable Development process also provides for partnerships between countries to achieve objectives; Iraq and Italy have already entered into a partnership under this process.

More information on the Sustainable Development process is provided below.

PREPARATION OF A SUSTAINABLE DEVELOPMENT STRATEGY

In 1992, the United Nations Conference on Environment and Development (UNCED) declared that "Governments, in cooperation where appropriate with international organizations, should adopt a national strategy for sustainable development. This strategy should build upon and harmonize the various sectoral, economic, social and environmental policies and plans that are operating in the country." In 1997, the Special Session of the UN General Assembly on the review of Agenda 21, called upon all countries to complete, by the year 2002, the national strategy for sustainable development. This strategy should build upon and harmonize the contributions and responsibilities of all interested parties. The following discussion of sustainable development strategies is based upon the United Nation's guidance document, the entire text of which may be found at http://www.un.org/esa/sustdev/publications/nsds_guidance.pdf.

Sustainable development has three principal dimensions: economic growth, social equity and protection of the environment. At the heart of sustainable development is the challenge of evaluating and managing the complex interrelationships between economic, social and environmental objectives. Agenda 21 promotes National Sustainable Development Strategies (NSDSs) as mechanisms for translating a country's goals and aspirations for sustainable development into concrete policies and actions. In the present case, this document is focused on creating the technical framework necessary to develop a portion of the National Sustainable Development Strategy for the region of the Mesopotamian Marshlands.

A sustainable development strategy is a coordinated, participatory and iterative process of thoughts and actions to achieve economic, environmental and social objectives in a balanced and integrated manner. The process encompasses situation analysis, formulation of policies and action plans, implementation, monitoring and regular review. It is a cyclical and interactive process of planning, participation and action in which the emphasis is on managing progress towards sustainability goals rather than producing a "plan" as an end product.

A sustainable development strategy is a tool for informed decision-making that provides a framework for systematic thought across sectors and territory. It also helps to institutionalize processes for consultation, negotiation, mediation and consensus building on priority societal issues where interests differ. Development of the strategy empowers countries to address inter-related social and economic problems by helping them to build capacities, develop procedures and legislative frameworks; allocate limited resources rationally and present timetables for actions. Countries can benefit from formulating strategies both directly (as a result of making development more sustainable) and indirectly (from the process itself).

The United Nations' experience of the past decade and current practices suggest that sound and effective sustainable development strategies have certain elements in common or defining features. These underlying elements are:

- Country ownership and strong political commitment;
- Integrated economic, social and environmental objectives across sectors, territories and generations;
- Broad participation and effective partnerships;
- Development of capacity and enabling environment;
- Focus on outcomes and means of implementation.

The elements mentioned above can be made operational through putting in place, on a continuous basis, four critical processes: political, participatory, technical and resource mobilization processes.

The **technical process** of formulating a sustainable development strategy involves various activities: undertaking assessment of the economic, social and environmental situation, identifying problems, setting clear priorities, establishing goals and objectives, developing the investment program, monitoring and evaluation. These would include developing a knowledge base and building on existing strategies; designing a system for harmonizing key economic, social and environment related policies and building capacity for the strategy on a continuous basis.

The current document is intended to provide a substantial contribution towards this technical basis. The current document is intended to be a living document that will be updated through a consensus review by Iraq's ministries and other stakeholders and through the collection of additional data as specific needs are defined. The current document contains technical information related to hydrology, agriculture, environmental preservation, water supply and sanitation needs of the region. Additional technical analyses may be required for transportation, economic development, social welfare, health and education. Each of these technical elements should be summarized in a separate plan, with all of the plans then combined into the single Sustainable Development Strategy.

The **political process** involves ensuring the existence of a strong political commitment from the top leadership as well as from local authorities of a country. National Councils for Sustainable Development have also proved to be useful in bringing various stakeholders together for the formulation and implementation of the strategy. The political process in Iraq is undergoing a dynamic period of change and instability. While there are serious issues facing the government at this time, the re-development of southern Iraq, the provision of social welfare, health, educational, and economic opportunities, and the protection of its unique environment and culture, are issues that cannot wait for the resolution of the national political process. Fortunately, Iraq has a dedicated and well-trained civil service who are capable and prepared to take on this task, given adequate resources. At the national level, the Ministries of Water Resources, Environment, Municipalities and Public Works, Planning, work together on these tasks

The **participatory process** entails the full involvement of relevant groups (both government and non-governmental) in appropriate tasks including strategy design, exchanging information, decision-making, and implementation. It is necessary to decide how much participation is possible and necessary and design participatory processes that are multi-layered and inclusive. The media needs to be effectively used both to create a forum for debate as well as for raising awareness. Iraq does not have a history of utilizing the participatory process for regional decision-making, however over the past few years it has taken great strides towards the development of a more consultative approach. Numerous grass-roots organizations have been initiated, many of which are focused on the social welfare, economic development, and environmental preservation within the area of the Mesopotamian Marshlands. The technical plans (for marshland management, water resource management, agriculture, social welfare, transportation and infrastructure, and economic development) should all be developed through a consultative process with the appropriate stakeholders.

The **resource mobilization process** involves ensuring the availability of adequate finance for the implementation of the strategy. Resources for the strategy development process may need to be mobilized from both domestic and international sources, as appropriate. It is important to ensure the availability of adequate domestic resources for all projects, and full engagement of the private sector in the strategy development process. Given the strong global interdependence, mechanisms need to be developed for involving the international community in the strategy process, while the country remains in full ownership of the process. In Iraq's case, although it has large oil reserves, its economic and financial capacity still requires the involvement of donor nations and organizations to assist it in achieving these goals over the short and medium term. Working with donor countries and organizations will also assist Iraq in developing its capacity for civil society development and further its good relationships with these other countries.

In addition, effective implementation of a sustainable development strategy requires the follow-up and monitoring of what is happening, an understanding of what works and what does not. Putting in place an effective monitoring and evaluation mechanism is vital for the strategy process. Process (systems based) evaluation measures the implementation of activities and how effectively this is done. Monitoring of outcomes involves measuring the effect of the activities that have been undertaken, mainly the more immediate, tangible or observable changes. Impact assessment aims to ascertain the more long term and widespread consequences of the intervention. Based on these indicators annual reports should be prepared to enable stakeholders to see progress made.

The sustainable development strategy process is an adaptive process that would require putting in place mechanisms, policies, legal and institutional frameworks for coordinating and integrating economic, social and environmental aspects. Key measures that need to be taken in this context are: developing a sustainable development strategy culture; institutionalization of the strategy process; putting in place appropriate legal and enforcement mechanisms; and mobilizing, engaging and strengthening national capacity for continuous strategy development process.

ORGANIZATIONS INVOLVED IN THE MARSHLANDS

The following sections describe organizations involved with managing, researching, or conserving the marshlands of southern Iraq. All of these organizations, along with the leaders of local townships and villages, should be involved in the process of developing and implementing the Marshlands Management Plan.

Iraqi Governmental Bodies

The following are the Iraqi government agencies that are most intimately involved with management of the marshlands and its economic and human resources, although other agencies' involvement may also be necessary or appropriate. So far, the ministries that have been intimately involved in the planning and studies process have included the Ministry of Water Resources (specifically, the Center for the Restoration of Iraqi Marshes), the Ministry of Environment, the Ministry of Municipalities and Public Works. In January 2004, a meeting was held in Baghdad between nine ministries (Water Resources, Environment, Municipalities, Oil, Education, Health, Agriculture, Planning, and Culture) to discuss the idea of the restoration of the marshes and the role of each of the ministries and how can they work together. However, little coordination has been happening, and given the security situation in Iraq, it is understandable that the ministries have been focused on direct problems that each can address without having to refer to the needs and values of other ministries. Following is a description of the larger of the entities involved.

The Ministry of Water Resources (MoWR): The MOWR was formerly known as the Ministry of Irrigation, is the lead agency for restoration of the Iraqi Marshlands and has declared this to be their highest priority. The Ministry has already acted to restore water flow to portions of the marshlands, as requested by the local marsh dwellers. As part of its effort to assure a scientific basis for the restoration of the marshes, the MoWR has created the Center for Restoration of Iraqi Marshlands (CRIM). The MoWR plays a critical role in determining the allocation of water resources to various uses and areas and at different times and thus is critical in developing the Sustainable Development Strategy and the Marshland Management Plan.

The Center for Restoration of the Iraqi Marshlands (CRIM): CRIM was created by Iraq's Ministry of Water Resources in late 2003 for the purpose of conducting studies and developing plans for the restoration of the marshes in coordination with other Iraqi ministries. CRIM is headed by a director general, however, within the organizational structure of the MoWR, it is a separate office reporting to one of four advisors to the Minister of Water Resources. CRIM is organized into three main technical sections, hydraulics, ecology, and socio-economy. The CRIM is working on several studies, in cooperation with other ministries, donor nations and NGO's. The studies cover all the major sectors discussed above and CRIM personnel were instrumental in the collection and analysis of much of the data presented in this report.

Ministry of the Environment (MoE): The Iraqi Ministry of the Environment (MoE) is a new ministerial-level agency created in 2003. Its current focus with respect to the Mesopotamian Marshlands is the conservation of biodiversity in the Huweizeh Marsh and on evaluation and remediation of environmental contamination in the soil, water, and air. Employees of the MoE participate in the monthly field visits to Abu Zirig and Kurmashia marshes and other marshes that have been covered by the studies being presented in this report. The MoE is also on the Steering Committee of CRIM and takes an active role in its leadership. Further, the ministry has been designated as the focal point for future collaboration on biodiversity surveys and other environmental projects that will be carried out in co-sponsorship with IMET and other donor nations.

Ministry of Municipalities and Public Works (MMPW): The Ministry of Municipalities and Public Works became responsible for the delivery of potable water and collection and treatment of the sewage services after 2003. Prior to that, delivery of potable water was within the responsibility of the Ministry of the Interior. Given the state of water treatment plants in the south of Iraq and the rest of the country, the ministry is faced with an enormous task to assess the status of each of the plant, to update and upgrade the existing services and plants, which have been severely impacted by the lack of investment over the last 35 years. A vast majority of the cities and villages within the three southern governorates (Basrah, Maysan and Dhi Qar) lack even a basic water distribution network or a water treatment network. To determine the needs of the marshes area and to better plan the ministry's future efforts, it has created a section for the Urban Planning of Restoration of the Marshes. The section has been active over the past year and has participated in some of the training exercises as well as the collection of field data and survey analyses.

Ministry of Oil: The Ministry of Oil is the entity responsible for oil extraction and marketing. Given that the marshes of southern Iraq is underlain by three super giant oil fields, this ministry plays a major role in decision-making process of where restoration can take place and how that restoration will be impacted by existing oil production operations and future exploration, extraction and processing. To date, the Ministry of Oil has been tangentially involved with the process of planning; however, this ministry must be a major entity when it comes to making decisions about the future of the marshes.

Ministry of Culture: The Ministry of Culture organized an architectural competition to design a Research Center and Museums in the re-flooded Mesopotamian Marshes. The competition was won by RKBT, a designed team of three Canadian architects of Iraqi origin; Sahar Rassam, Riadh Tappuni and Sal Tappuni, along with Richard Kroeker, an architect based in Canada, and sustainability engineer Trevor Butler from the UK. Once constructed the facility would be a center of ecological research on the marshes as well as a museum on the area and would offer community assistance to the local population in terms of training and skill development to help create jobs and economic development in the area. At this time, funds are being sought to begin construction of the project, however, the effort has not been fruitful to date.

Regional Governance: Under the newly approved constitution of Iraq, there are provisions that allow for the creation of regions or districts by combining two or more governorates under one regional government. At the present time, the area of the marshes is under the control of three governorates. As such, the governors and governing councils, who have a higher degree of autonomy than the past constitution allowed, are also directly involved in making decisions as to the direction of development of the marshes. The newly empowered governors and governorate councils have the authority over water supply and sewage projects in their governorates as well as the distribution of limited budgets. The degree of coordination and overlap between the central or federal ministries and the offices in the governorates is not clear and is awaiting the passage of laws by the new parliament to clarify the areas of responsibilities.

Donor Governments

The involvement of international community in the restoration of the Iraqi marshlands has provided not only financial resources but also technology transfer and the influx of new ideas for environmental conservation and development of a participatory decision-making process. The primary governments involved have included the Italian Ministry of the Environment, the Canadian International Development Agency, Japan's International Cooperation Agency, and the U.S. Agency for International Development.

Italian Ministry of the Environment and Territory (IMET): IMET has been one of the first enthusiasts for the marshes and has supported marshland research and monitoring projects since 2003. Through grants to the Iraq Foundation and Nature Iraq, several large planning projects have been completed, including this report.

Canadian International Development Agency (CIDA): In June 2004, the Canadian International Development Agency (CIDA) pledged up to $300 million in overall assistance for humanitarian and reconstruction efforts in Iraq. As part of this effort, CIDA has granted $3 million (Canadian) to the University of Waterloo's Wetlands Research Centre to provide technical assistance for restoration of the Mesopotamian Marshlands. The Canadian assistance has focused on building scientific and wetland policy capacity with Iraqi universities, NGOs, and the MoE. It is the understanding of the authors that CIDA is particularly interested in funding further the effort to restore the marshes through the encouragement of the creation, training and support of governance bodies responsible for the restoration of the marshes.

Japan International Cooperation Agency (JICA): The government of Japan has been involved in the restoration and redevelopment of the marshes through a grant of 13 million US dollars to the United Nations Environmental Program. UNEP has utilized the grant money to conduct training seminars and capacity building for Iraqi officials and stakeholders in various subjects from sewage treatment to remote sensing. They have also funded the construction of water desalination plants and sewage treatment plants using phytotechnology principles.

United States Agency for International Development (USAID): Through USAID, several initiatives have been undertaken that were fully, or partially focused on the marshes and the Marsh Arabs. In 2003, Developing Alternatives, Inc. (DAI) conducted a field mission to explore the existing conditions in southern Iraq and the feasibility of following the steps outlined in the earlier efforts focused on defining the way forward. A second mission was conducted later in Feb 2004 and several projects focused on agriculture resulted from that visit. The projects included working on fishery to hatch native species. Currently, DAI is tasked with conducting a 100 million dollars study into agricultural improvements in Iraq. One of the main tasks in this project is the creation of a computer model for the Tigris and Euphrates Rivers and their distributaries, reservoirs and tributaries.

Iraqi Scientific Institutions

For many years, scientific research in the marshlands was hindered by security and logistical difficulties; many of those difficulties remain today. Since 2003, many professors and students from Iraq's universities have conducted field work and research on environmental conditions in Iraq, supported by scientists from universities around the world. Adequate resources, including re-building libraries and laboratories, are still necessary to equip these institutions to support the scientific work that will be necessary to aid the restoration process.

University of Basrah: The University of Basrah is the primary higher educational institution in southern Iraq. Its Marine Science Center was established in 1976 and employs over 40 full-time professors and researchers. The center staff and graduate students participated in many of the research projects conducted by IMET and all of the projects being sponsored by CIDA through the CIMI project of the University of Waterloo in Canada. The center also worked with USAID on various projects in 2004 and 2005. IMET continued funding for the fish hatching project conducted by the Marine Science Center in addition to the continued monitoring of various stations in the marshes.

University of Baghdad: The University of Baghdad is the largest and oldest university in Iraq with over 40,000 students in the various colleges and institutes associated with it. Undergraduate and graduate students of biology and ecology and geology have been involved in the research projects of the marshes conducted by Iraq Foundation/Nature Iraq and the Iraqi Ministries.

University of Mustansiriya: The University of Mustansiriya, located in Baghdad, was established in 1963 and generally enrolls about 15,000 students. (Its predecessor, Mustansiriya College, was founded in 1232). Members of the staff of the college of environmental engineering as well as graduate students have been associated with the monitoring of Abu Zirig Marsh and the creation of models for the marshes of Iraq.

University of Thi Qar: The University of Thi Qar is one of the recently founded universities in Iraq and members of the faculty and staff of the university have been involved in the field visits conducted by Iraq Foundation/Nature Iraq and the Iraqi Ministries with funding through CIMI and IMET grants.

Scientific Institutions Outside Iraq

Kuwait Institute of Scientific Research: Kuwait Institute for Scientific Research (KISR) was established in 1967 to carry out applied scientific research in three fields: petroleum, desert agriculture and marine biology. KISR has conducted significant research on the environmental effects of the draining of the marshlands on the Gulf.

University of Waterloo Wetlands Research Centre: The Wetlands Research Centre at the University of Waterloo is committed to research and training on all aspects of wetlands, including evaluation and classification, ecology, hydrology, geochemistry, function, values, management and conservation. The Centre is the recipient of a $3-million grant from the Canadian International Development Agency. It is believed that CIDA will continue to provide funding on capacity building and support for marshland restoration efforts

Royal Holloway Institute for Environmental Research: The Royal Holloway Institute for Environmental Research is a university-based environmental research and consultancy institution with particular expertise in wetland ecosystems. The Institute undertakes pure and applied research in wetland science, and is also the home of the IUCN Commission on Ecosystem Management, which provides guidance on integrated ecosystem approaches to the management of natural and modified ecosystems. The Institute's Director, Dr. Edward Maltby, conducted some of the earliest research of the draining of the Mesopotamian Marshlands, in the late 1990s under a grant from the Amar Appeal and participated in USAID's scientific expedition to the marshlands in February 2004

Duke University Wetland Center: The goal of the Duke University Wetland Center is to provide sound scientific knowledge that will lead to sustainable wetland functions and values for the nation and the world. The center works toward this goal by conducting, sponsoring and coordinating research and teaching on critical wetland issues. The Center's Director, Dr. Richardson participated in USAID's scientific expeditions to the marshlands in June 2003 and February 2004.

U.S. Army Corps of Engineers (USACE): Since March 2003, the U.S. Army Corps of Engineers (USACE) has provided technical assistance to Iraq's Ministry of Water Resources (MoWR) throughout Iraq. The U.S. Army Corps of Engineers and the Ministry of Water Resources are jointly developing a hydrologic model of the Tigris and Euphrates Basin through a grant from USAID to the Hydraulic Engineering Center (HEC). Nature Iraq is entering into an agreement with USACE to encourage technology and expertise transfer to Iraqi technicians and engineers through future training programs.

Iraqi Nongovernmental Organizations

Before the war of 2003, very few independent, nongovernmental organizations (NGO) existed in Iraq. No organizations existed to provide education and research in the marshland areas. Many new groups formed after the war, but they suffer from lack of experience and inadequate funding. In addition, a number of Iraqi organizations that operated outside of the country, entered Iraq after the war and brought with them their knowledge and expertise in NGO administration, project management and fundraising. Nature Iraq, a partner in the New Eden Team, is an example of this latter group.

Nature Iraq: Nature Iraq began originally as the Eden Again Project of the Iraq Foundation, a Washington, DC based NGO. Following the war, Nature Iraq was established as a wholly Iraqi NGO focused on environmental research. Its staff include over 120 full and part time employees who work on various project sponsored by IMET, CIMI and UNEP. The organization also is working on environmental projects beyond the marshes and is building on the set of skills and staff developed as part of the marshes program. In addition, Nature Iraq attempts to use its expertise to help other Iraqi environmental NGO's gain experience and in the summer of 2005 it conducted a survey of Iraqi environmental groups and provided a regional training for twelve of these organizations from northern, central and southern Iraq in Amman, Jordan in September 2005.

The following is a list of Iraqi NGOs who have formed in the marshland areas or who have stated that they have projects in the marshlands. Please note that this is not a complete listing.

1. Chibayish Marshes Council (Nasiriyah)
2. Environment Protection Society in Thi-Qar (Nasiriyah)
3. Iraqi Green Peace Association (IGPA) (Basrah)
4. Iraqi Nature Conservation Society (INCS) (Baghdad)
5. Iraqi Marshes Association (Baghdad)
6. Iraqi Woman's Charitable Association (IWCA) (Basrah)
7. Marsh Arab Forum (Nasiriyah)
8. Scientific Society for Developing Marshes in Iraq (Nasiriyah)
9. Woman & Environment Organization (Baghdad)

INTERNATIONAL AND REGIONAL CONSERVATION ORGANIZATIONS

The following organizations are actively involved in conservation issues regarding the marshlands of southern Iraq.

United Nations Environmental Program (UNEP): UNEP has historically provided leadership and scientific expertise to the issue of the desiccation of the Mesopotamian Marshlands. In 2001, Mr. Hassan Partow prepared the report entitled "The Mesopotamian Marshlands: Demise of an Ecosystem." This report provides an accurate, objective summary of the state of the Mesopotamian

Marshlands as of 2001. Another study, the "Desk Report on the Environment in Iraq" was prepared by UNEP's Post Conflict Assessment Unit in March 2003. In 2004, UNEP began to implement a new program funded by the government of Japan to aid in the restoration of the marshes using technological solutions for the provision of drinking water and sewage treatment. Several training seminars were held in Amman, Cairo, Japan on the use of phyto-technologies to treat sewage water; on management of water assets, and on remote sensing technologies. Further, six pilot projects were designed and constructed to provide potable water supplies for the residents of various villages in the south of Iraq. Future funding and projects are pending.

Birdlife International: BirdLife International is a global alliance of conservation organizations working together for the world's birds and people. In 1994, BirdLife published its report "Important Bird Areas of the Middle East" that provided essential information on the bird life and habitats within the Middle East including Iraq. BirdLife participated in the training of members of bird watching teams that were later mobilized in southern Iraq to conduct seasonal surveys through funding by the University of Waterloo (CIDA). The results of the bird survey will be published by Nature Iraq in a book titled the “Birds of Iraq.” Further, Nature Iraq is discussing the idea of becoming a partner of BirdLife International in Iraq to continue the partnership that was started with the bird survey project.

Royal Society for the Conservation of Nature: The Royal Society for The Conservation of Nature is an independent voluntary organization in Jordan devoted to the conservation of Jordan's natural resources. RSCN was established in 1966 under the patronage of Her Majesty Queen Noor, with the mandate of protecting and managing the natural resources of Jordan. RSCN has co-sponsored many of the meetings that have been convened in Amman, Jordan to train various participants in the marshes restoration work. RSCN is also helping design future activities to protect the environment of Iraq through partnerships with Nature Iraq and other Iraqi and regional NGO’s focused on the environment.

PLAN PREPARATION

An Ecological Restoration Plan should be developed as part of a National Sustainable Development Strategy described above. This would be developed in conjunction with other portions of the Sustainable Development Strategy, including infrastructure development plans to ensure coordination amongst efforts and fulfillment of the ultimate goals of the region. The information and technical analysis provided in the New Eden Master Plan provides much of the data needed to develop the Ecological Restoration Plan; what is now needed is the political and participatory process. Detailed guidance on the development of an Ecological Restoration Plan is provided by RAMSAR Bureau at http://www.ramsar.org/key_guide_mgt_new_e.htm. The following paragraphs are based upon the guidance provided at the RAMSAR web site.

A wetlands management plan should be integrated into the public development planning system at local, regional and national levels. The integration of site management plans into spatial and economic planning at the appropriate levels will ensure implementation, public participation and local ownership. Furthermore, integration of the goals with the needs of the stakeholders will enhance the possibility of local as well as external funding. The management plan is part of a dynamic and continuing management planning process. The plan should be kept under review and adjusted to take into account the monitoring process, changing priorities, and emerging issues.

An authority should be appointed to implement the management planning process, and this authority should be clearly identified to all stakeholders. This is particularly important on a large site (such as the Mesopotamian Marshlands) where there is a need to take account of all interests, users, and pressures on the wetland, in a complex ownership and management situation. Given the myriad of stakeholders (MoWR, MoE, MMPW, MoO, MoT, Federal government, regional government, city councils, NGO's, etc.), it is rather difficult to "appoint" one leading agency to be the designated leader, however, it may be possible. The issue of who and how the planning process should be "led" by is going to be subject to discussions in coming meetings between the interested parties to be sponsored by the University of Waterloo. The results of the workshop will inform the next steps to be taken with respect to how to create an authority that will be the lead agency in charge of the planning of the restoration and long term management of the wetlands.

It is the permanent presence of water in wetlands, or at least for some significant period of time, that creates the soils, micro-organisms, and plant and animal communities such that the land functions in a different way from terrestrial habitats. Successful management of wetland sites therefore requires maintenance of these sources of water. The inter-connectedness of the hydrological cycle means that changes some distance from the wetland can have a detrimental impact. Insufficient water reaching wetlands, due to climate change, land use change, obstructions, storage and diversion of water for public supply, agriculture, industry and hydropower, are all major causes of wetland loss and degradation. A key requirement for wetland conservation and wise use is to ensure that adequate water of the right quality is allocated to wetlands at the right time. Consequently, achieving water allocation for wetlands will often be a long term process that needs careful planning and will include training and awareness-building about the benefits of wetlands. These benefits need to be presented in a manner in which the trade-offs with other water users can be evaluated. Some benefits, such as fisheries, can be given a monetary value that fits into a traditional financial analysis, but this is generally not the case for social, cultural and ecological benefits. One such effort is presented as part of this report. The socio-economic study focused on obtaining input from local stakeholders that represent the entire society and all its various sectors to determine a relative economic value of the wetlands. We are also aware that the Ministry of Planning is conducting similar studies that are focused on finding an economic value for the water being used in Agriculture, vs. industry, vs. ecology. The results of these studies should be summarized and used by the "leading authority" in the process of evaluating the various available alternatives or scenarios for restoration.

A 'stakeholder' is taken to mean any individual, group or community living within the influence of the site, and any individual, group or community likely to influence the management of the site. This will obviously include all those dependent on the site for their livelihood. Wetland management, and particularly the planning process, should be as inclusive as possible. Legitimate stakeholders, particularly local communities and indigenous people, should be strongly encouraged to take an active role in planning and in the joint management of sites. It is highly desirable that positive steps be taken to ensure that gender issues, including women and their interests, are fully taken into account at all stages in the process.

While this report attempts to collect and collate all available relevant information about the site in order to describe its ecological character and its functions and values, including all relevant socio-economic, cultural and educational features, we are aware that there a lot of data that exists with various entities and organizations working on the marshes. It is rather important that additional existing data be collected and collated to assure that widest possible foundation for understanding the ecological principals upon which the marshes evolved. Any shortfall of relevant information must be recorded, and projects should be planned to correct this deficiency. In time, as further information is collected and resources become available, the plan can grow, and may eventually meet all site management requirements. Once data collation and the preparation of the descriptive sections of the plan are complete, the process moves on to preparing management objectives concerning the maintenance of the ecological character and other aspects of interests to stakeholders. Once the obligations are known, planners can then move on to identify the management requirement.

The next step of developing a management plan is to define objectives. An objective is an expression of something that should be achieved through management of the site. Objectives should have the following characteristics: 1) Objectives must be quantified and measurable. If they are not measurable, it will be impossible to assess through monitoring whether they are being achieved. 2) Objectives should be achievable, at least in the long term. This is a very obvious, but often forgotten, characteristic - there can be little purpose in pursuing unattainable objectives. 3) Objectives must not be prescriptive: they define the condition required of a feature and not the actions or processes necessary to obtain or maintain that condition. Objectives are an expression of purpose. A differentiation should be made between the purpose of management and the management process, because the management undertaken to safeguard a feature will vary according to the condition of that feature. This report does not attempt to define the objectives, rather it gives the tools needed to study the various scenarios available to come up with alternatives or objective that can be further defined and studied in detail to plan the over all management plan for the marshes.

Once the objectives are defined, an action plan is developed to achieve them. For each action established, it is important that the following issues be given attention: 1) what priority is given to each action; 2) which entity has the responsibility for making sure the action is accomplished; 3) how much the action project will cost; 4) when the work will begin and when will it be finished; and 5) how the success of the project will be measured.

Once the action plan has been developed, for operational purposes it can be appropriate to compile the suite of management projects into an annual Operational Plan which is designed to guide and assist in monitoring implementation. It is essential that the plan change, or evolve, if the monitoring of results indicates that the objectives are not being achieved. The New Eden Group stands ready with funding for helping the Iraqi stakeholders use the tools presented herein and to provide scientific support in the planning of the future steps needed to further refine the master plan for the restoration and redevelopment of the marshes.

Preparation of Flow Pulse Recommendations

The primary purpose of this paragraph is to present a methodology for the development of a strategy for identifying key aspects of flow regimes that are important in sustaining a healthy restoration scenario in the marshes (see table below for an example of some of the benefits associated to the creation of flow pulses strategies for the marshes). This is accomplished by capturing existing information and knowledge and presenting it in a fashion that will best support the exercise of developing flow recommendations. Book 1 of this Plan was indeed developed with the intent of providing some of this background information.

FLOW COMPONENT	ECOLOGICAL ROLES
Low (base) flows	Normal level: Drought level: • Enable recruitment of certain floodplain plants • Purge invasive, introduced species from aquatic and riparian communities • Concentrate prey into limited areas to benefit predators
High pulse flows	• Shape physical character of river channel including pools, riffles • Determine size of stream bed substrates (sand, gravel, cobble) • Prevent riparian vegetation from encroaching into channel • Restore normal water quality conditions after prolonged low flows, flushing away waste products and pollutants • Aerate eggs in spawning gravels, prevents siltation • Maintain suitable salinity conditions in estuaries
Large floods	• Provide migration and spawning cues for fish • Trigger new phase in life cycle (e.g., insects) • Enable fish to spawn on floodplain, provide nursery area for juvenile fish • Provide new feeding opportunities for fish, waterfowl • Recharge floodplain water table • Maintain diversity in floodplain forest types through

prolonged inundation (i.e., different plant species have different tolerances)

- Control distribution and abundance of plants on floodplain
- Deposit nutrients on floodplain
- Maintain balance of species in aquatic and riparian communities
- Create sites for recruitment of colonizing plants
- Shape physical habitats of floodplain
- Deposit gravel and cobbles in spawning areas
- Flush organic materials (food) and woody debris (habitat structures) into channel
- Purge invasive, introduced species from aquatic and riparian communities
- Disburse seeds and fruits of riparian plants
- Drive lateral movement of river channel, forming new habitats (secondary channels, oxbow lakes)
- Provide plant seedlings with prolonged access to soil moisture

Table 10: list of benefits associated to flow pulses

It is usually very helpful to structure the literature review, summary report, and flow recommendations using a simple classification of river flow conditions into three "ecological flow components" – low flows, high flow pulses, and floods. Under natural conditions, low flows (also known as base flows) occur during periods between storm runoff or snowmelt, when groundwater contributions are the primary source of river flow. High flow pulses occur when a rainstorm or snow melt causes a rise in river levels, but the magnitudes of these high flow pulses are less than the river's bank-full level. Flood levels can be defined as anything greater than the bank-full level. In the literature review, information about hydro-ecological relationships is categorized according to whether the information applies to low flows, or high flow pulses, or floods. When reviewing pertinent literature, it is very important to note the time of year at which the flow condition needs to occur, such as the occurrence of floods during a spawning season. It is also helpful to distinguish whether the relationship being described needs or tends to occur every year, or only during unusually wet or dry years.

In performing the literature review, the various organization should look for both direct and indirect connections between the components of a flow regime and a variety of biota. Species-specific information can be extremely useful in developing initial flow recommendations, particularly if the species is known to be a keystone species, or if its flow needs are representative of a habitat guild, or if some phase(s) of its life cycle is strongly tied to specific flow conditions. Many of these flow-biota relationships will reflect direct connections, such as the flow levels needed to enable fish spawning migrations. However, other relationships will be indirect, such as the influence of freshwater flows on salinity distributions in estuaries that affect estuarine organisms. Because flows of various levels influence physical habitats, water chemistry, energy supplies, connectivity among different habitats, and species interactions, any information describing the inter-relationship of flow with these other ecosystem variables could be useful in developing flow restoration recommendations. Attention also should be paid to the necessary intra- and inter-annual variability in each of the three flow conditions. For example, sustaining a population of fish may require large floods that enable access to floodplain spawning areas during the spring season, but the fish may not need such access every year.

Definition of water flow requirements

The following paragraphs describe the type of information which is typically collected prior to the preparation of flow pulse recommendation. The

Hydrology

Assess differences between natural, historic, present day, and future hydrologic conditions:

1. Prepare "typical" hydrographs (both annual and decadal hydrographs) for undeveloped and developed conditions.
2. Categorize the natural hydrologic regime into ecological flow components: low flows, high flow pulses, floods. Estimate quantitative values for each of these components under natural, historic, present, and (if appropriate) future conditions.
3. Prepare flow duration curves for undeveloped and developed conditions.
4. Provide schematic drawing of drainage network, noting the mean annual flow and drainage basin area at all available stream gauge stations.
5. Provide tabular summary of water uses and water structures, at the finest level of detail available.
6. Characterize typical groundwater-surface water interactions

Hydraulics

Assess the influence of different flow levels on river stage and floodplain inundation at selected river reaches:

1. Develop river stage-discharge relationships.
2. Plot the relationship between flow and estimated percent of marshes inundated at representative transects.
3. Develop flow depth and velocity estimates across river and marshes transects.

Geomorphology

Assess changes in physical river conditions over time:

1. Plot the river's present-day longitudinal profile from topographic maps or field survey information
2. Characterize historical changes in longitudinal river slope, if adequate data are available (e.g., at multiple river flow monitoring station locations).
3. Review historical aerial photographs to assess changes in river plan form and floodplain over time
4. Assess changes in channel cross-sectional shape, if data are available (e.g., at river flow monitoring stations)
5. Develop sediment budget estimates for appropriate representative time periods, such as historic, pre-dam agricultural, and post-dam.
6. Estimate flows necessary to entrain sediments (to maintain desired streambed composition).
7. Estimate channel forming flows necessary to maintain desired channel geometry.
8. Estimate channel migration flows needed to sustain floodplain development.

Water Quality

Assess changes in chemical qualities of river over time:

1. Characterize natural and post-development patterns of water temperature, including seasonal and diurnal fluctuations.
2. Characterize natural and post-development patterns of dissolved oxygen in water, including seasonal and diurnal fluctuations.
3. Where appropriate, delineate estuarine patterns in the freshwater-saltwater interface, considering dynamics associated with low flow, high flow pulse, and floods during dry, average, and wet years.
4. Identify known relationships between reservoir releases and response of contaminants present in the reservoir.

Freshwater and Estuarine Ecology

Characterize life histories of key species and necessary habitat conditions:

1. Define life history stages for a diverse cross-section of species, such as aquatic plants, invertebrates, and resident and anadromous fishes, along with any known relationships to flow components and their seasonality. Specific life history aspects to consider include adult foraging, survival, and gonadal development; spawning migration and activity; egg, larva, and juvenile development; juvenile growth and survival.
2. Define relationships between flow components and maintenance or access to critical habitat for completion of life history stages for key species.

3. Describe ways in which flow components will influence primary productivity, decomposition processes, and nutrient dynamics.

Riparian Ecology

Characterize life histories of key species and necessary habitat conditions:

1. Define life history stages for a diverse cross-section of riparian obligate flora and fauna species, along with known relationships to flow components and the seasons in which they occur.
2. Define relationships between flow components and maintenance or access to riparian habitat conditions.
3. Describe relationships between flow components and vulnerability to disturbances such as fire or introduced species invasions.
4. Describe ways in which flow components will influence primary productivity, decomposition processes, and nutrient dynamics

REFERENCES

Balla, D and T Kalettka. 2005. Sulfate retention capacity of the German wetland region Spreewald. ICID 21st European Regional Conference, Frankfurt, Germany.

Chimney, M.J., M. Numgesser, J. Newman, K. Pietro, G. Germain, T. Lynch, g. Goforth, and M.Z. Moustafa 2001. Stormwater treatment areas – status of research and monitoring to optimize effectiveness of nutrient removal and annual report on operation compliance. In: 2000 Everglades Consolidated Report. South Florida Water Management District, West palm Beach, FL, USA.

Gillespie, DT. 1976. A general method for numerically simulating the stochastic time evolution of coupled chemical reactions. Journal of Computational Physics, 22:403-434.

Hopkins, J.S. 2001. Special water quality survey of the Pecos and Gallinas Rivers below the Viveash and Manuelitas fires. Prepared for the Surveillance and Standards Section, Surface Water Quality Bureau, New Mexico Environmental Department, Santa Fe, NM, USA.

IMET. 2004. New Eden Water and Energy Project. Technical Book 1. Abu Zirig Marshland Restoration Project. Free Iraqi Foundation.

Kadelec, R.H. and R.L. Knight. 1996. Treatment Wetlands. CRC Press, Inc. Boca Raton, FL. USA.

Mackay C.E, M. Johns, J.H. Salatas, B. Bessinger, and M. Perri. 2006. Stochastic Probability Modeling to Predict the Environmental Stability of Nanoparticles in Aqueous Suspension. Integrated Environmental Assessment and Management, (In Press).

McIntosh, A.W. 1991. Trace metals in freshwater sediments: A review of the literature and an assessment of research needs. In: Metal Ecotoxicology – Concepts and Applications. M.C. Nedman and A.W. McIntosh (eds.). Lewis Publishers, Chelsea, MI, USA.

Mitsch, W.J. and J.G. Gosselink. 1993. Wetlands. Second Edition. Van Nostrand Reinhold, New York. USA.

Neilson, A.H. 2000. Organic Chemicals – An Environmental Perspective. CRC Press, Inc. Boca Raton, FL. USA.

Prairie, Y., C. Duarte, J. Kalff, and C. Duarte. 1989. Unifying Nutrient – Chlorophyll relationships in lakes. Canadian Journal of Fisheries and Aquatic Sciences 46:1176-1182.

Redfield, AC. 1958. The biological control of chemical factors in the Environment. American Scientist 46:205-221.

Sansanayuth, P., A. Phadungchep, S. Ngammontha, S. Ngdngam, P. Sukasem, H. Hoshino, and M.S. Tabucanon. 1996. Shrimp pond effluent: Pollution problems and treatment by constructed wetlands. Water Science and Technology 34:93-98.

UNEP. 2005. Environmental aspects of eutrophication. In: Planning and Management of Lakes and Reservoirs: An Integrated Approach to Eutrophication. Technical Publication 11:1-4-1.

USEPA. 2002. Procedures for the Derivation of Equilibrium Partitioning Sediment Benchmarks (ESBs) for the Protection of Benthic Organisms: Metal Mixtures (Cadmium, Copper, Lead, Nickel, Silver, and Zinc). US Environmental Protection Agency, EPA-600-R-02-011.

ANNEX I

ANNUAL VOLUME BALANCE FOR REFLOODING MANAGEMENT

The following images show the results of the zero-dimensional model analysis per each marsh. The plots depict the annual volume balance according to different inflow system and different re-flooding percentage and the annual volume balance with different outlet discharge capacity.

Abu Zirig Marsh

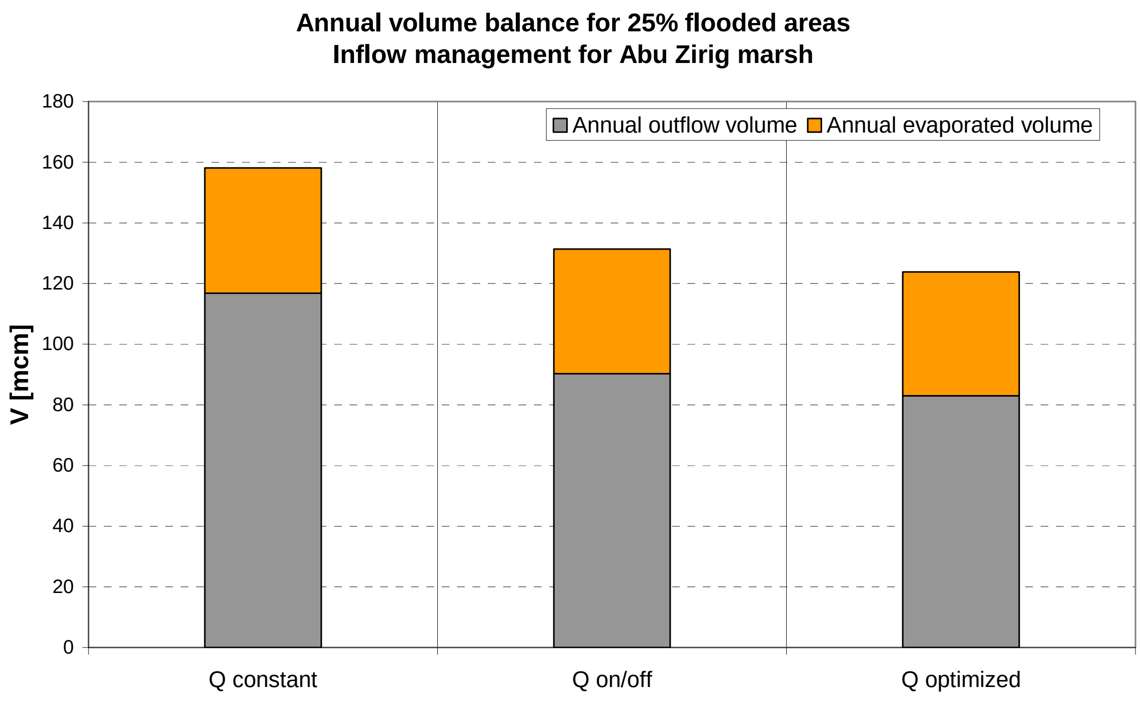


Figure 46: Annual volume balance for SI, On-Off, OI methods, for Abu Zirig – 25%

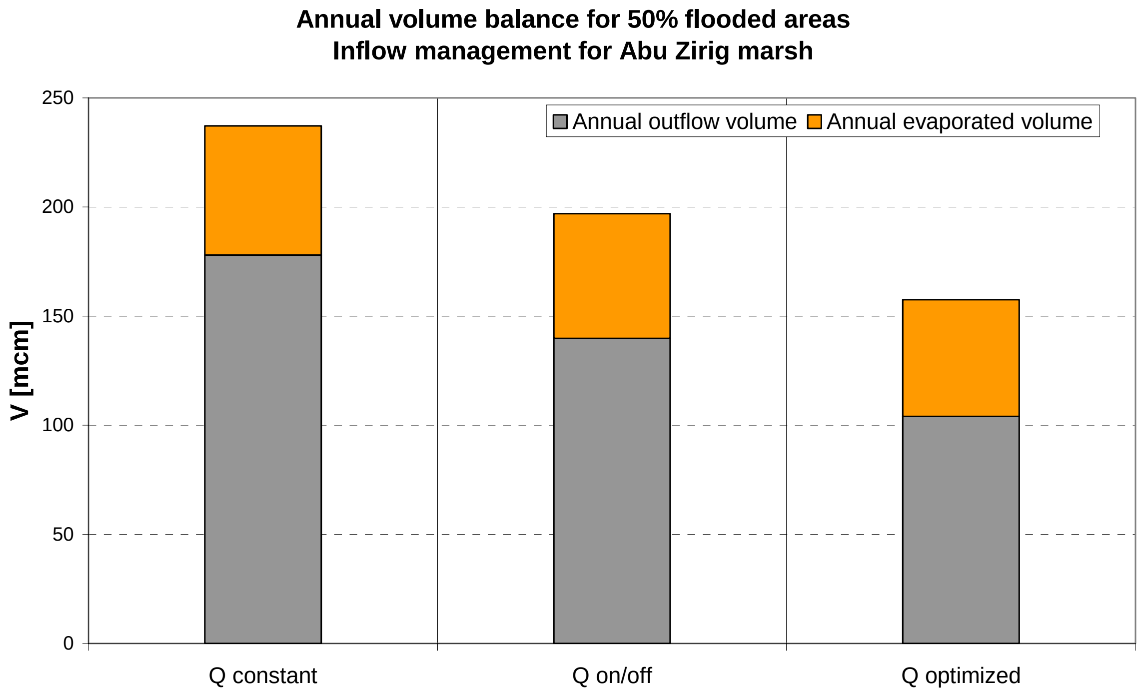


Figure 47: Annual volume balance for SI, On-Off, OI methods, for Abu Zirig –50%

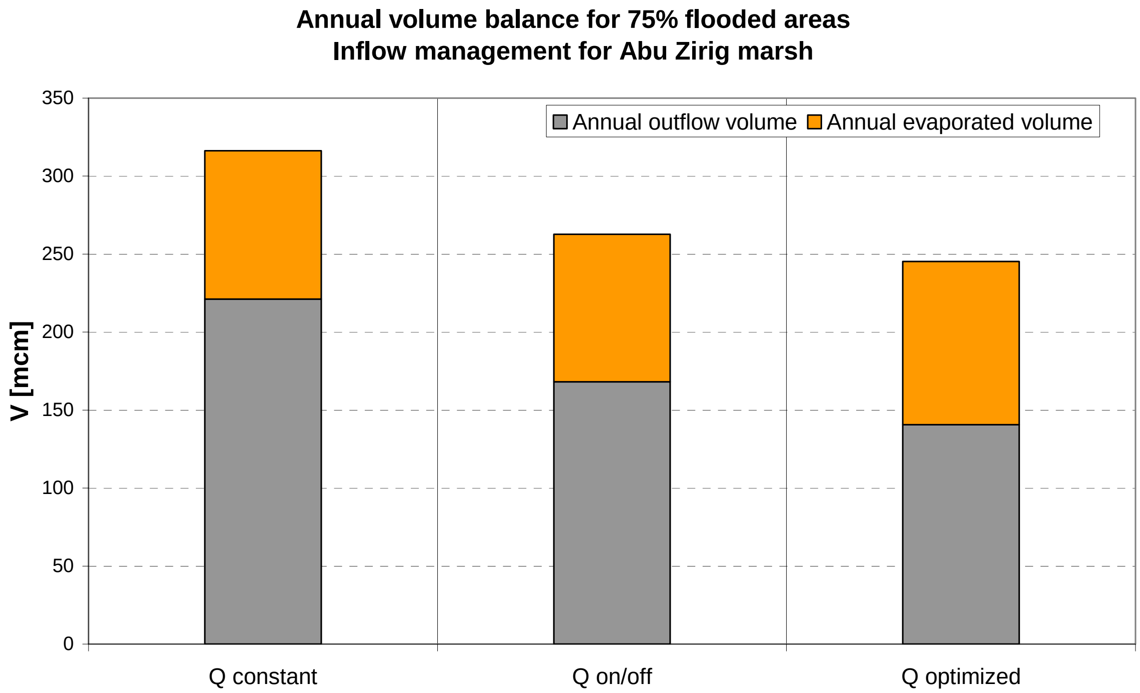


Figure 48: Annual volume balance for SI, On-Off, OI methods, for Abu Zirig – 75%

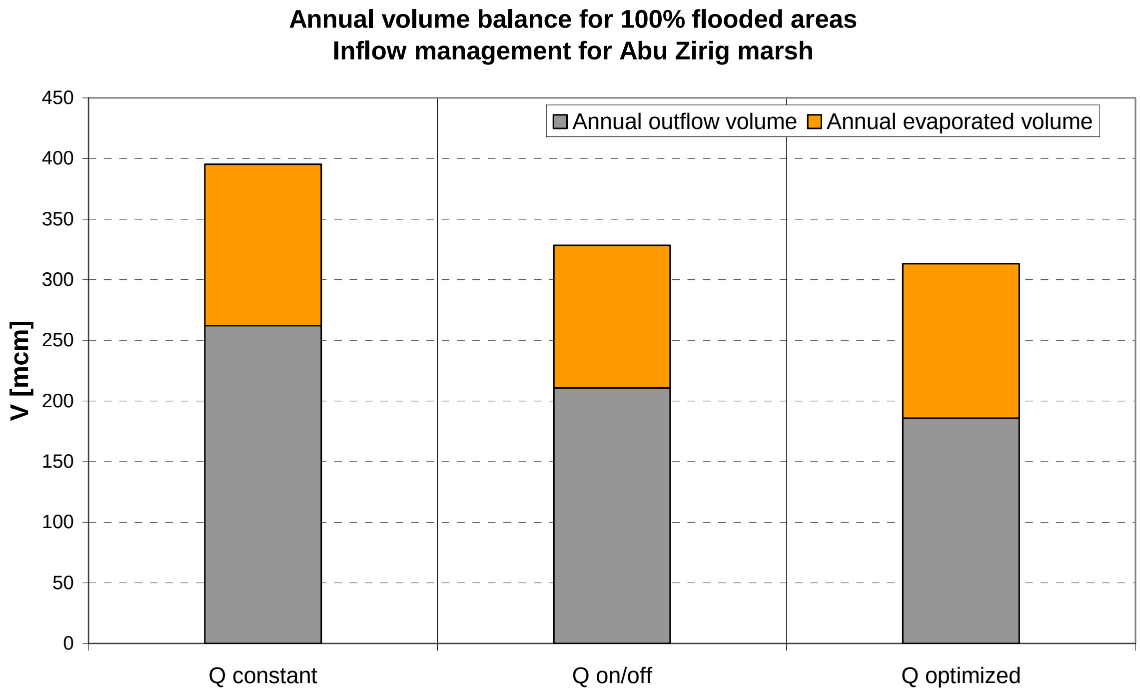


Figure 49: Annual volume balance for SI, On-Off, OI methods, for Abu Zirig – 100%

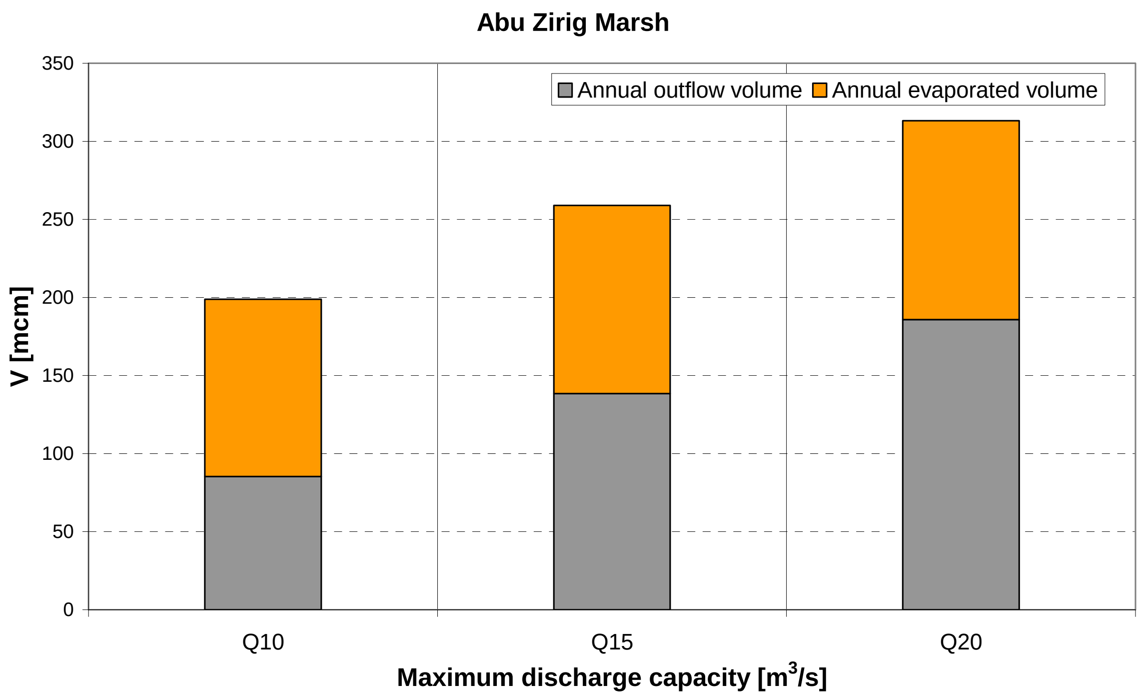


Figure 50: Annual volume balance for Abu Zirig Marsh with different outlet discharge capacity

Central Marsh

The Euphrates river is responsible for low reflooding scenarios, with an extension less than 25%: flooded areas are located in the southern part of the marsh. For this reason the inflow necessary for low reflooding percentages was not studied and the volume balance for 25% scenario is not shown.

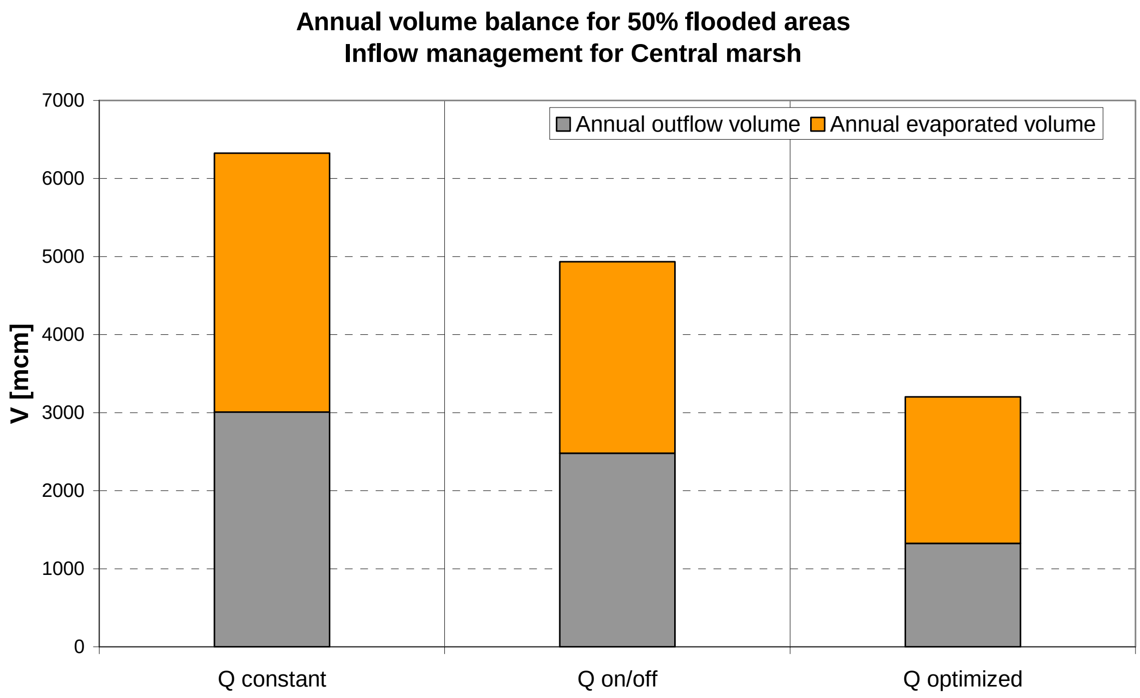


Figure 51: Annual volume balance for SI, On-Off, OI methods, for Central marsh – 50%

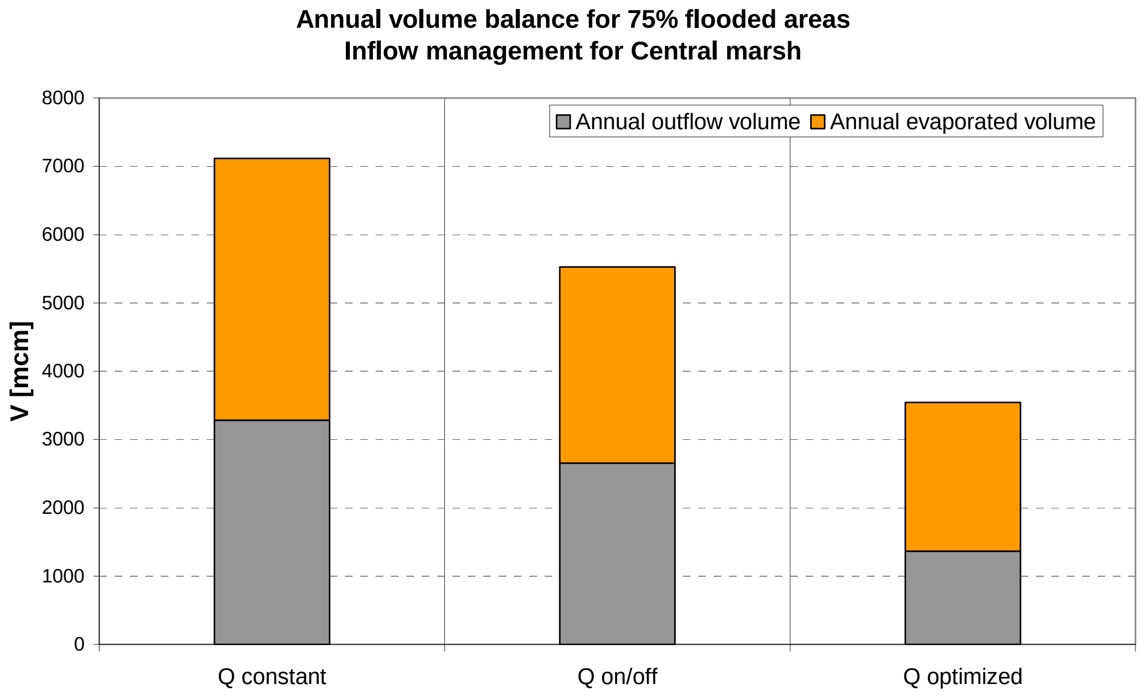


Figure 52: Annual volume balance for SI, On-Off, OI methods, for Central marsh – 75%

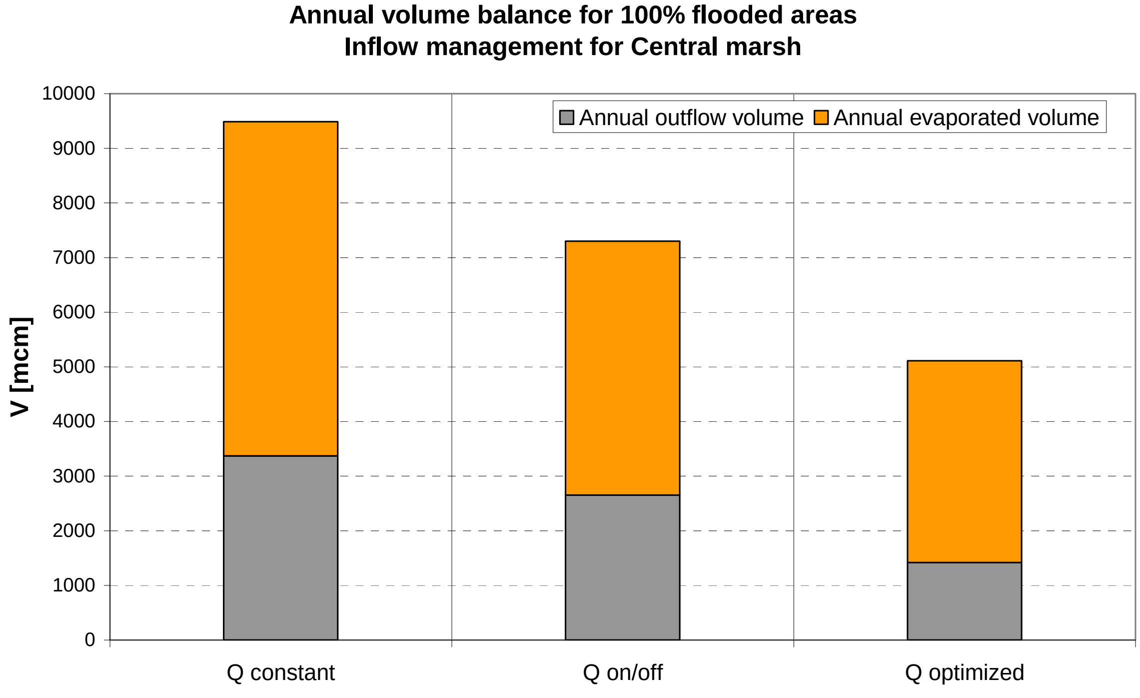


Figure 53: Annual volume balance for SI, On-Off, OI methods, for Central marsh – 100%

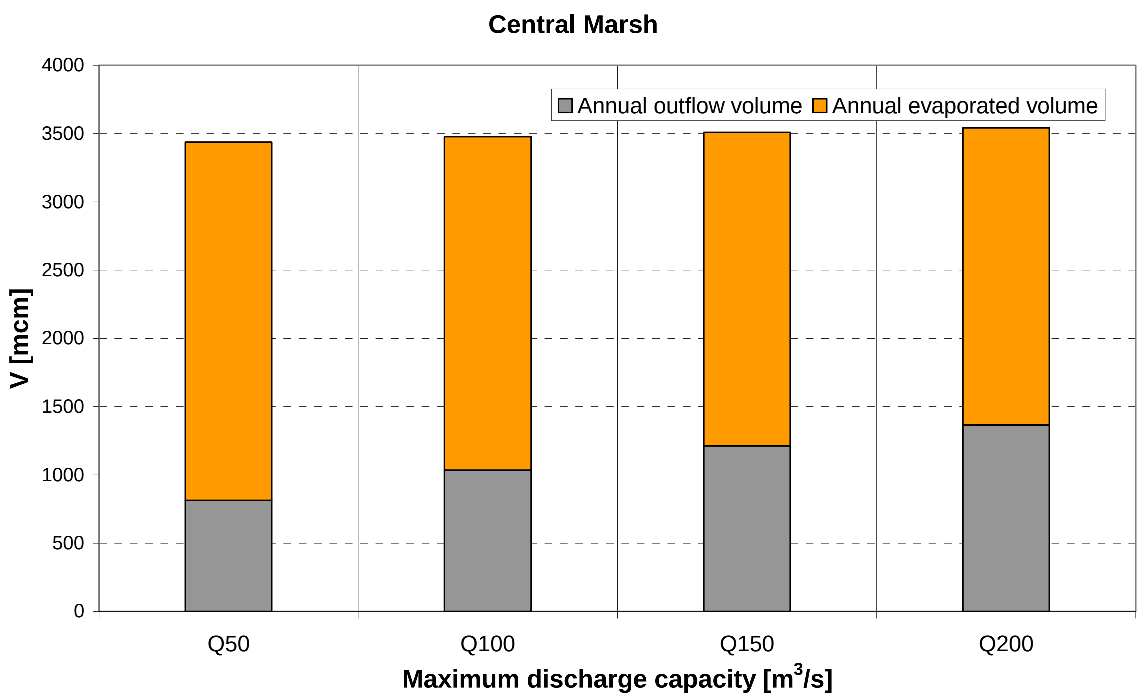


Figure 54: Annual volume balance for Central Marsh with different outlet discharge capacity

Hammar Marsh

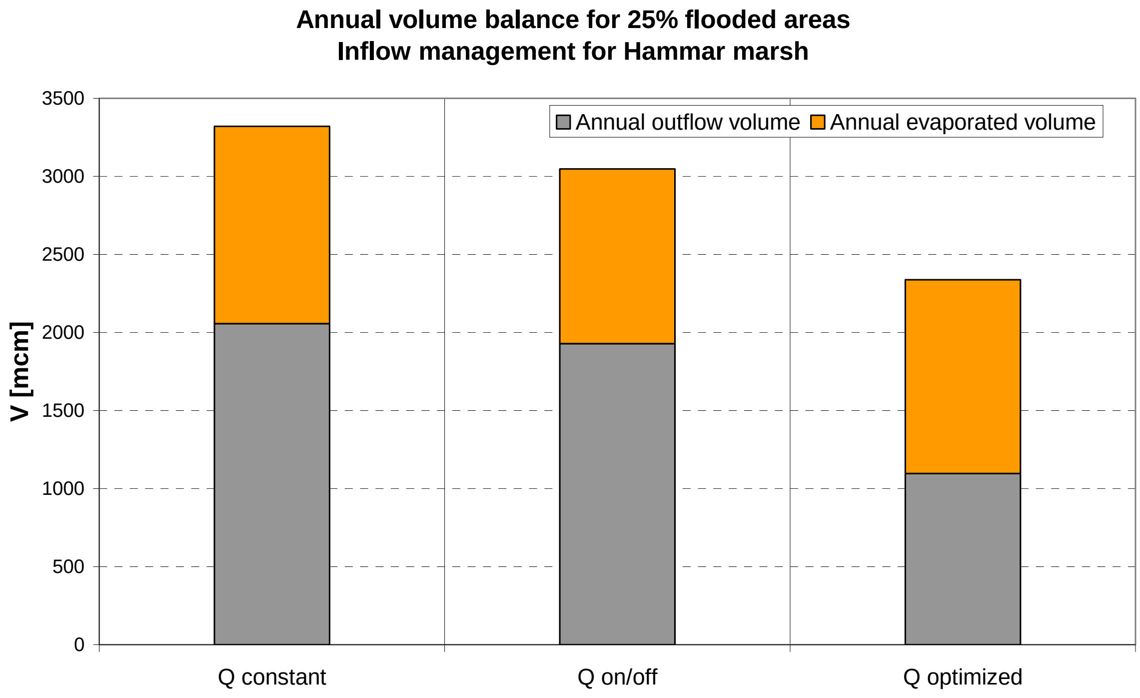


Figure 55: Annual volume balance for SI, On-Off, OI methods, for Hammar marsh – 25%

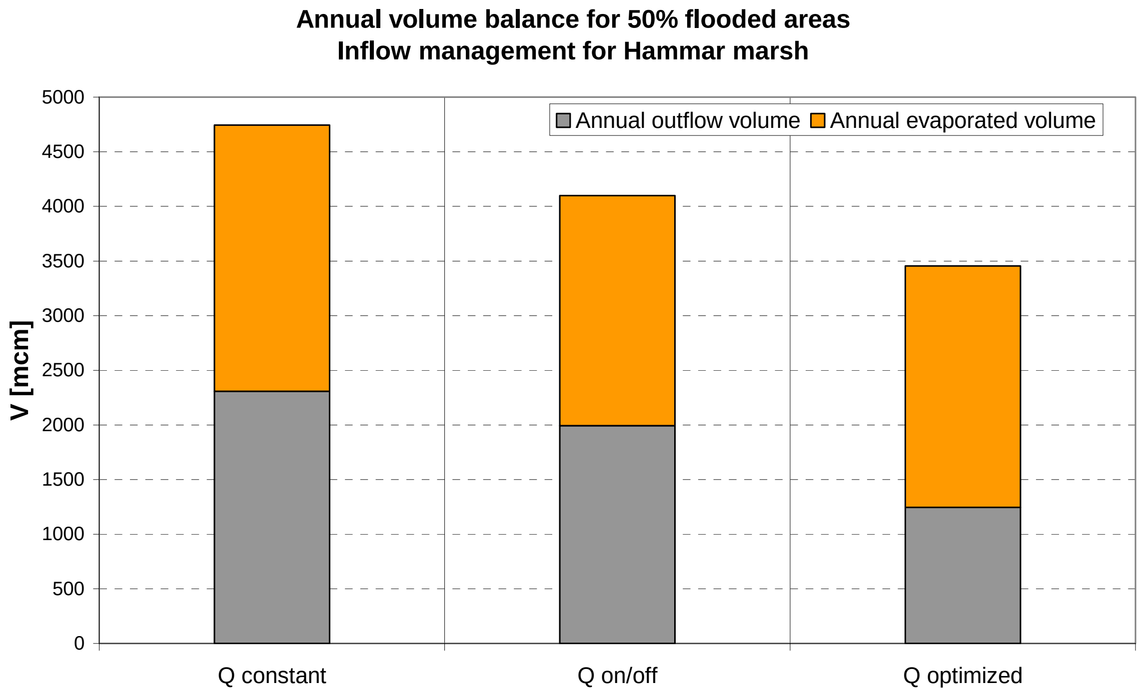


Figure 56: Annual volume balance for SI, On-Off, OI methods, for Hammar marsh – 50%

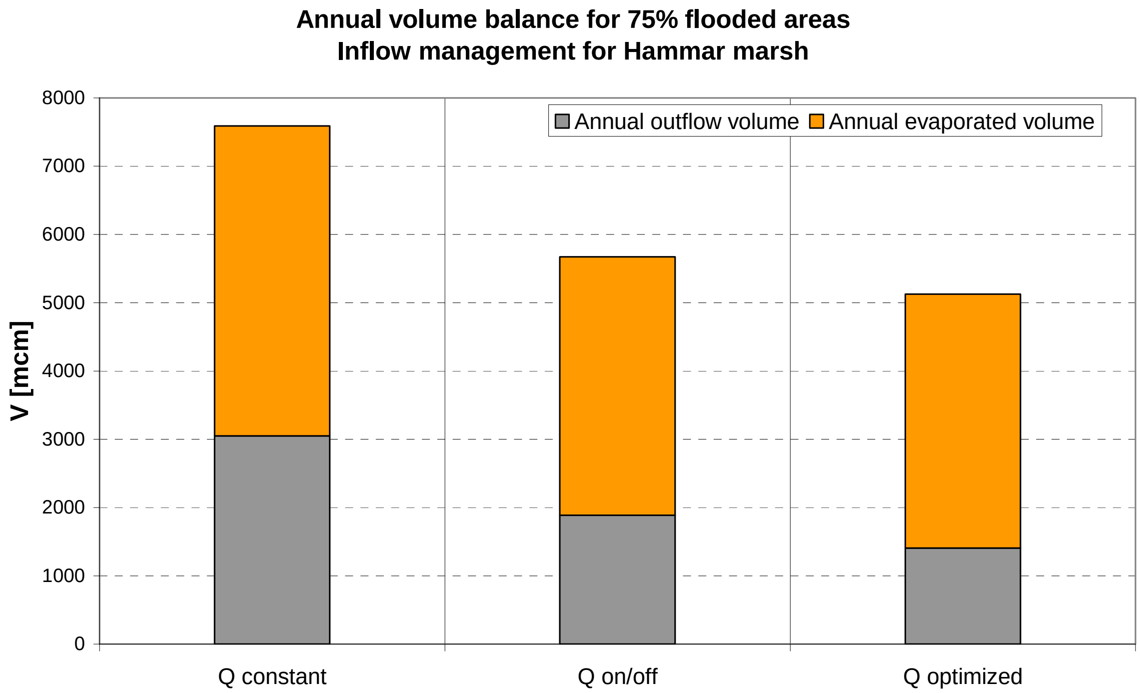


Figure 57: Annual volume balance for SI, On-Off, OI methods, for Hammar marsh – 75%

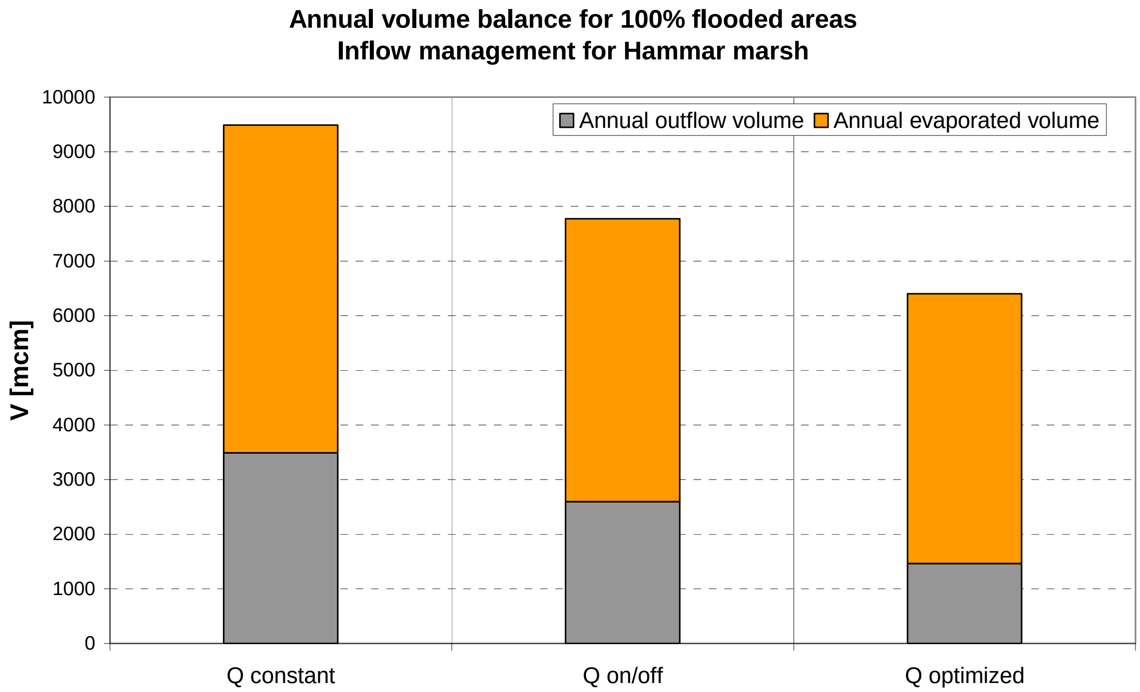


Figure 58: Annual volume balance for SI, On-Off, OI methods, for Hammar marsh – 100%

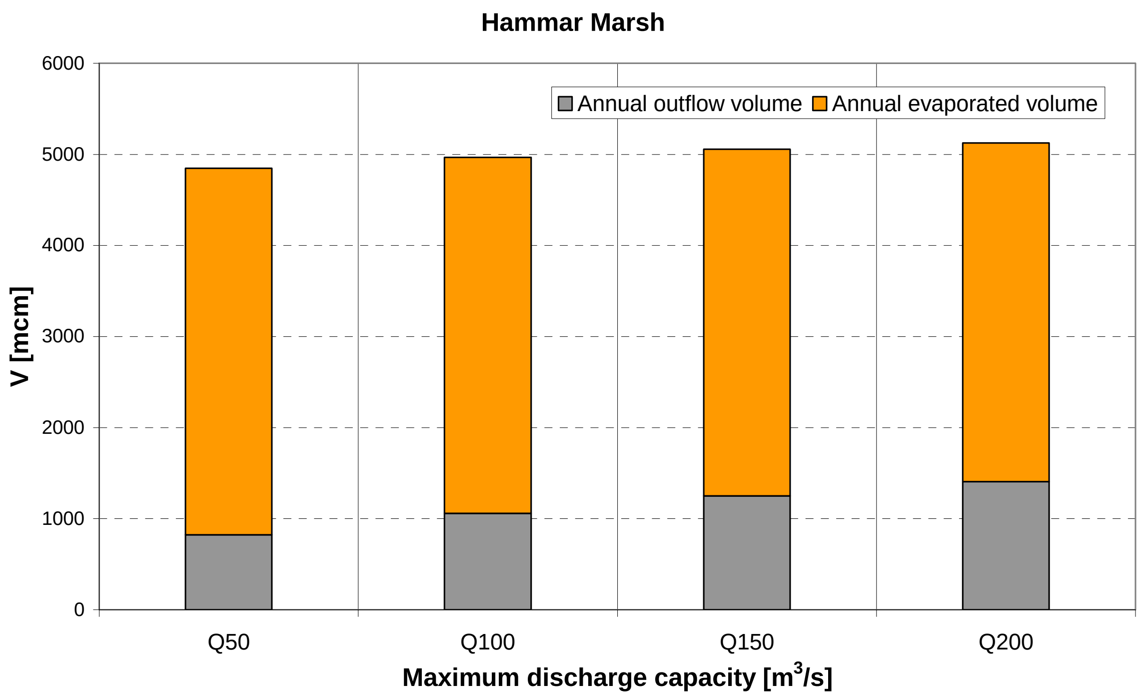


Figure 59: Annual volume balance for Hammar Marsh with different outlet discharge capacity

Hawizhe Marsh

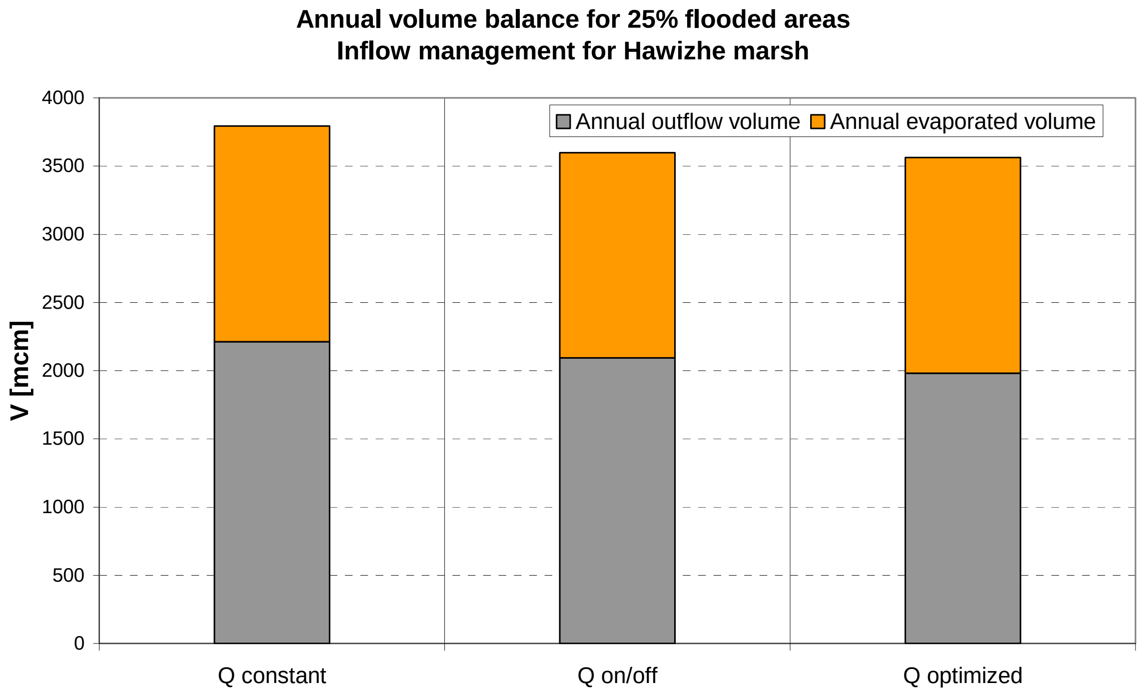


Figure 60: Annual volume balance for SI, On-Off, OI methods, for Hawizhe marsh – 25%

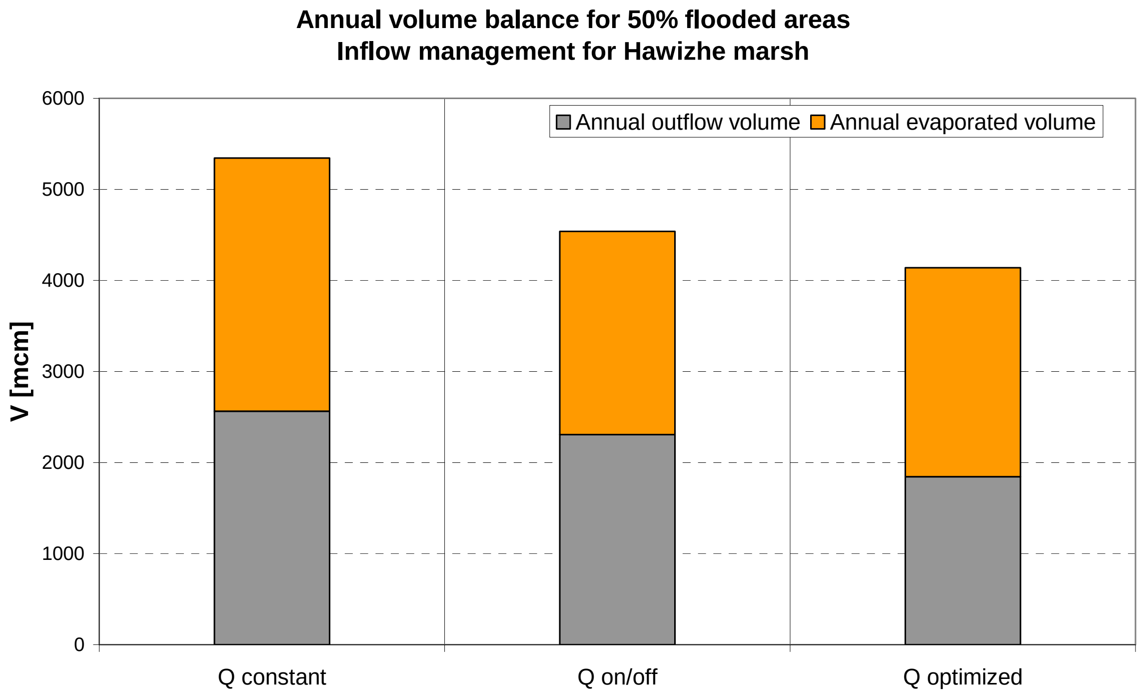


Figure 61: Annual volume balance for SI, On-Off, OI methods, for Hawizhe marsh – 50%

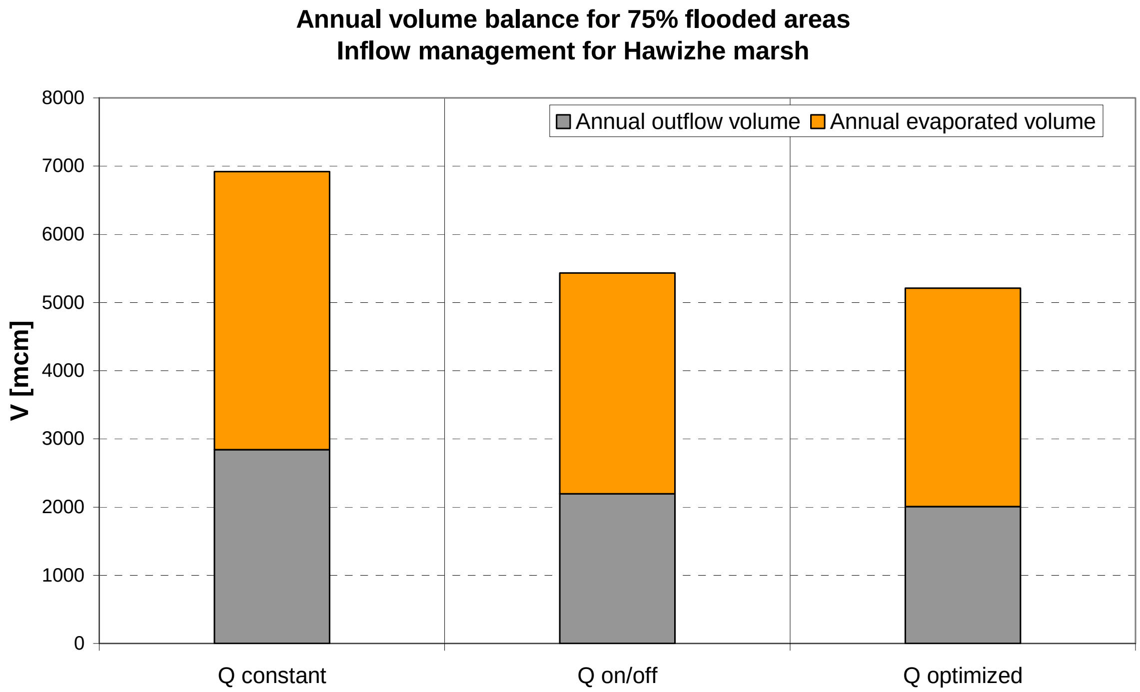


Figure 62: Annual volume balance for SI, On-Off, OI methods, for Hawizhe marsh – 75%

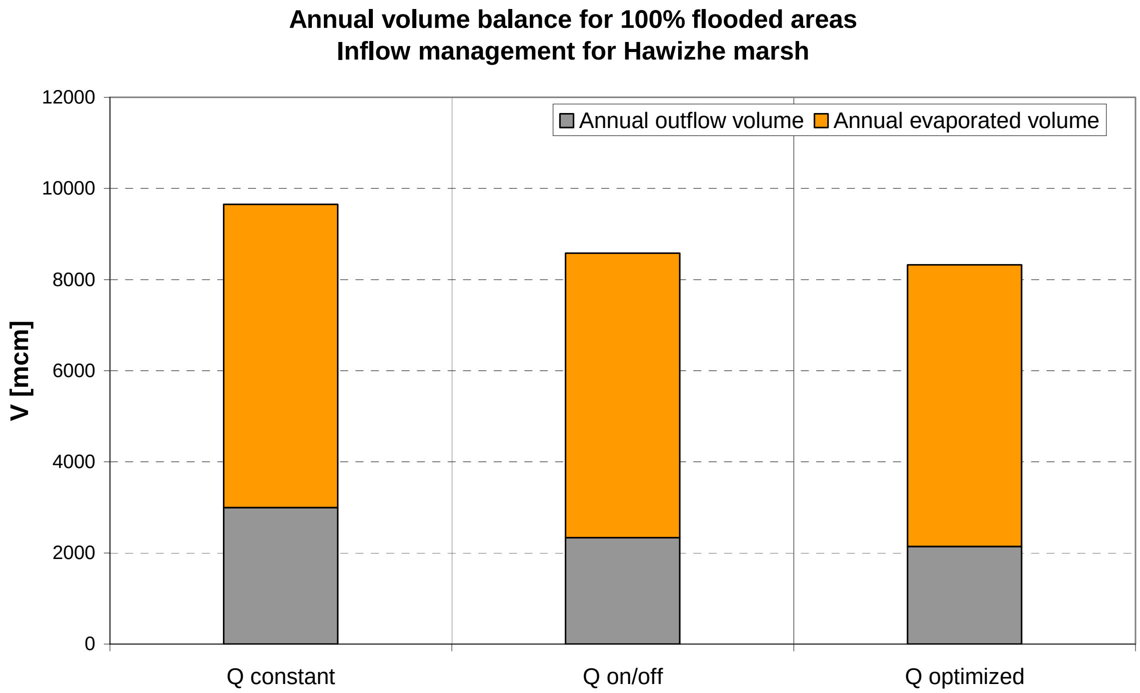


Figure 63: Annual volume balance for SI, On-Off, OI methods, for Hawizhe marsh – 100%

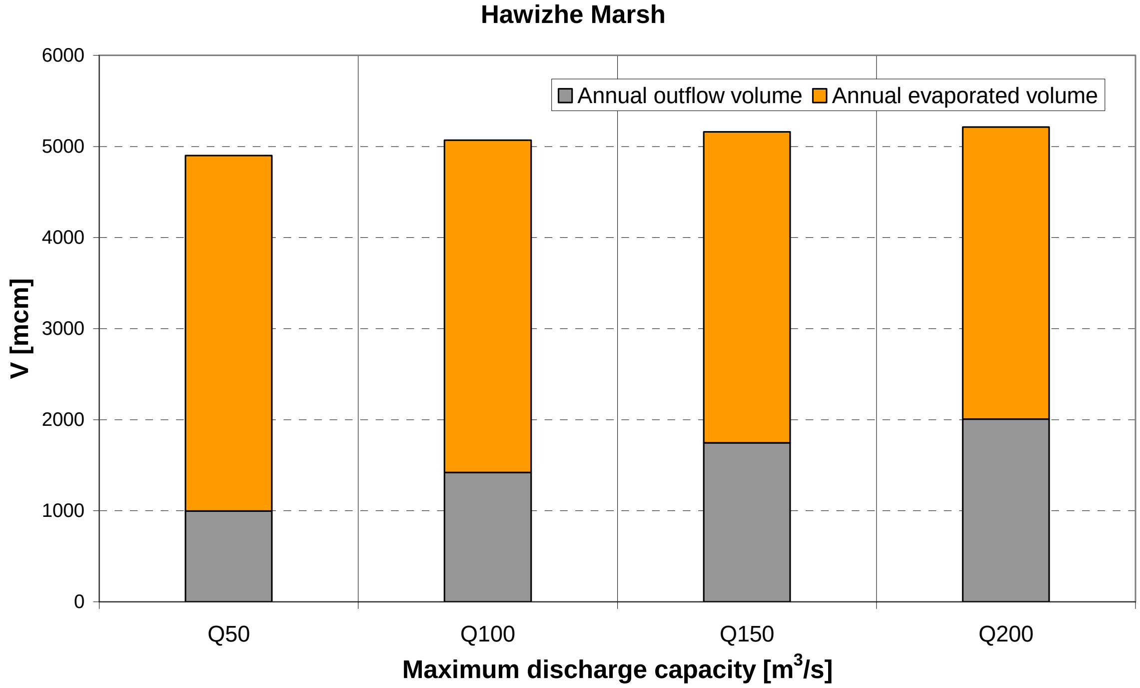


Figure 64: Annual volume balance for Hawizhe Marsh with different outlet discharge capacity

Total Cumulative Marsh

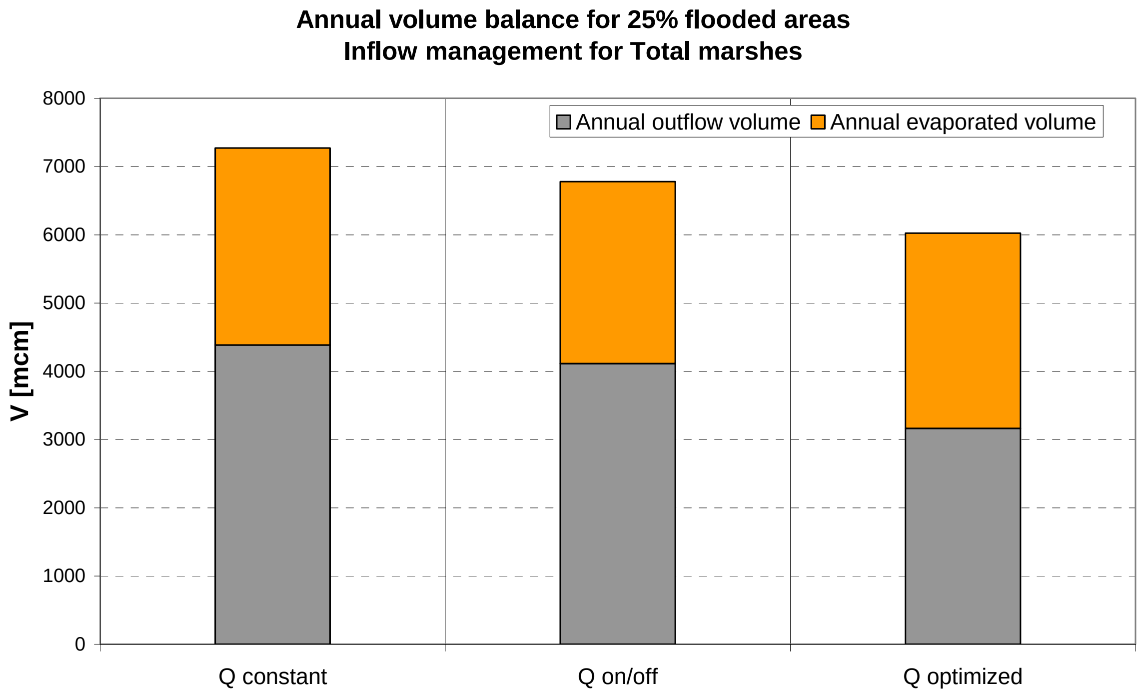


Figure 65: Annual volume balance for SI, On-Off, OI methods, for total marshlands area – 25%

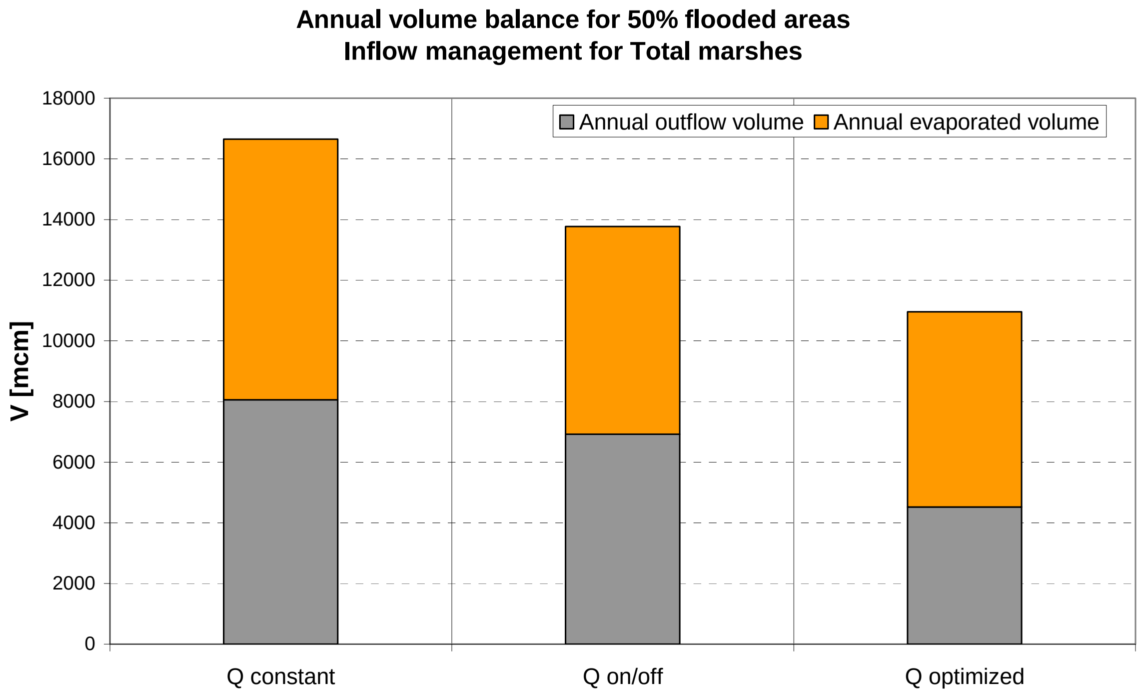


Figure 66: Annual volume balance for SI, On-Off, OI methods, for total marshlands area – 50%

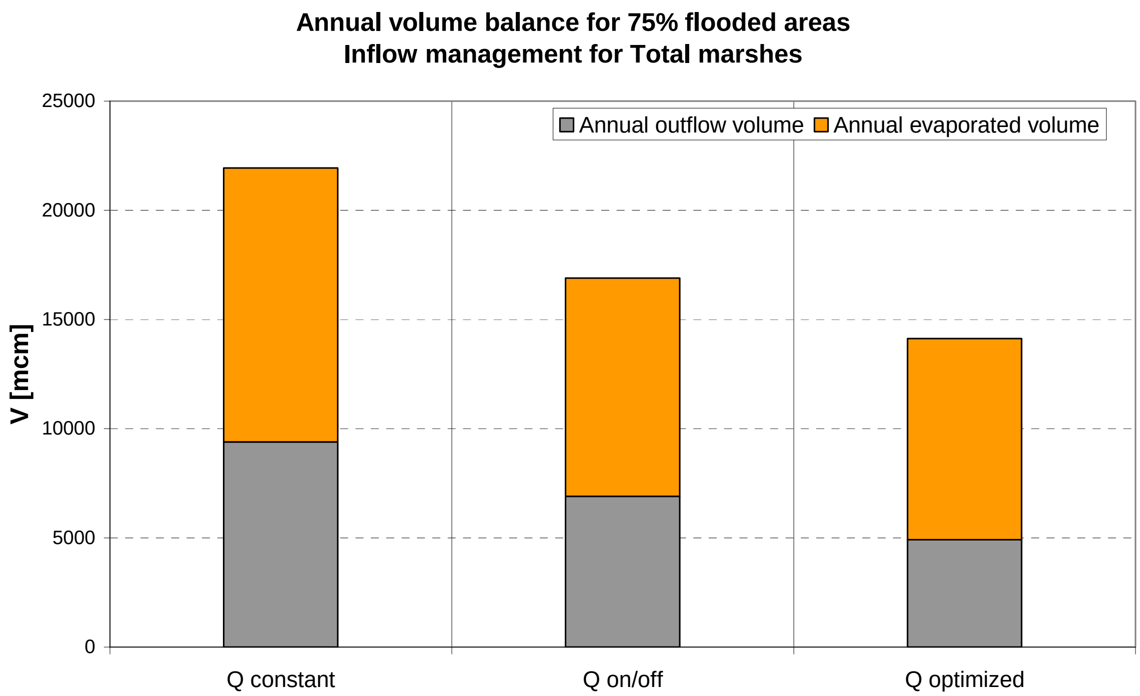


Figure 67: Annual volume balance for SI, On-Off, OI methods, for total marshlands area – 75%

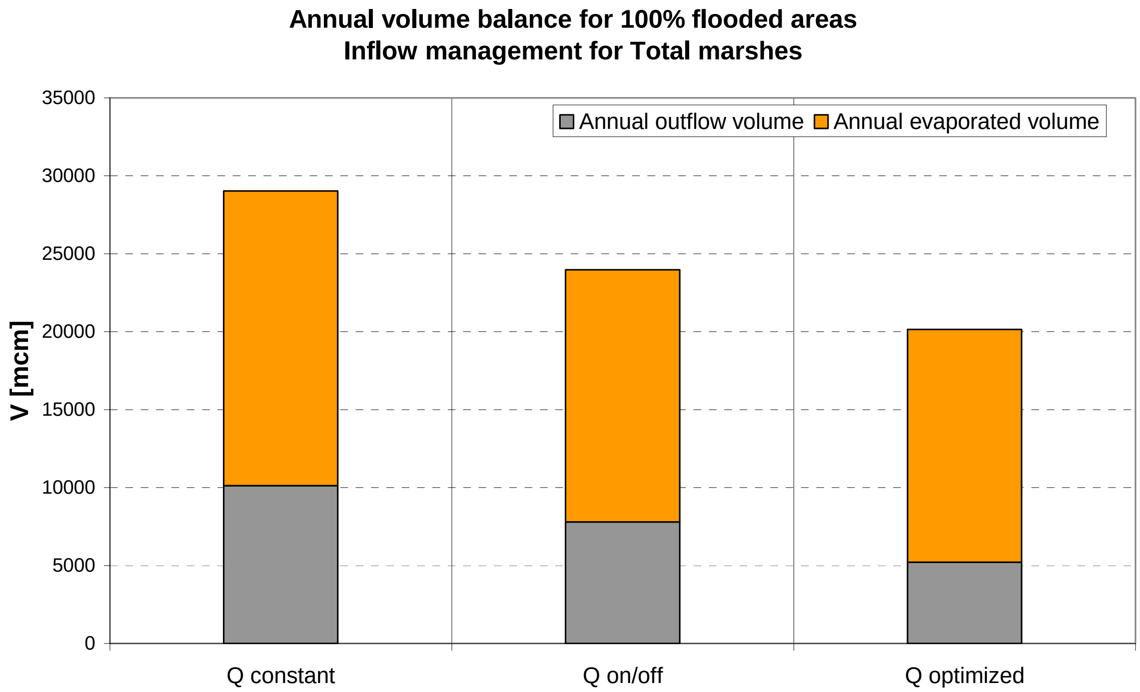


Figure 68: Annual volume balance for SI, On-Off, OI methods, for total marshlands area – 100%

ANNEX II

WATER REQUIREMENTS FOR MARSHLANDS REFLOODING

The following graphs depict the water requirements for marshlands re-flooding, according to different percentage of restoring. The annual water requirement plot is followed by the monthly analysis; the months during the summer period (from June to August) were not analysed because the flow that enters the marshes is minimum and the plots would not be significant because the values are quite near low.

Abu Zirig Marsh

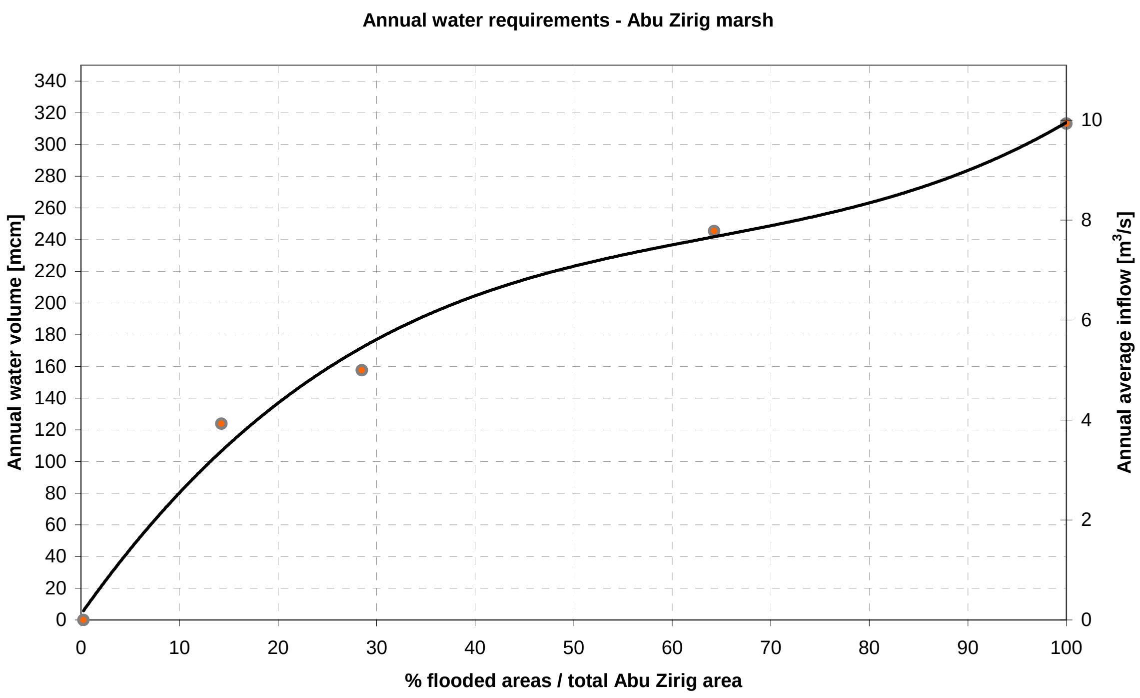


Figure 69: Annual water requirements for Abu Zirig Marsh

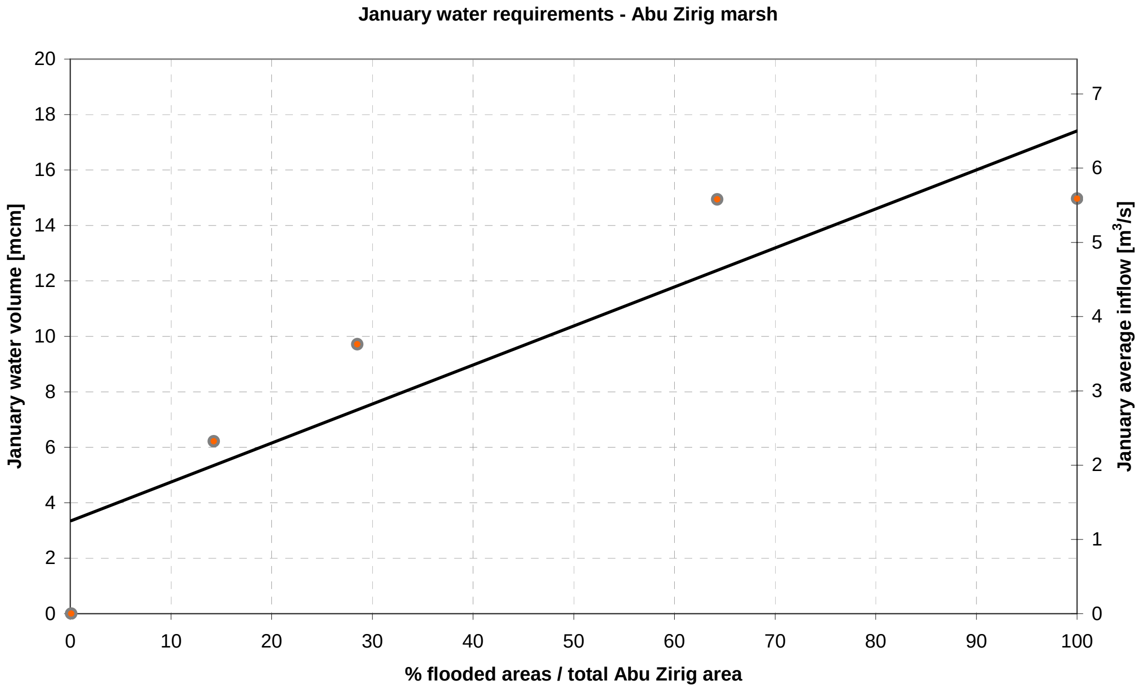


Figure 70: January water requirements for Abu Zirig Marsh

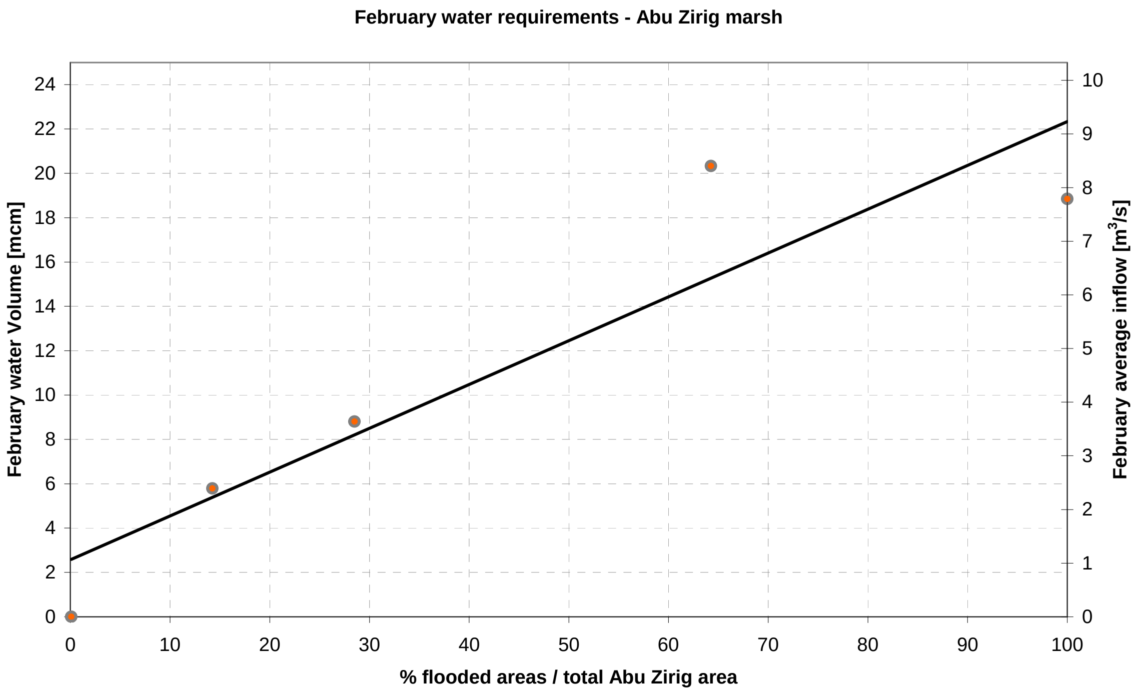


Figure 71: February water requirements for Abu Zirig Marsh

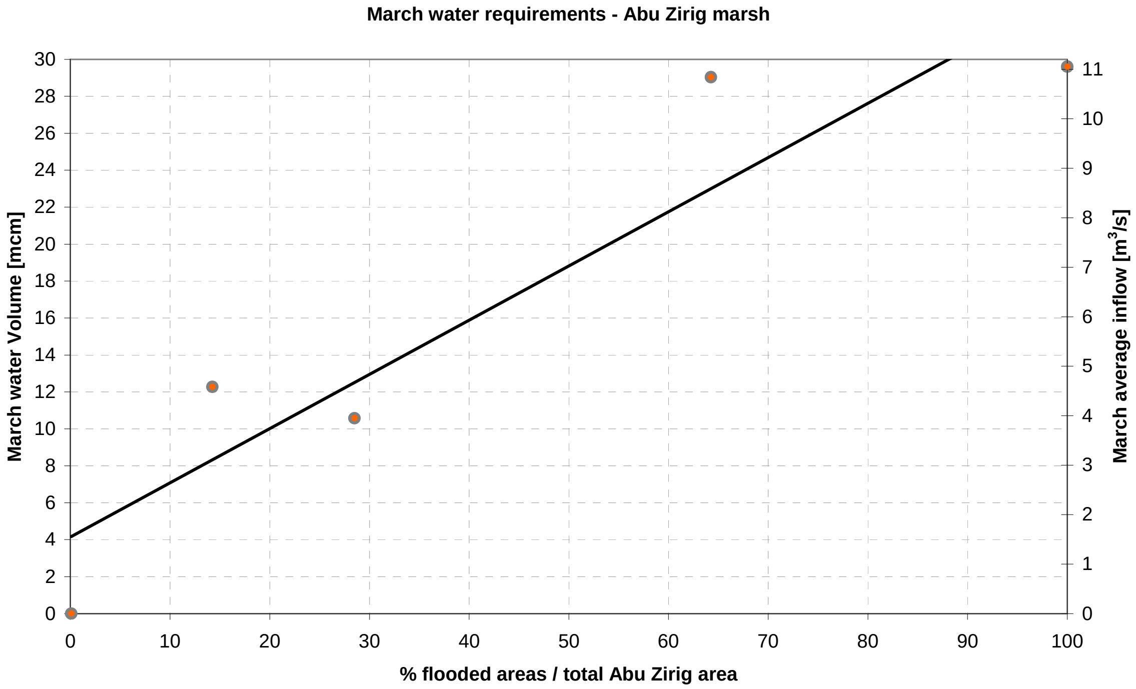


Figure 72: March water requirements for Abu Zirig Marsh

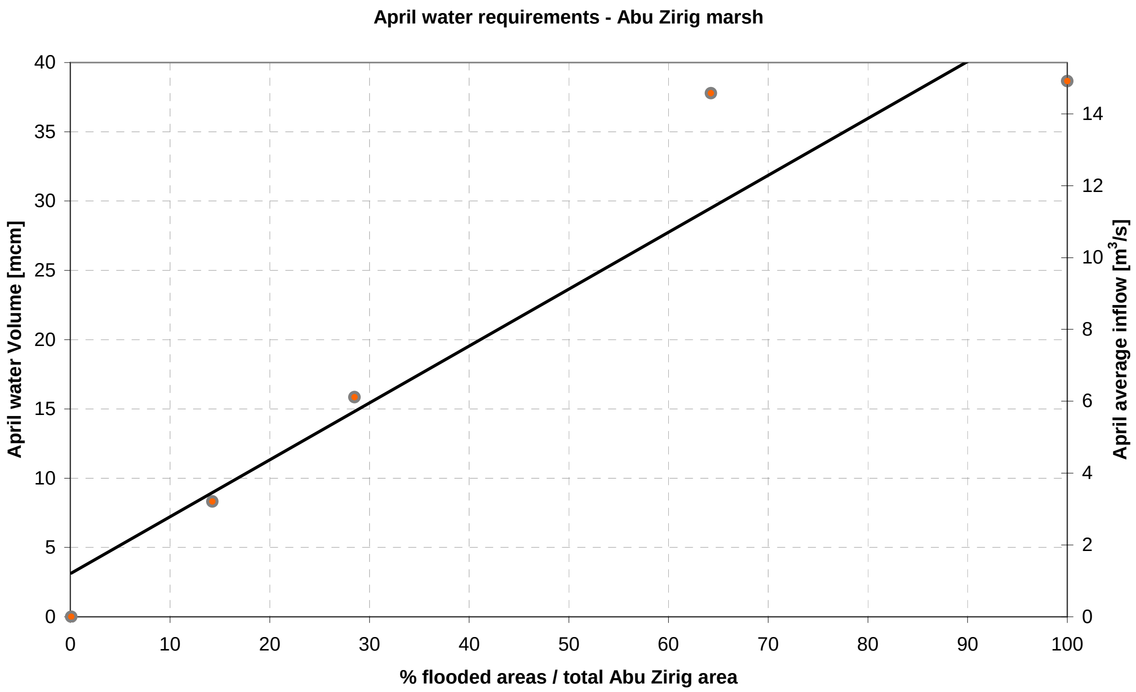


Figure 73: April water requirements for Abu Zirig Marsh

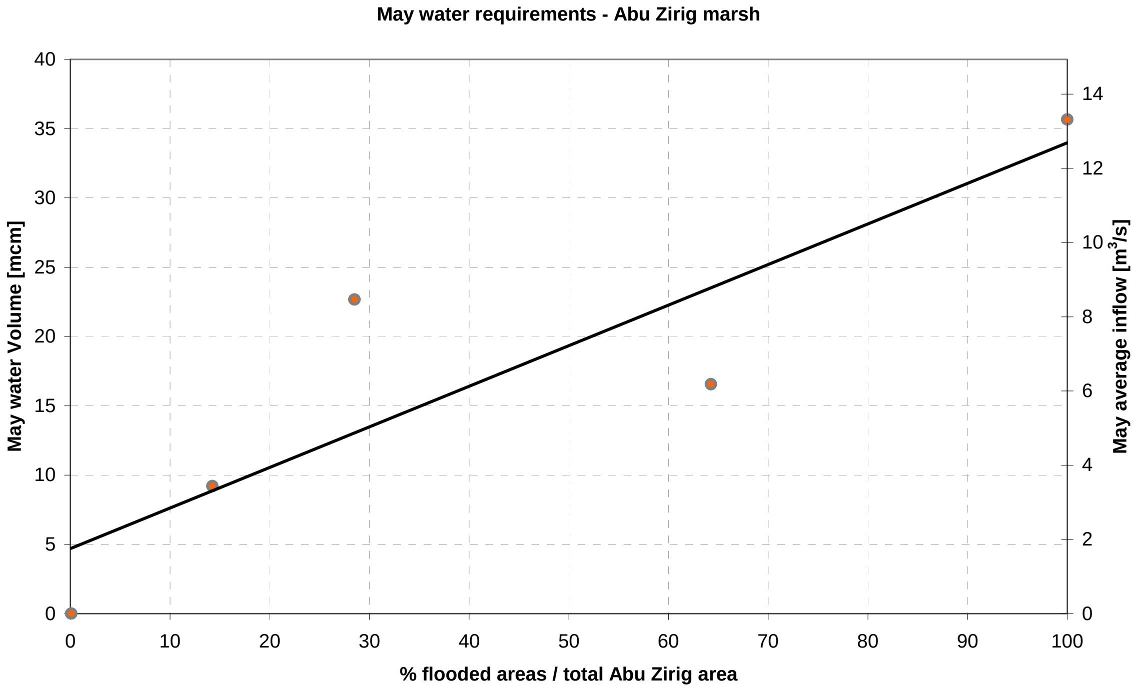


Figure 74: May water requirements for Abu Zirig Marsh

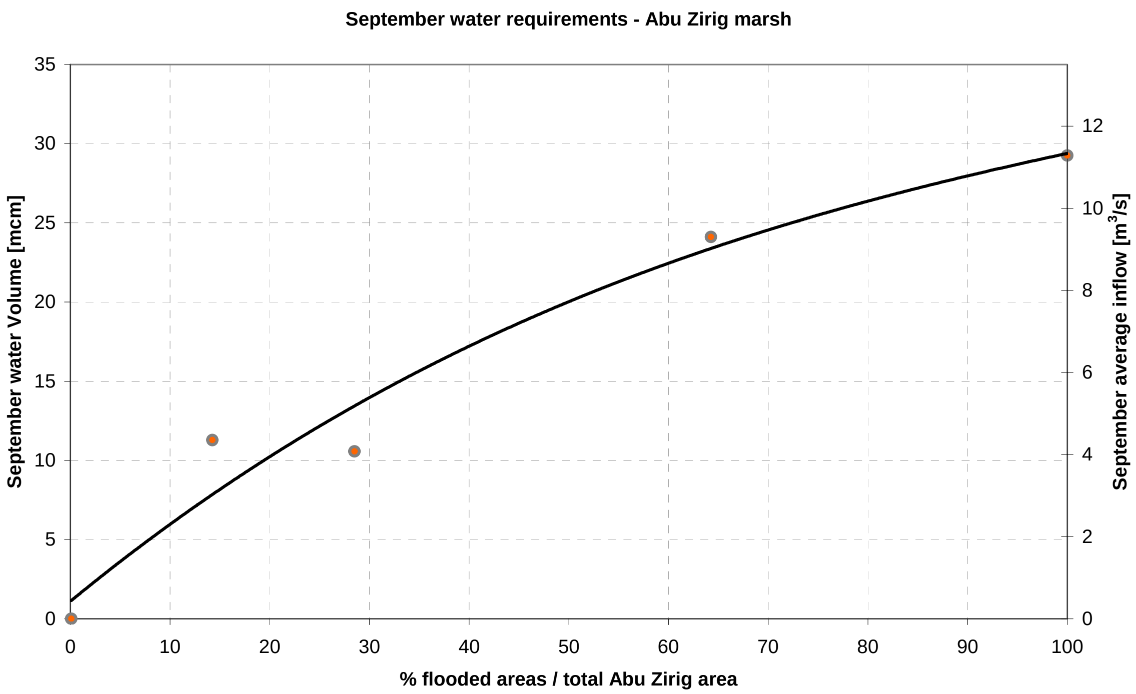


Figure 75: September water requirements for Abu Zirig Marsh

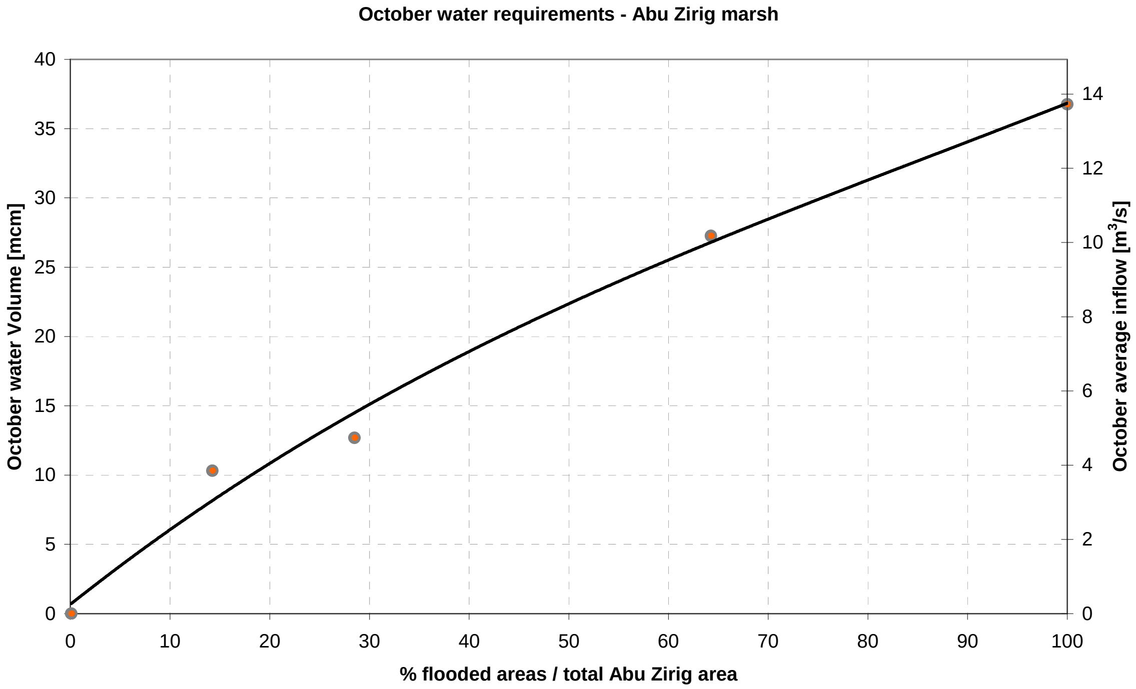


Figure 76: October water requirements for Abu Zirig Marsh

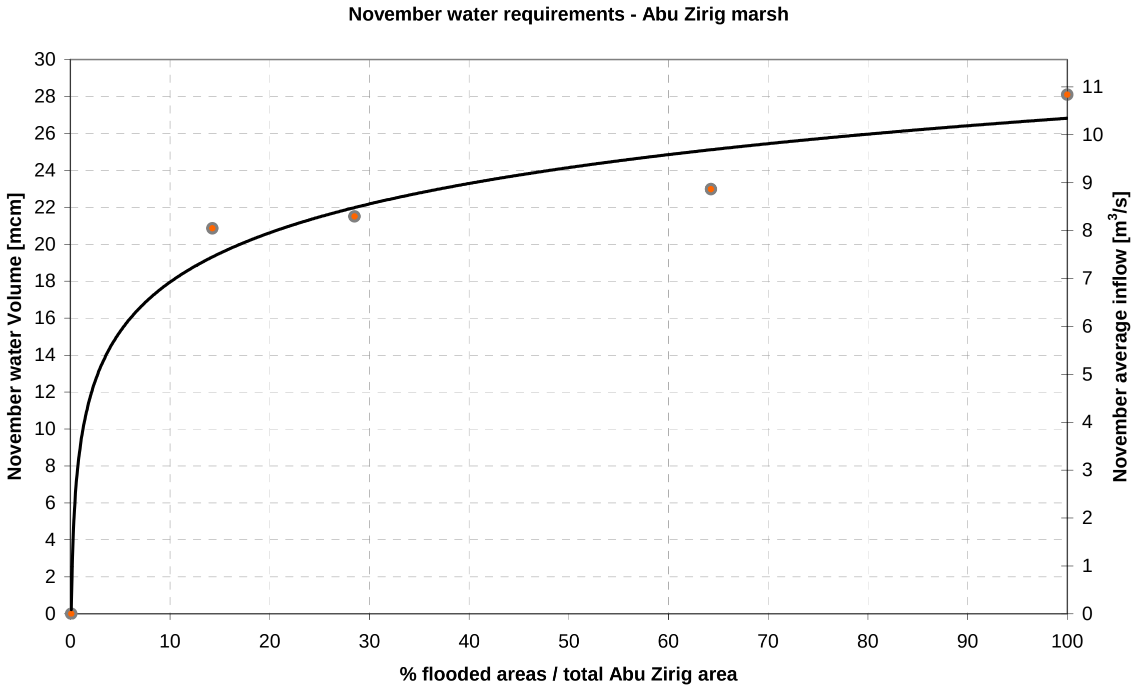


Figure 77: November water requirements for Abu Zirig Marsh

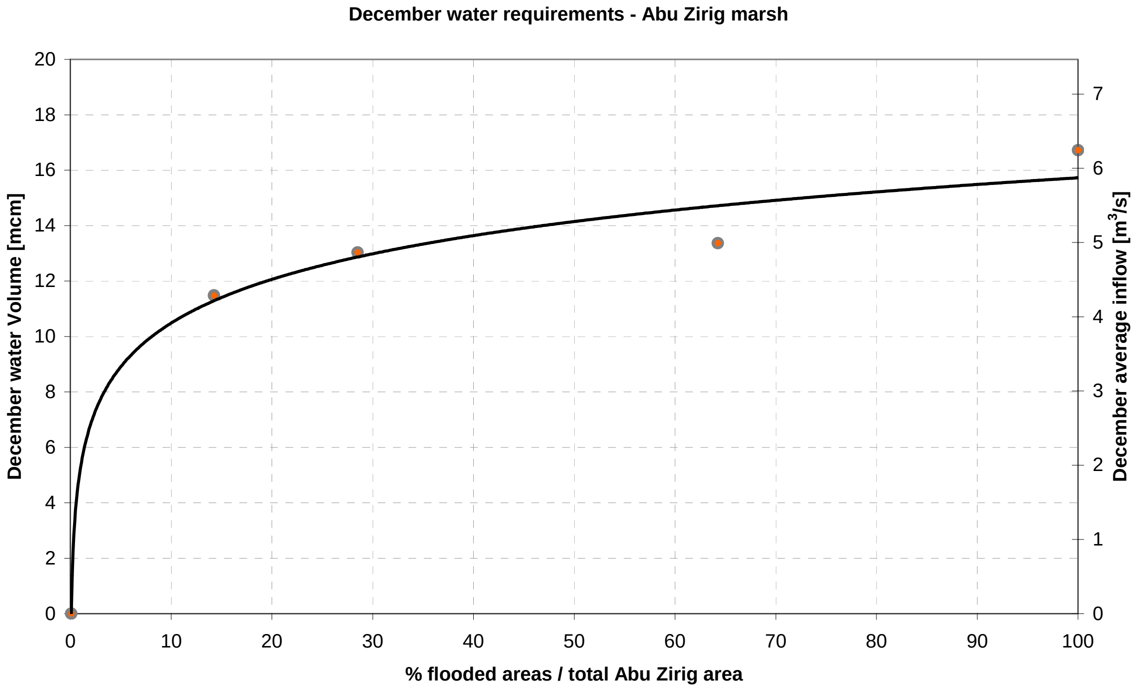


Figure 78: December water requirements for Abu Zirig Marsh

Central Marsh

The Euphrates river is responsible for low reflooding scenarios, with an extension less than 25%: flooded areas are located in the southern part of the marsh. For this reason the inflow necessary for low reflooding percentages were not studied, and the monthly plots don't show calculation points around the 25%. In the annual graph low reflooding percentage was included considering the amount of evaporation due to Euphrates flooded area as a water requirement; in this way the amount of water necessary for balancing the water lost due to evaporation can be estimated over a year.

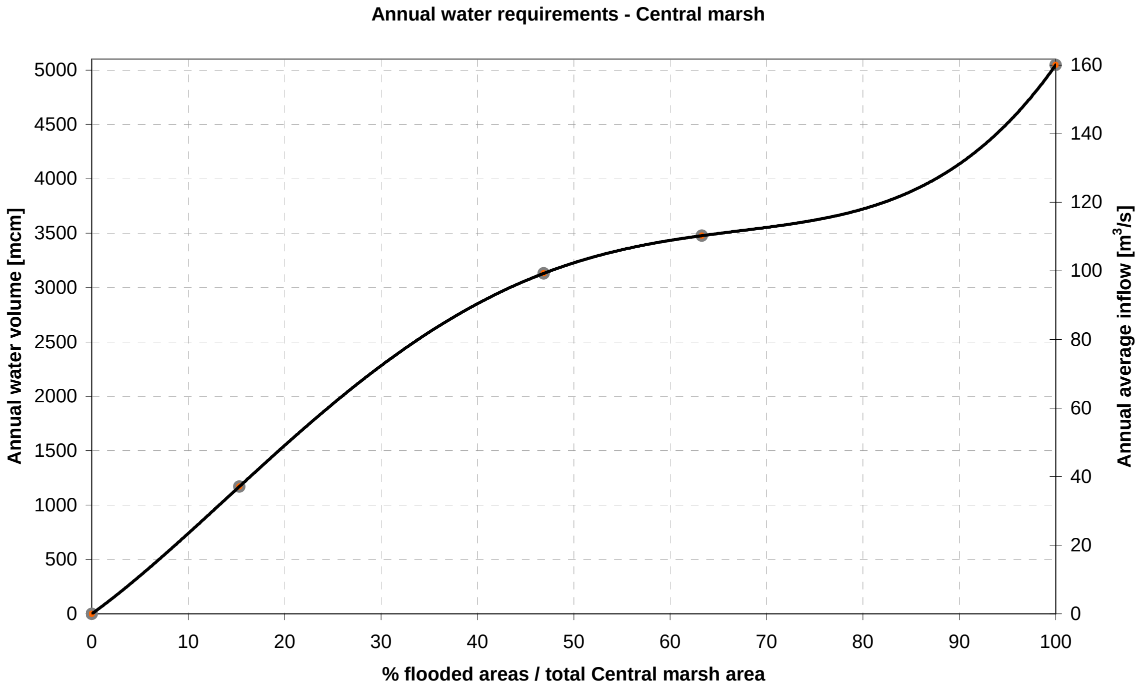


Figure 79: Annual water requirements for Central Marsh

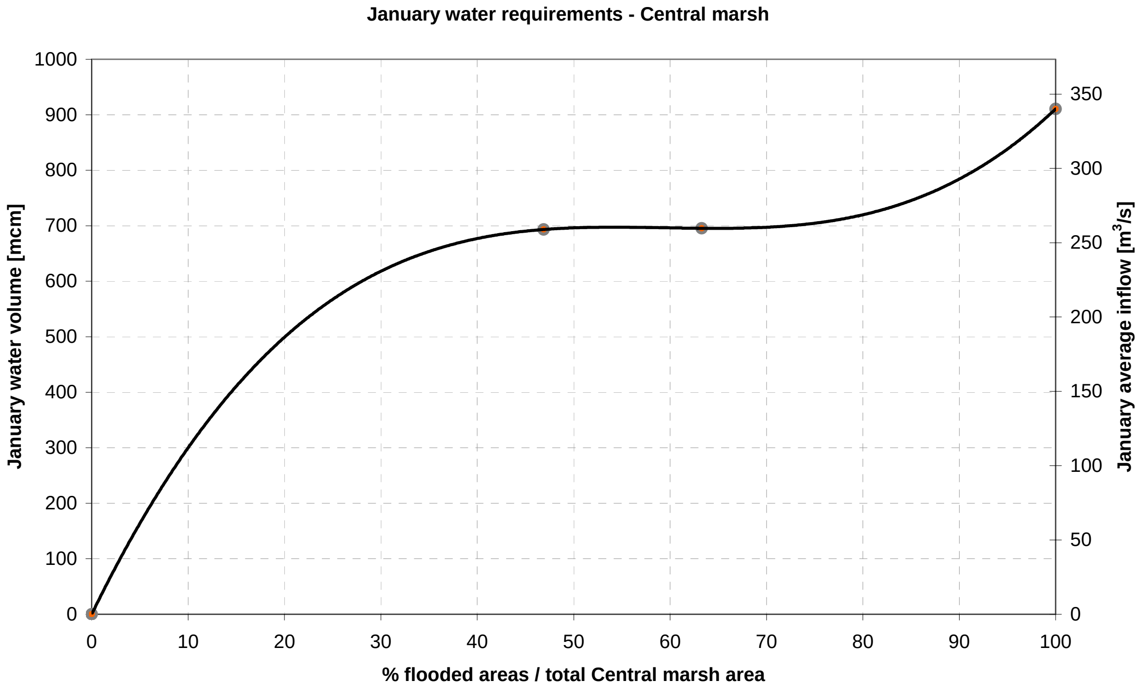


Figure 80: January water requirements for Central Marsh

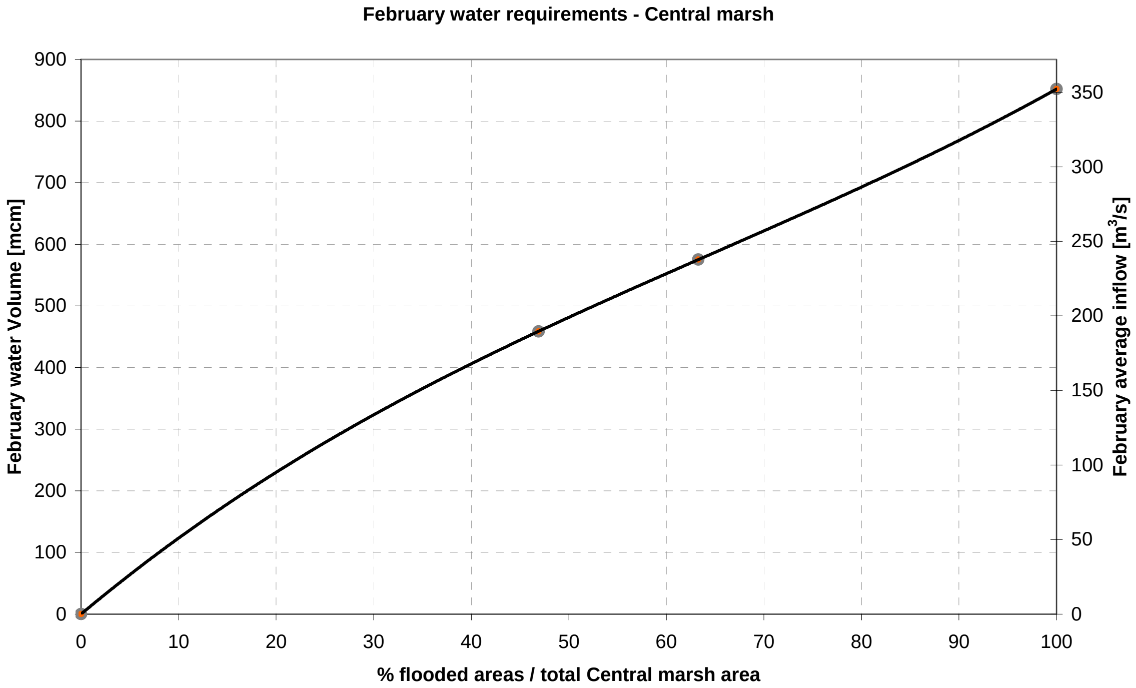


Figure 81: February water requirements for Central Marsh

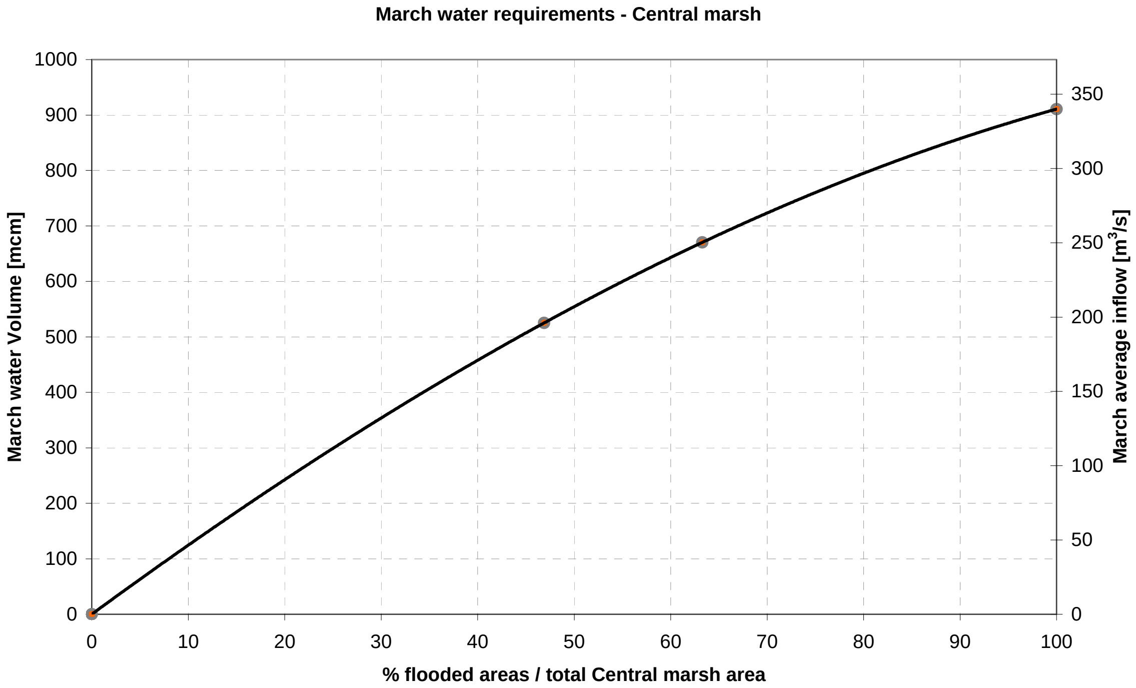


Figure 82: March water requirements for Central Marsh

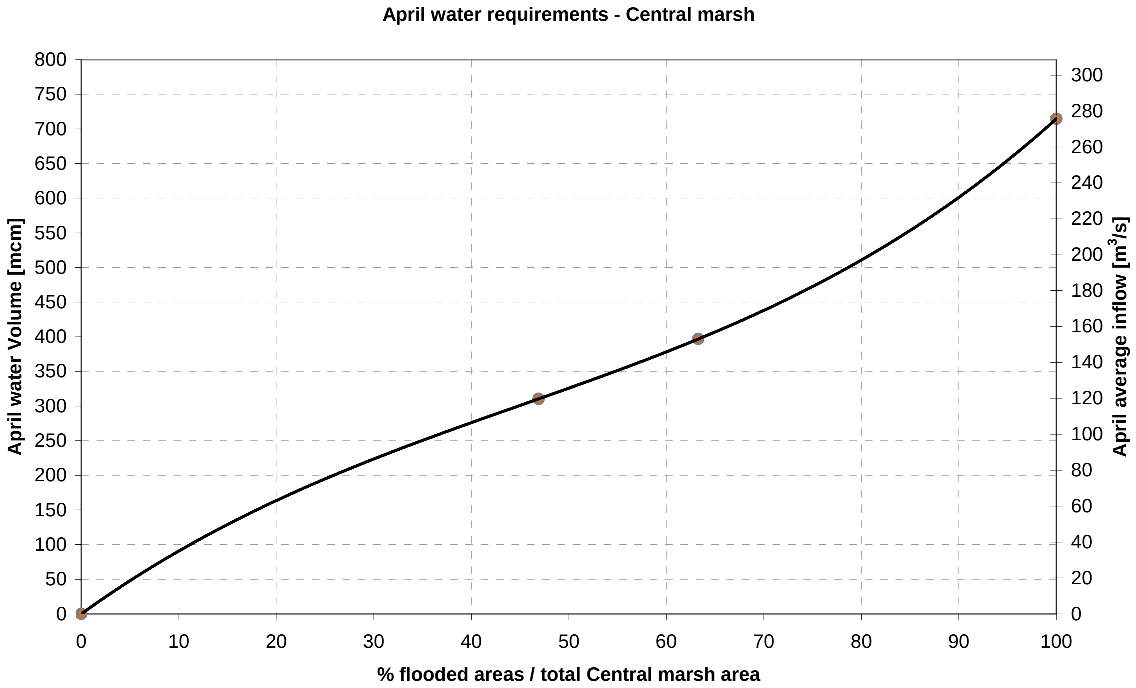


Figure 83: April water requirements for Central Marsh

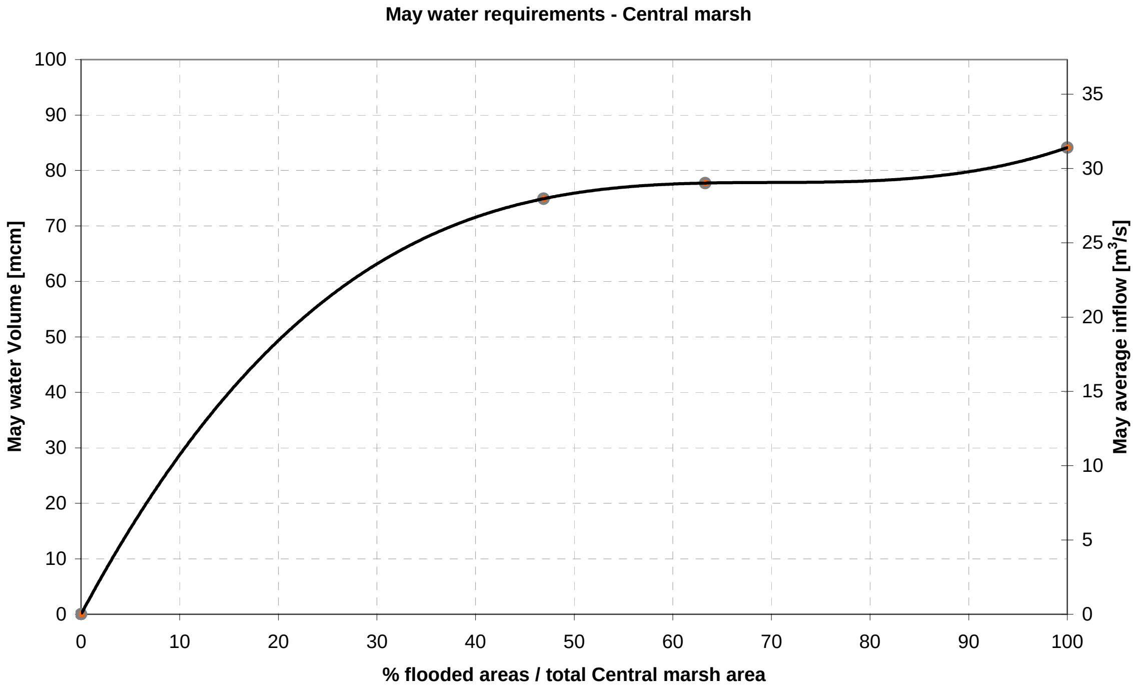


Figure 84: May water requirements for Central Marsh

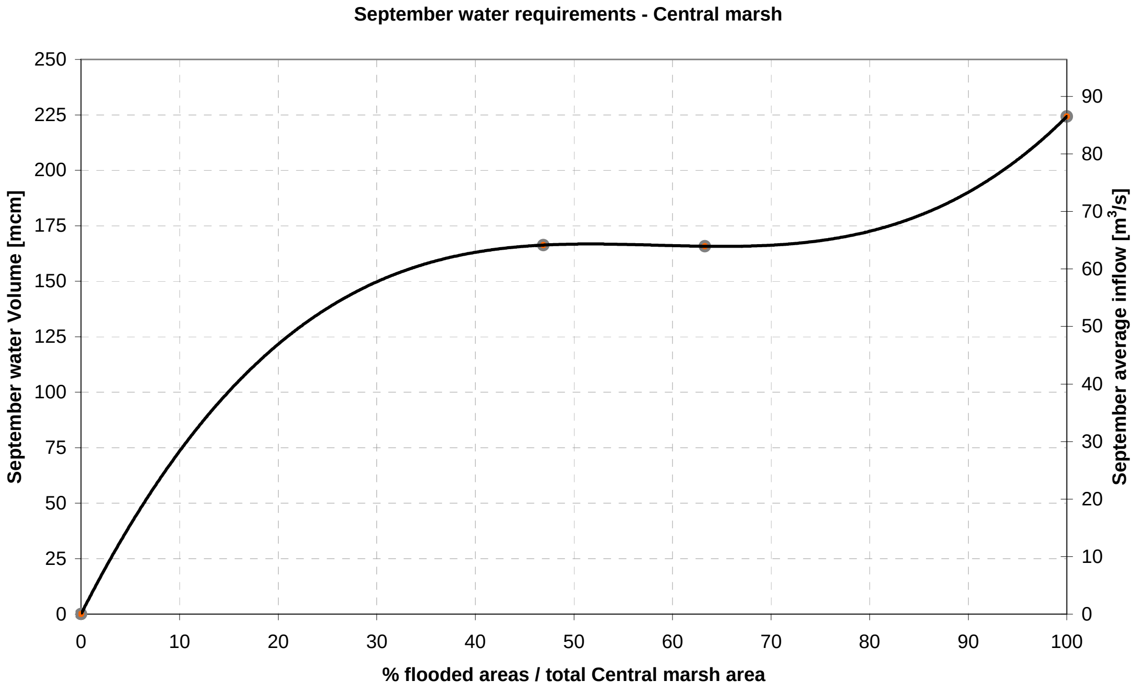


Figure 85: September water requirements for Central Marsh

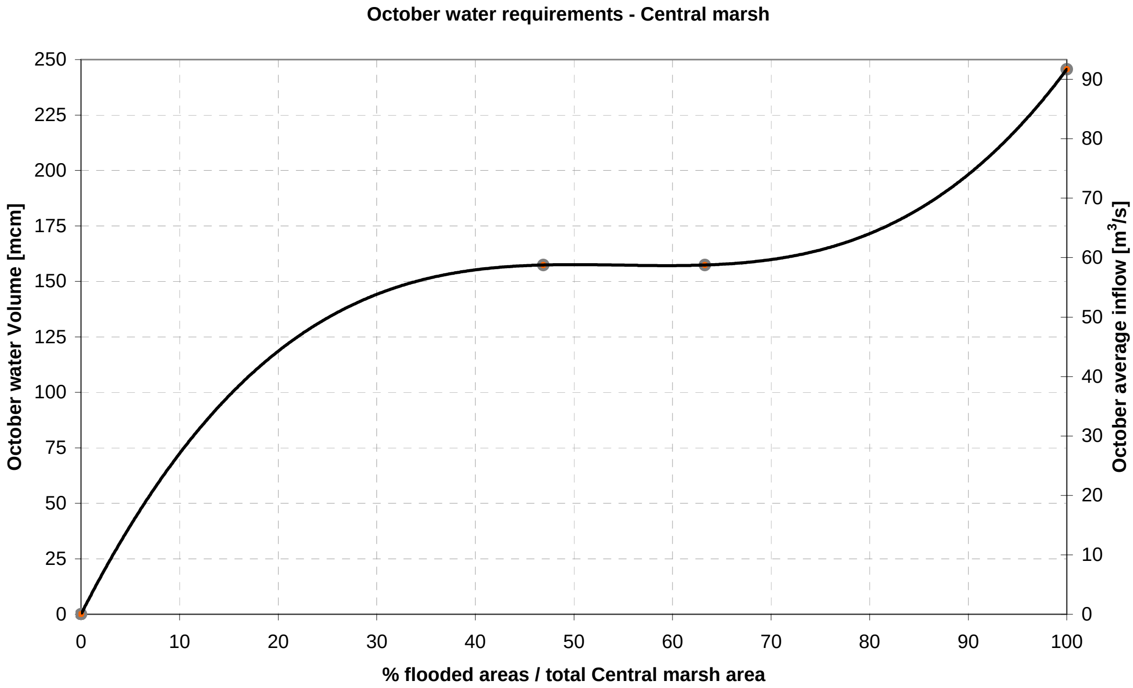


Figure 86: October water requirements for Central Marsh

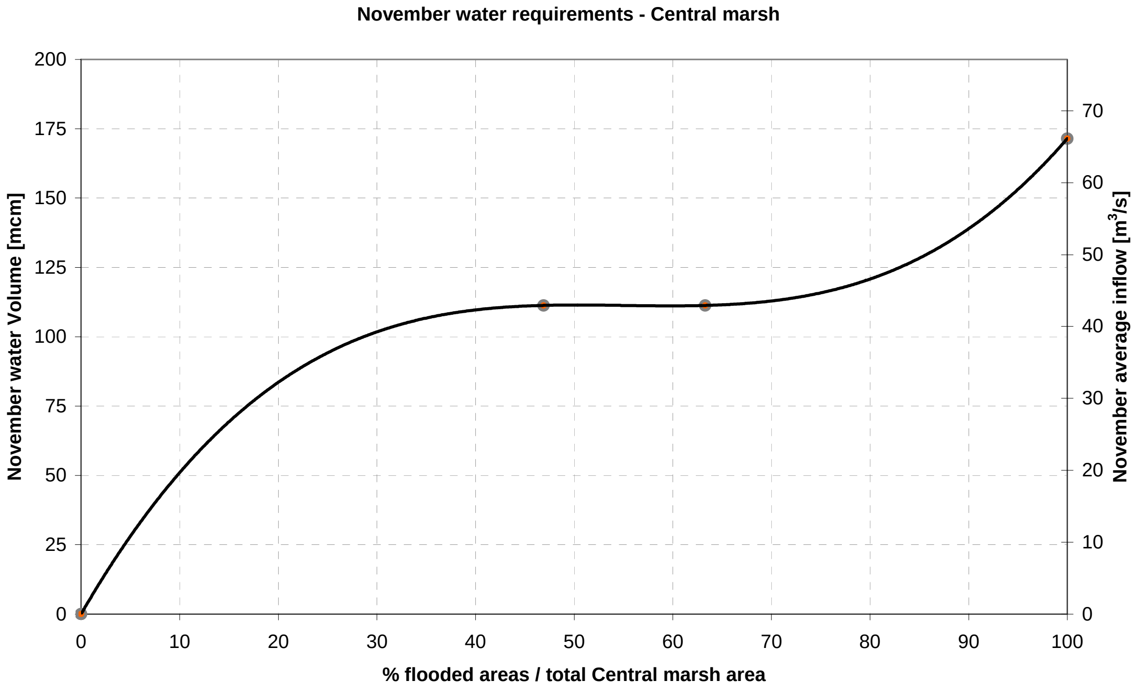


Figure 87: November water requirements for Central Marsh

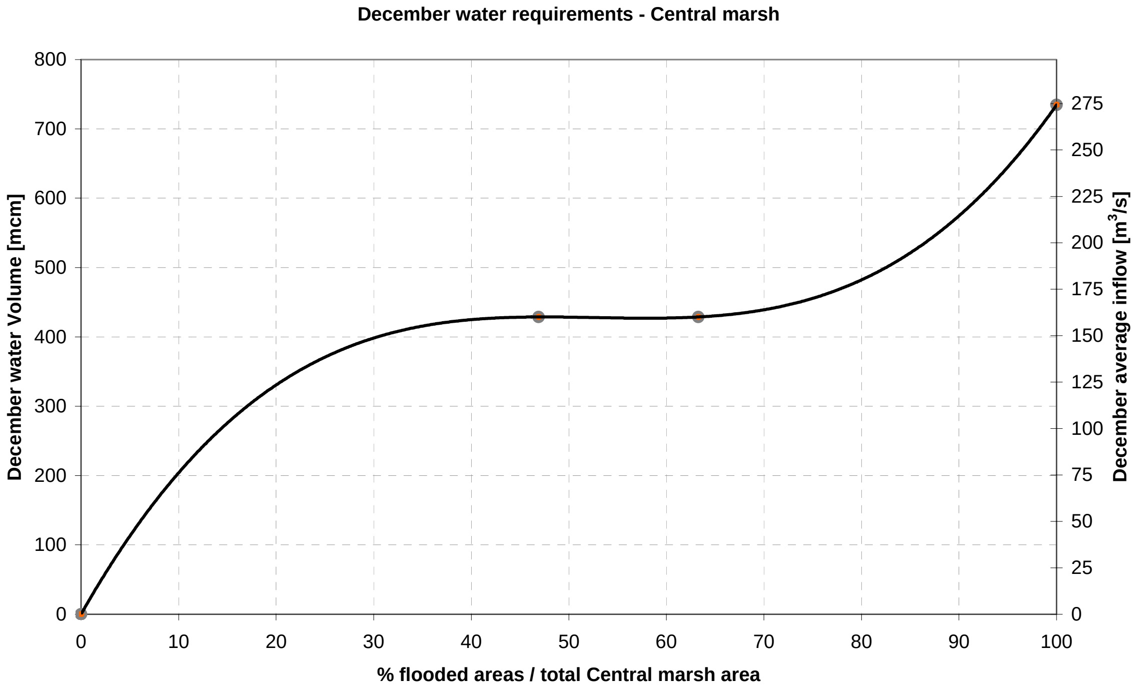


Figure 88: December water requirements for Central Marsh

Hammar Marsh

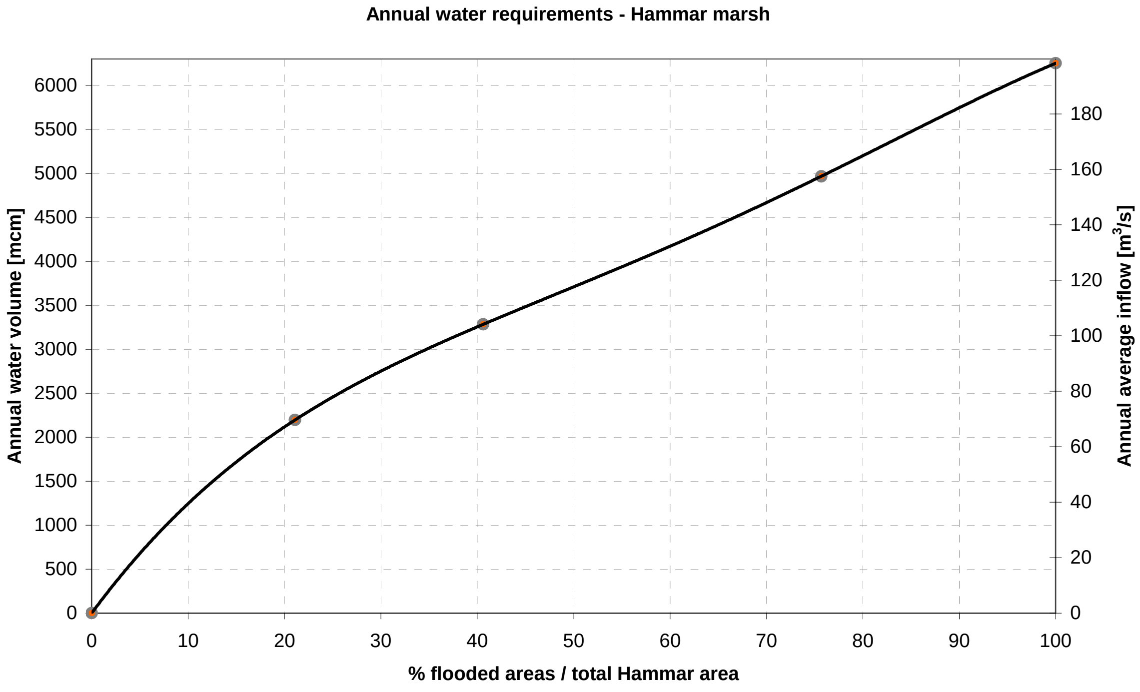


Figure 89: Annual water requirements for Hammar Marsh

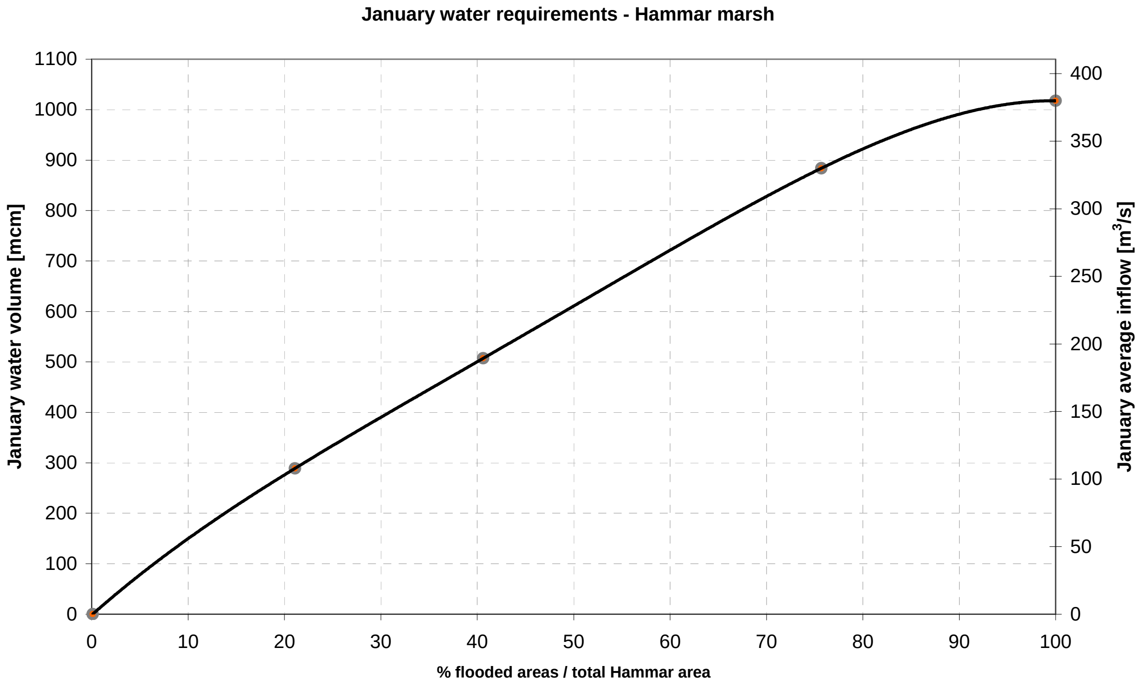


Figure 90: January water requirements for Hammar Marsh

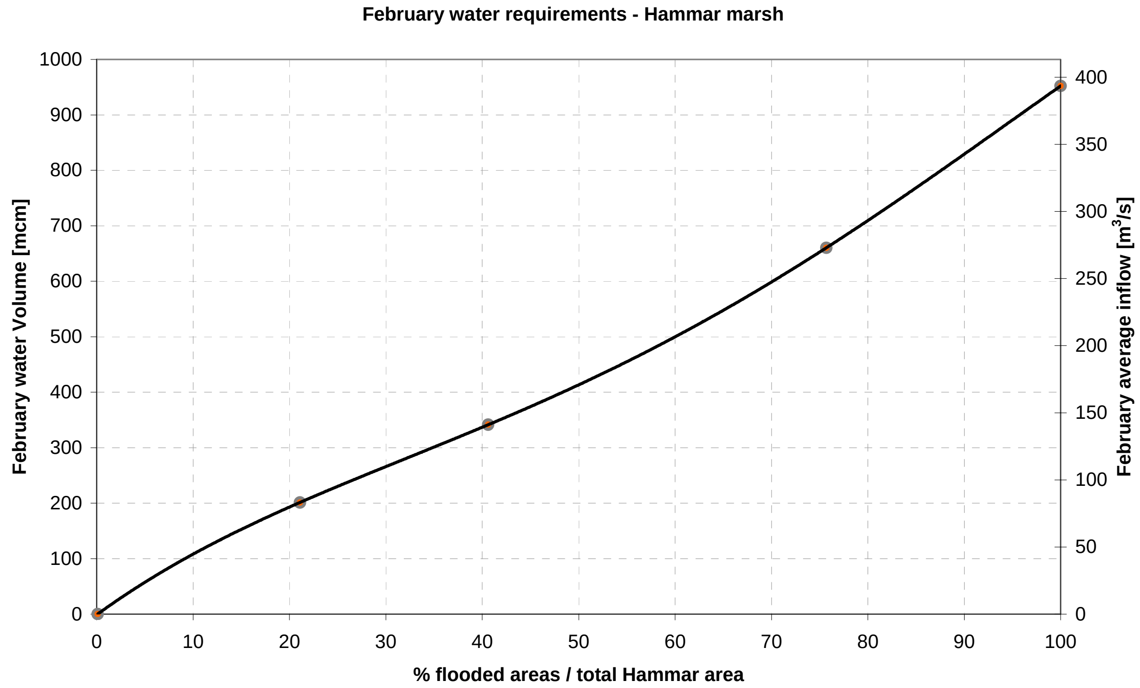


Figure 91: February water requirements for Hammar Marsh

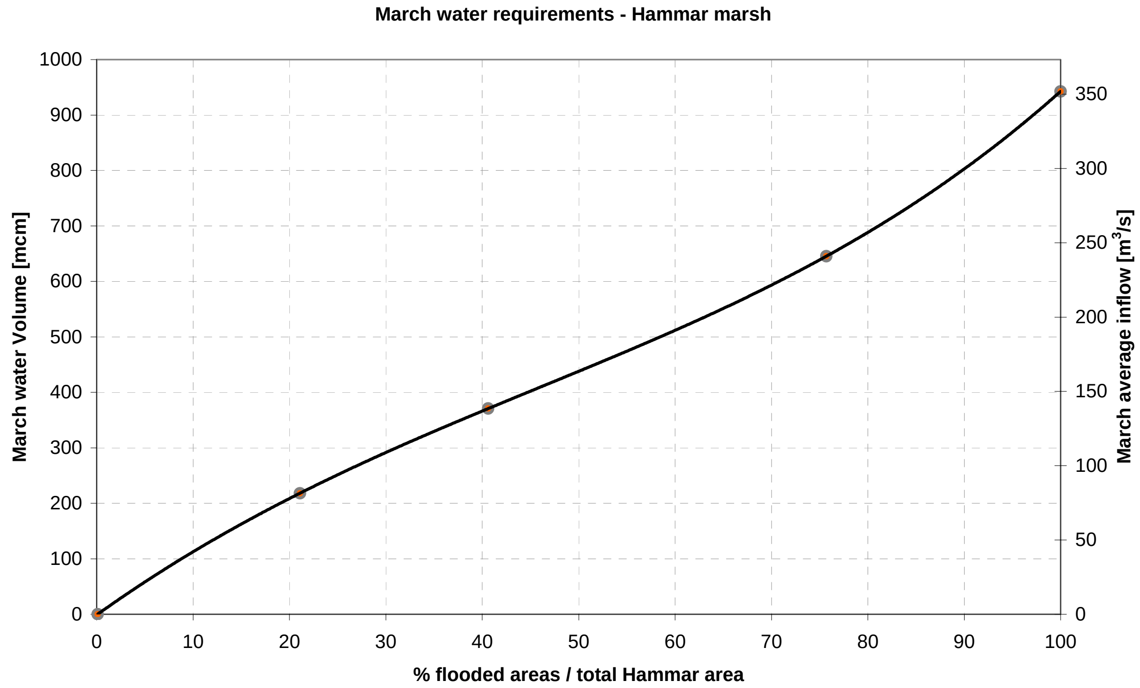


Figure 92: March water requirements for Hammar Marsh

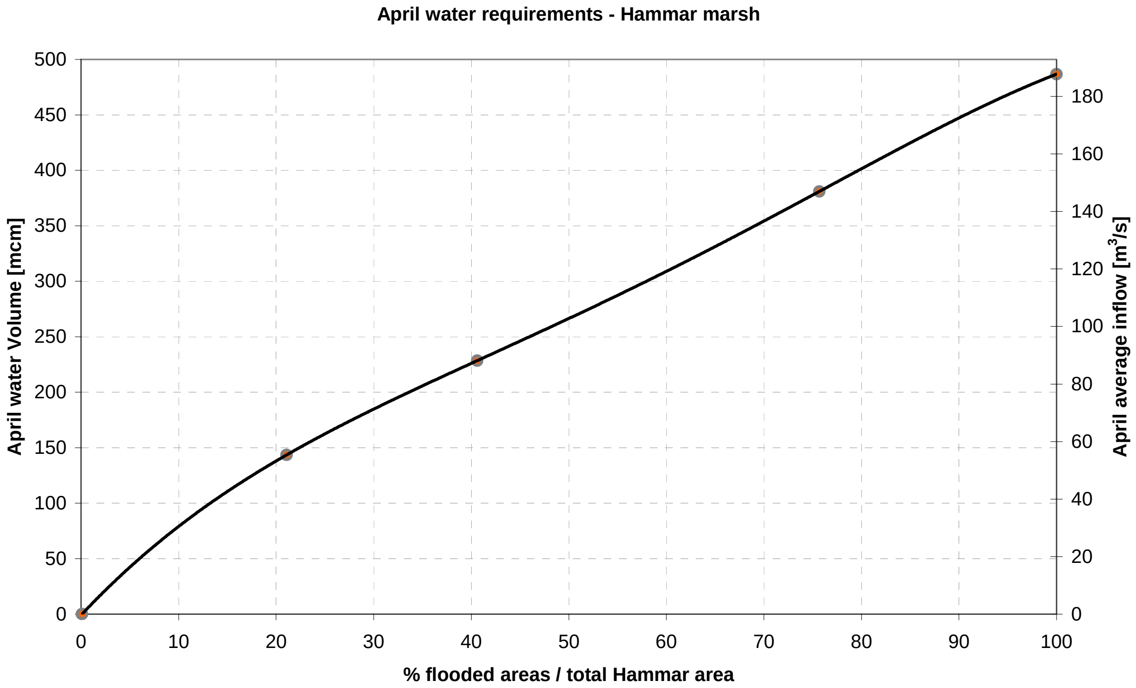


Figure 93: April water requirements for Hammar Marsh

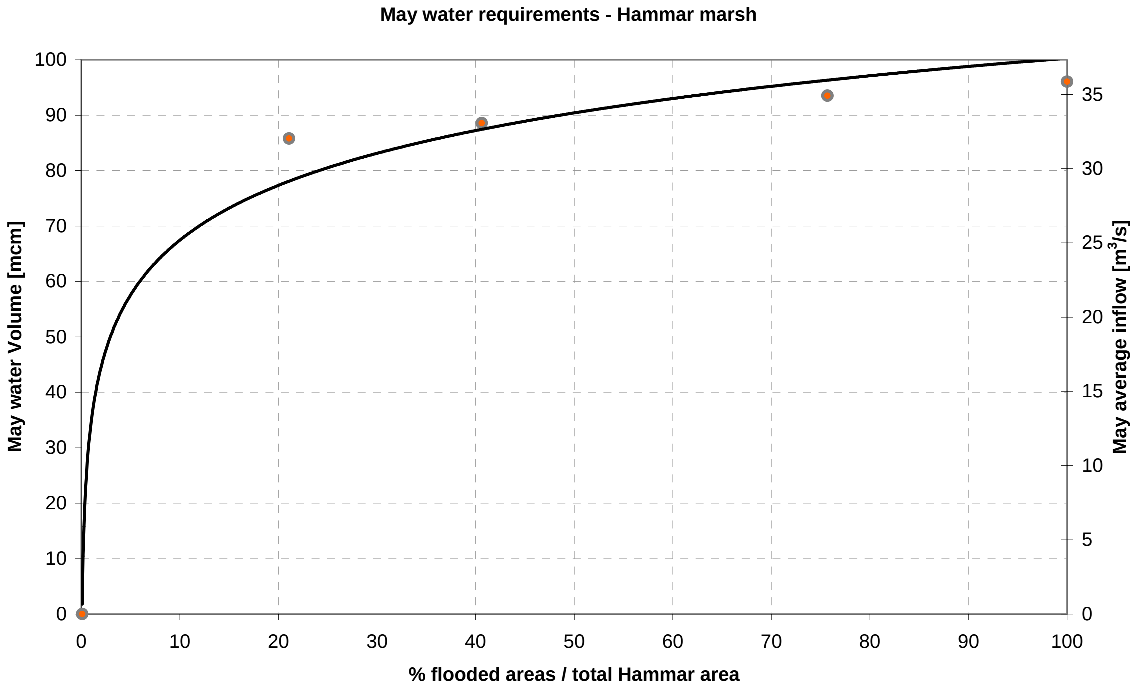


Figure 94: May water requirements for Hammar Marsh

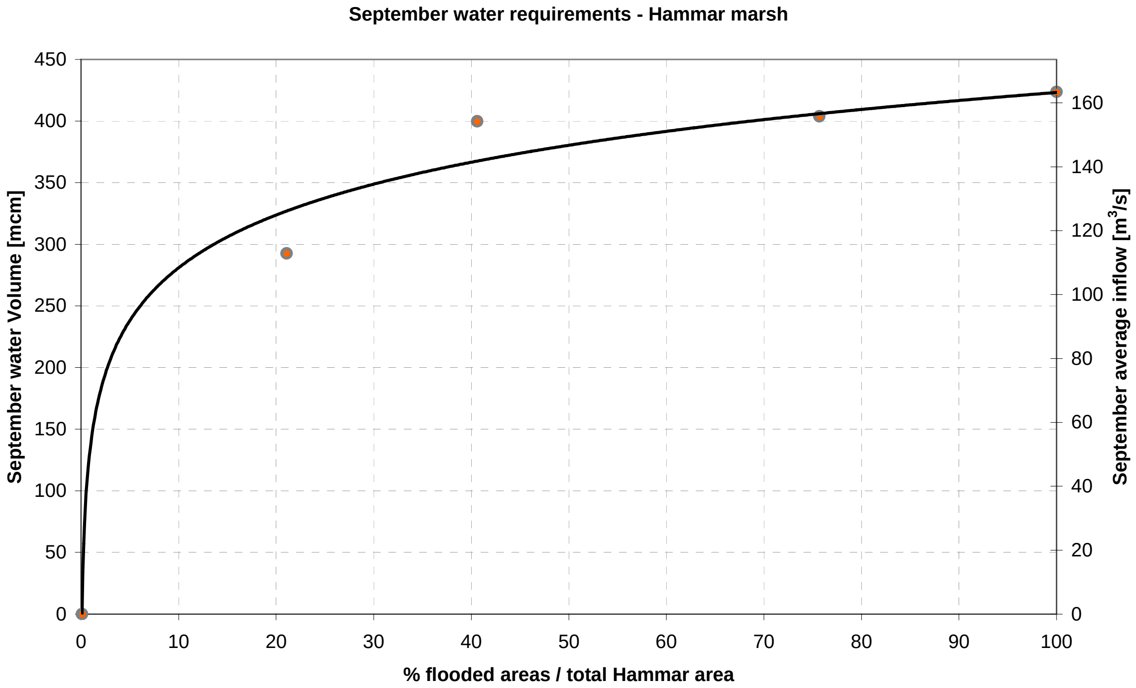


Figure 95: September water requirements for Hammar Marsh

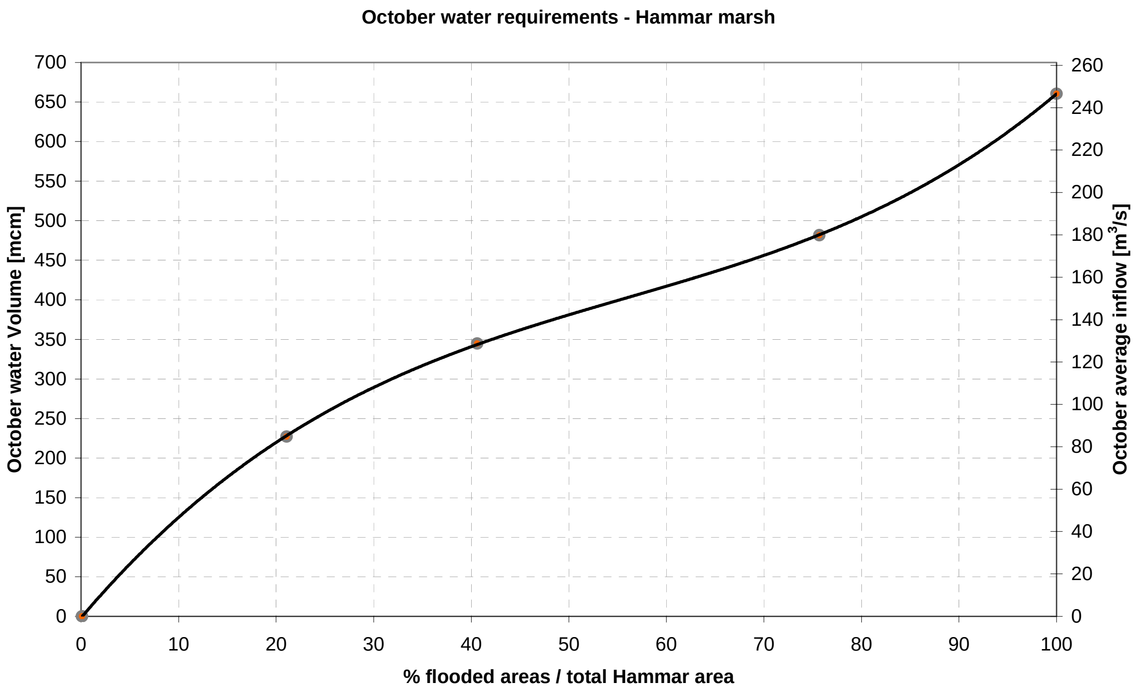


Figure 96: October water requirements for Hammar Marsh

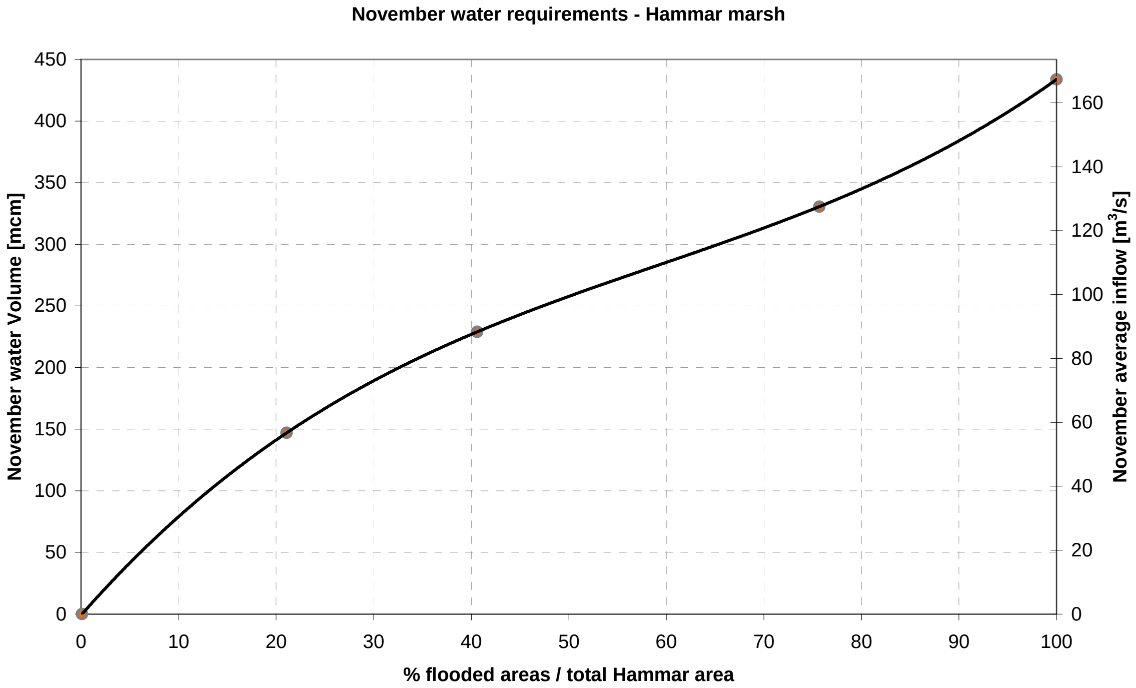


Figure 97: November water requirements for Hammar Marsh

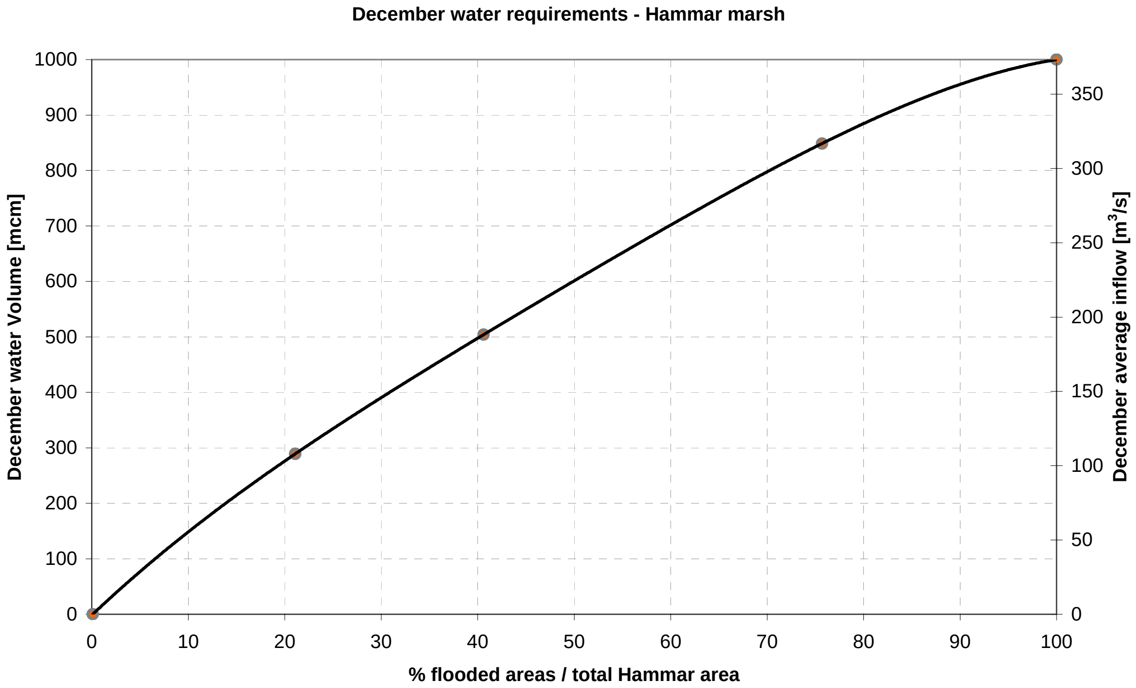


Figure 98: December water requirements for Hammar Marsh

Hawizhe Marsh

Hawizhe marsh receives iraqi and iranian contribute. The following plots don't illustrate the 100% reflooding scenario. In fact for the 100% scenario the iranian contribute is much higher than the other percentages and a comparison is not possible. The 100% scenario considers that a consistent iranian inflow feeds an area that is not flooded in the other scenarios.

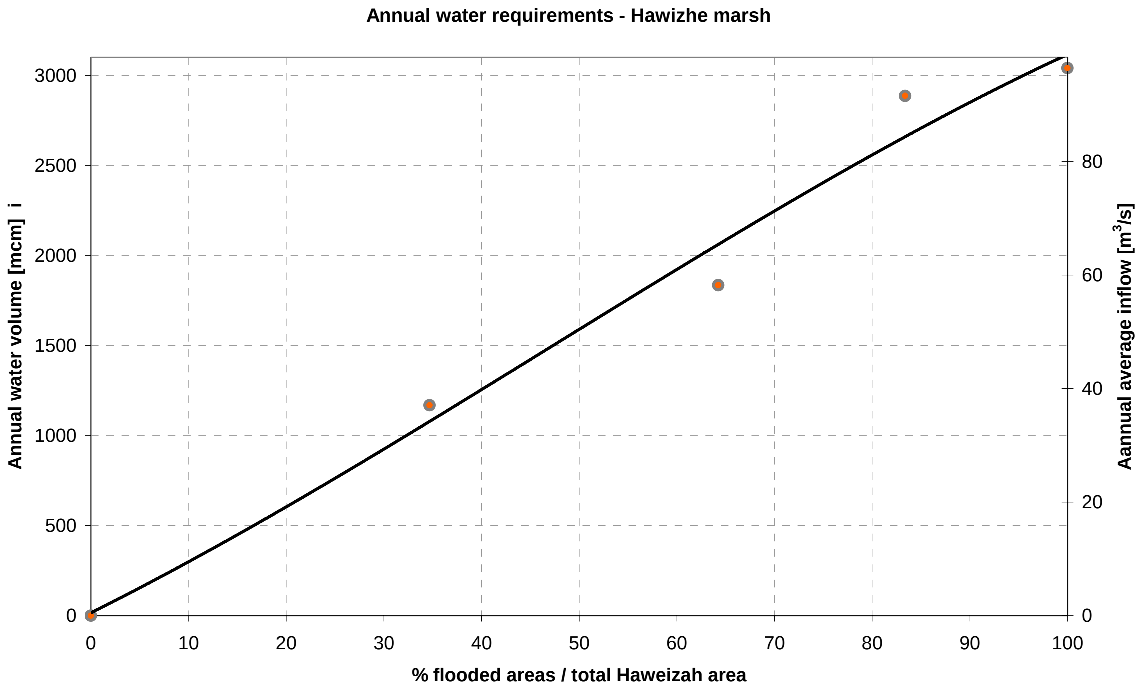


Figure 99: Annual water requirements for Hawizhe Marsh

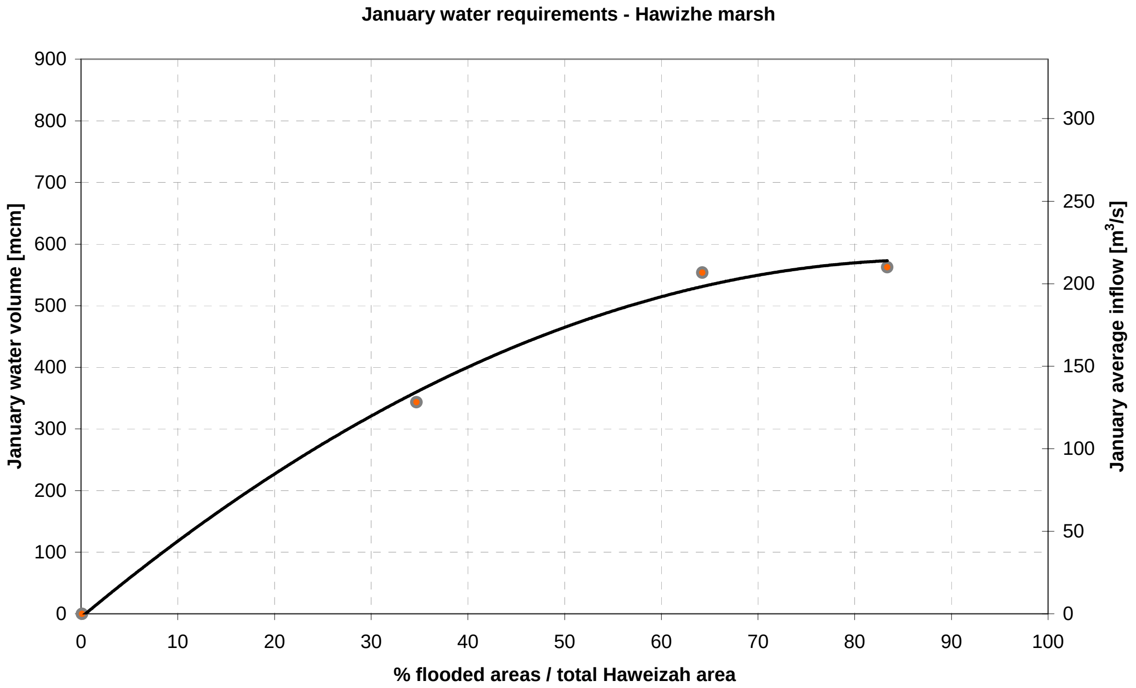


Figure 100: January water requirements for Hawizhe Marsh

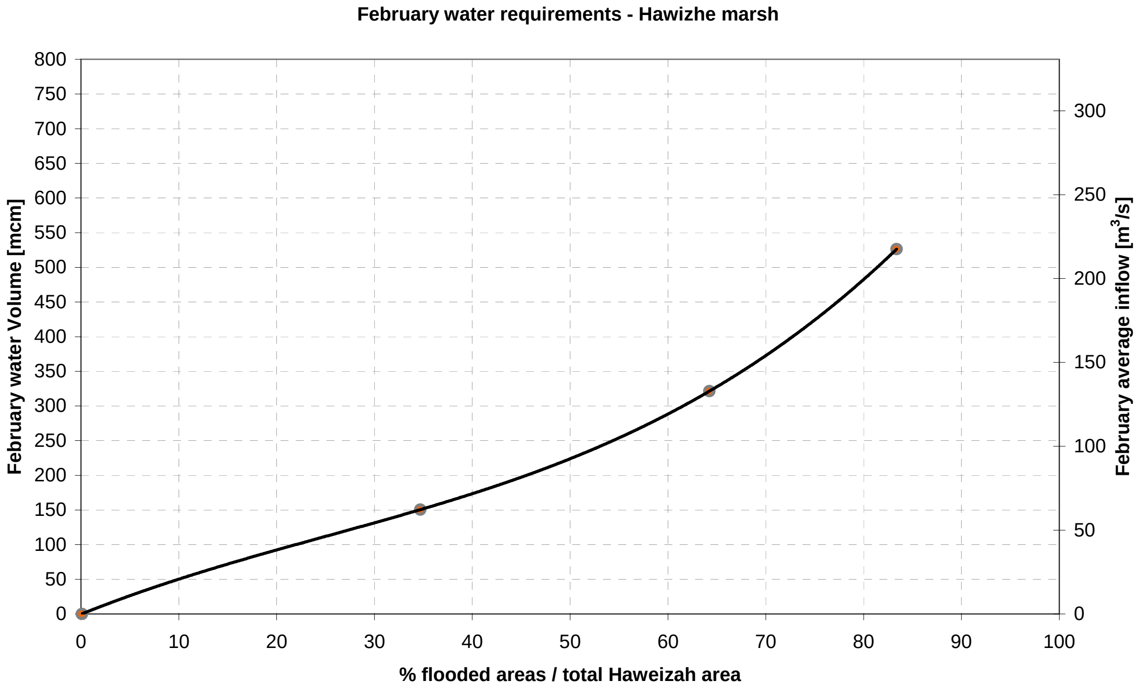


Figure 101: February water requirements for Hawizhe Marsh

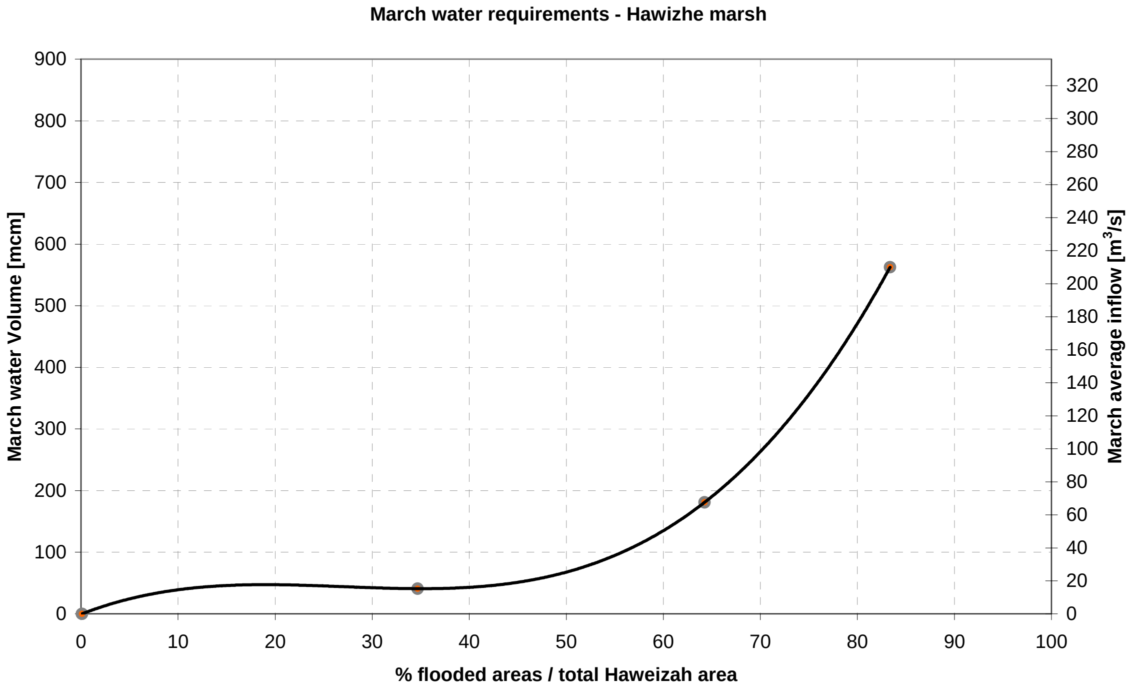


Figure 102: March water requirements for Hawizhe Marsh

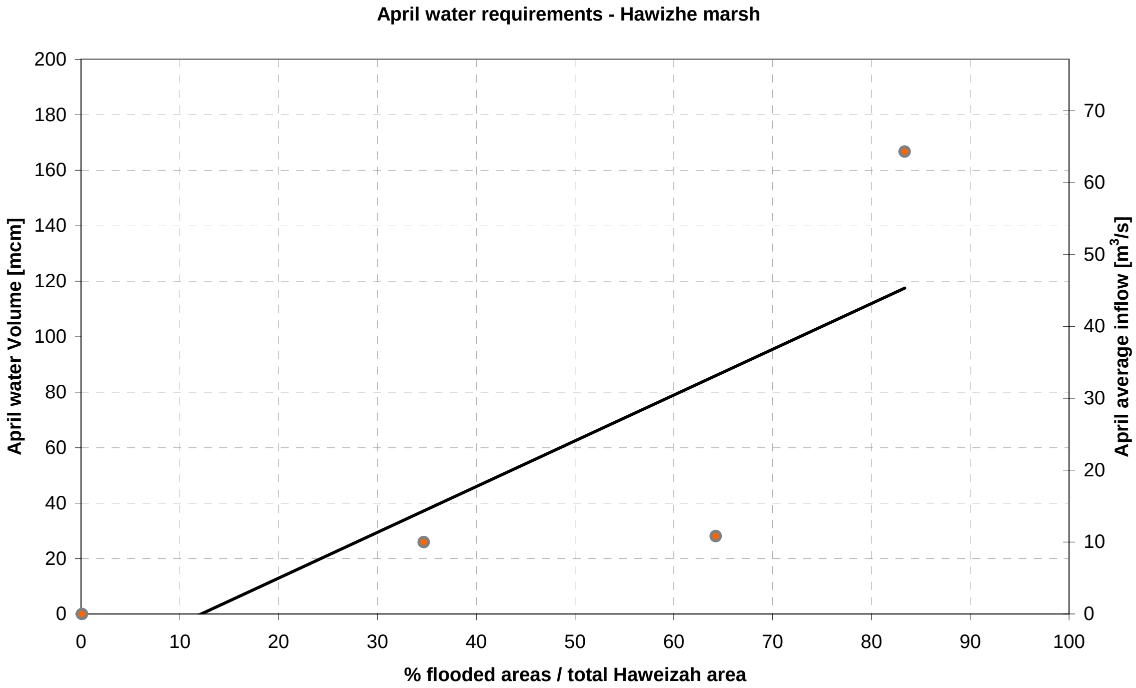


Figure 103: April water requirements for Hawizhe Marsh

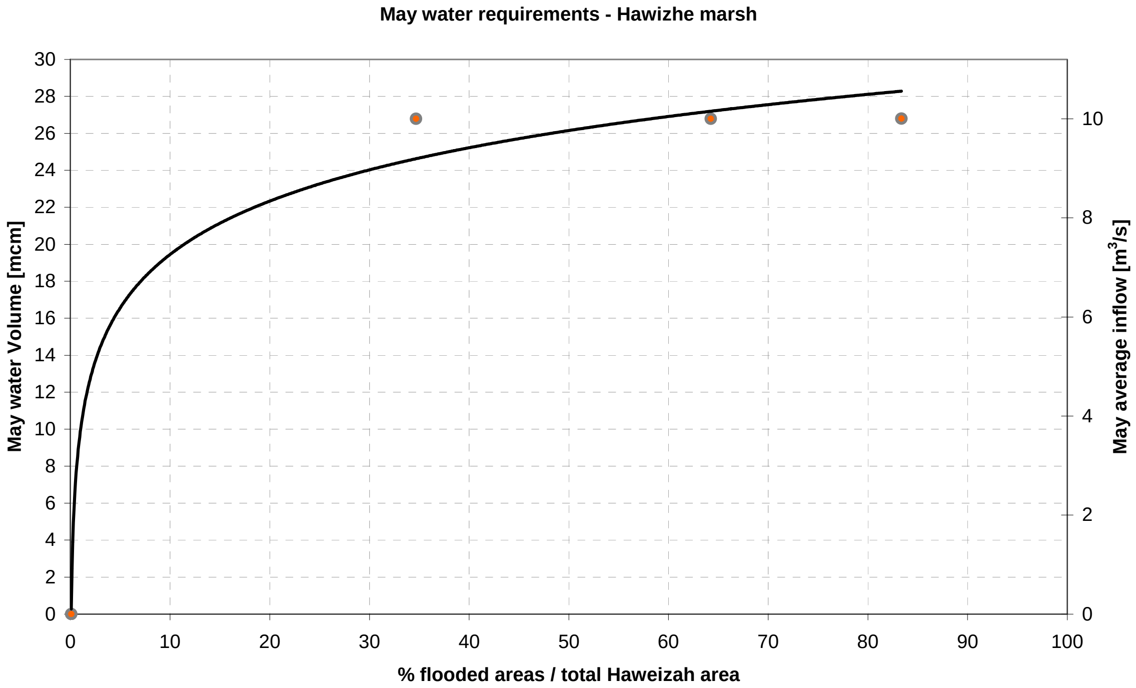


Figure 104: May water requirements for Hawizhe Marsh

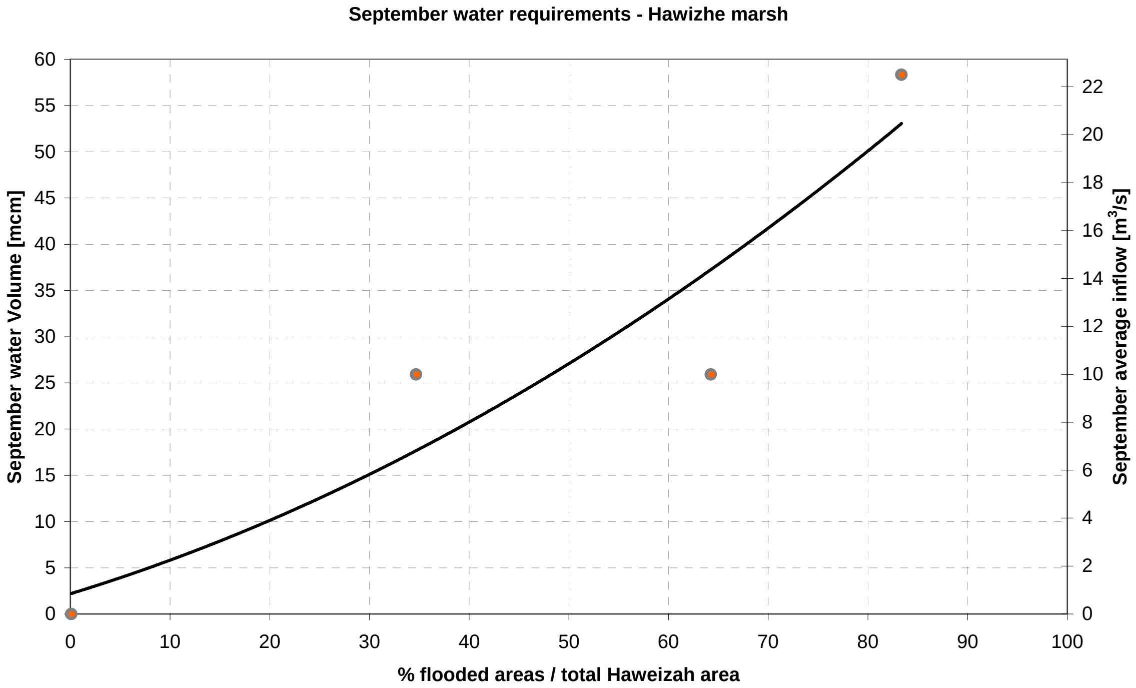


Figure 105: September water requirements for Hawizhe Marsh

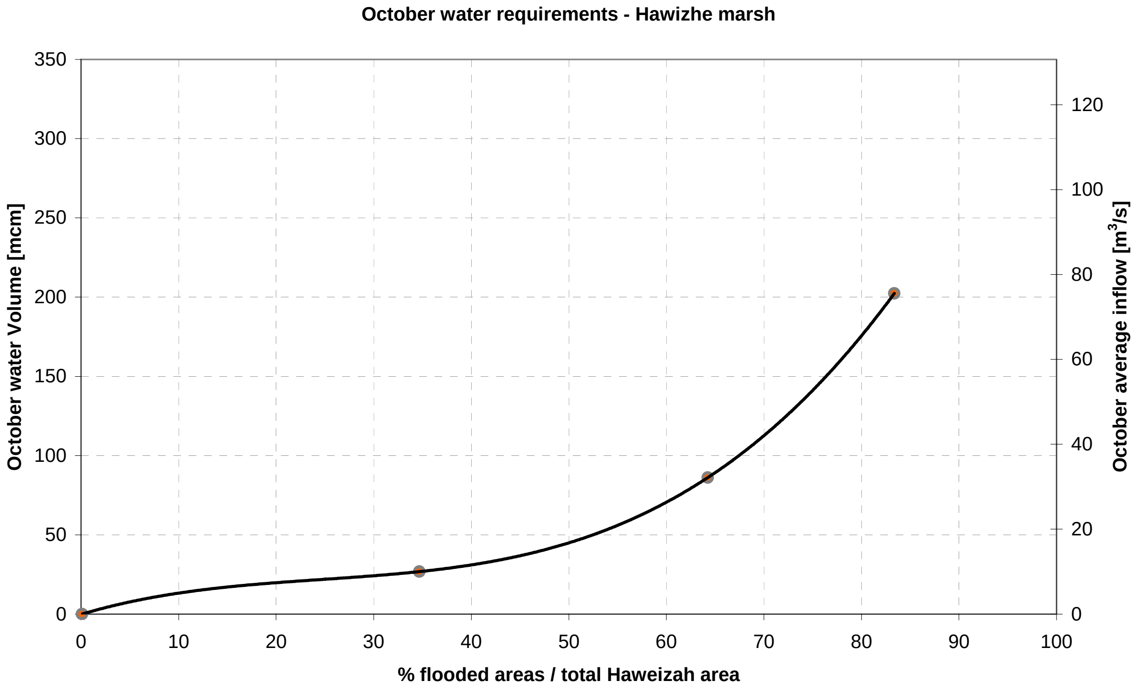


Figure 106: October water requirements for Hawizhe Marsh

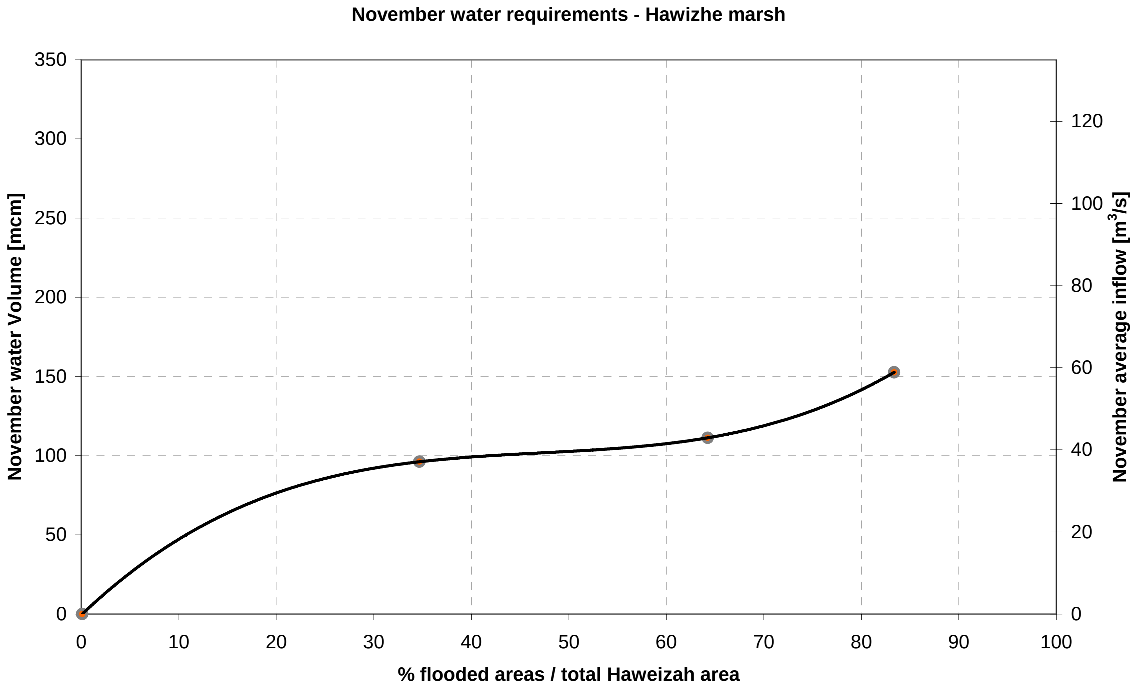


Figure 107: November water requirements for Hawizhe Marsh

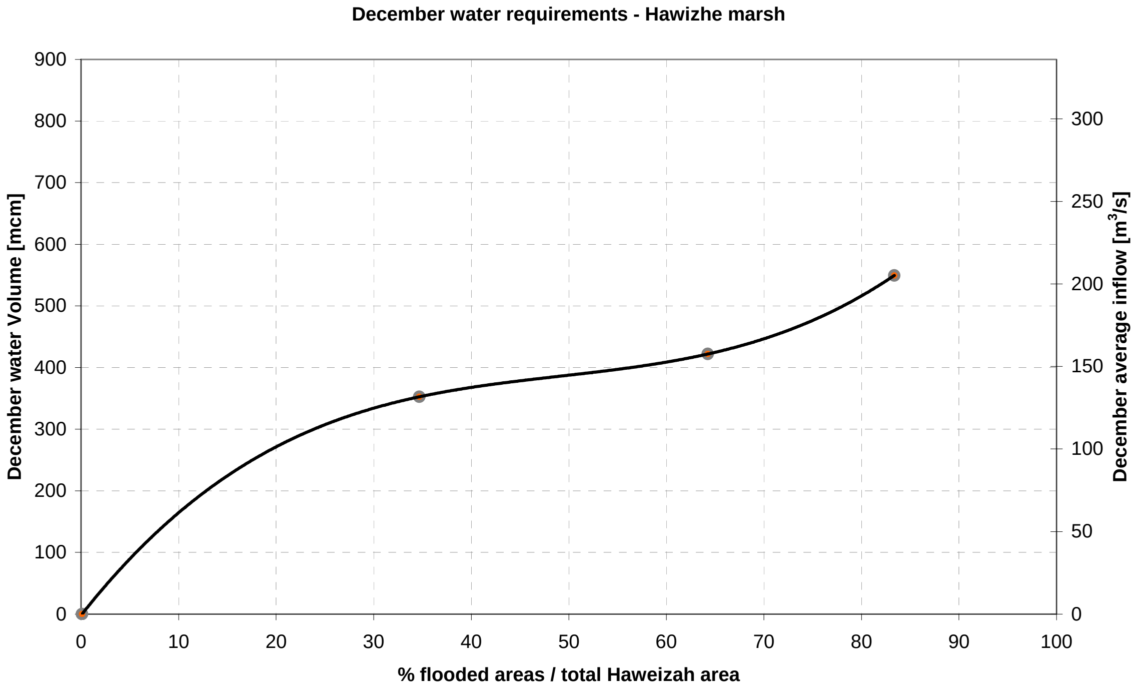


Figure 108: December water requirements for Hawizhe Marsh

Total Cumulative Marsh

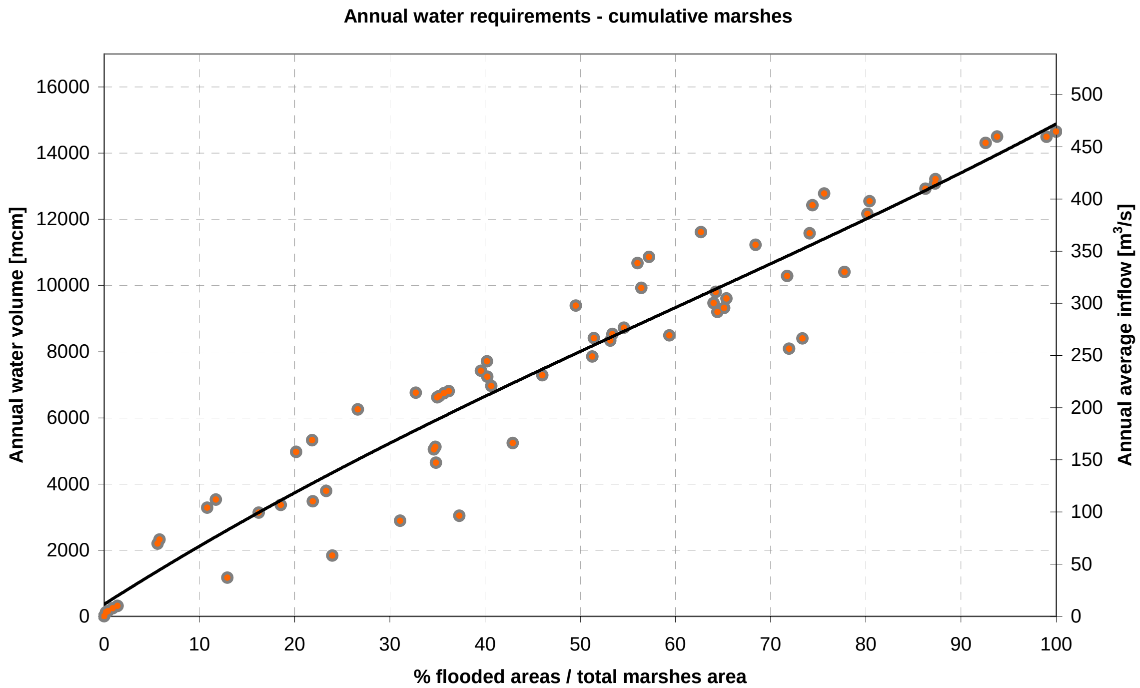


Figure 109: Annual water requirements for total marshlands area

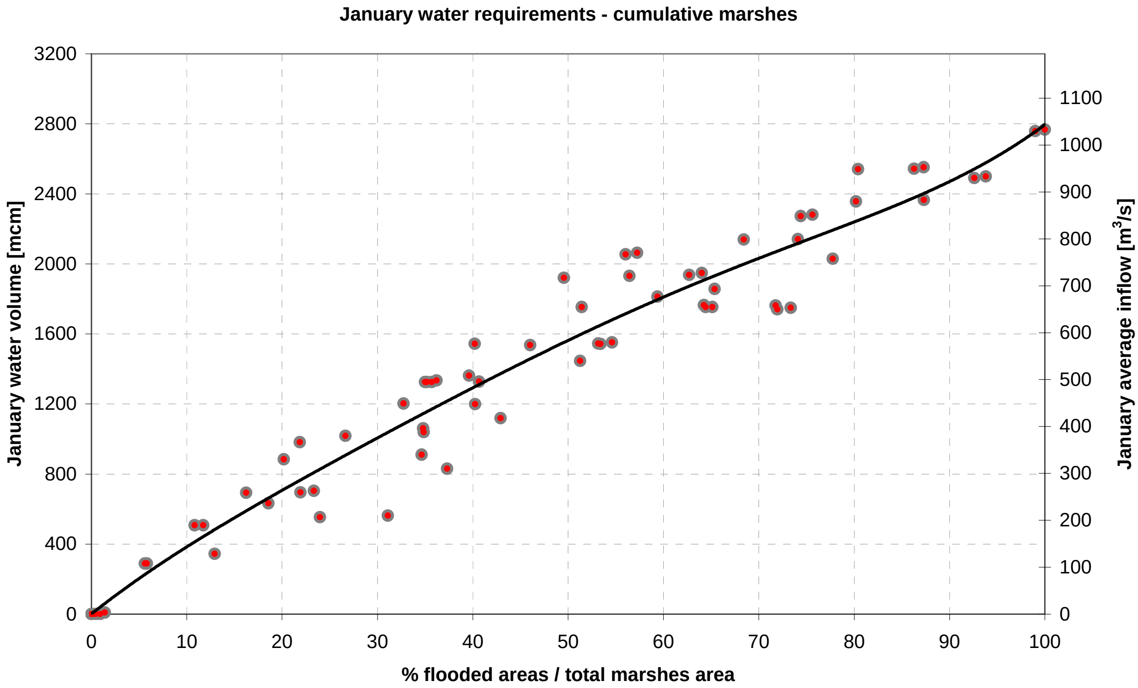


Figure 110: January water requirements for total marshlands area

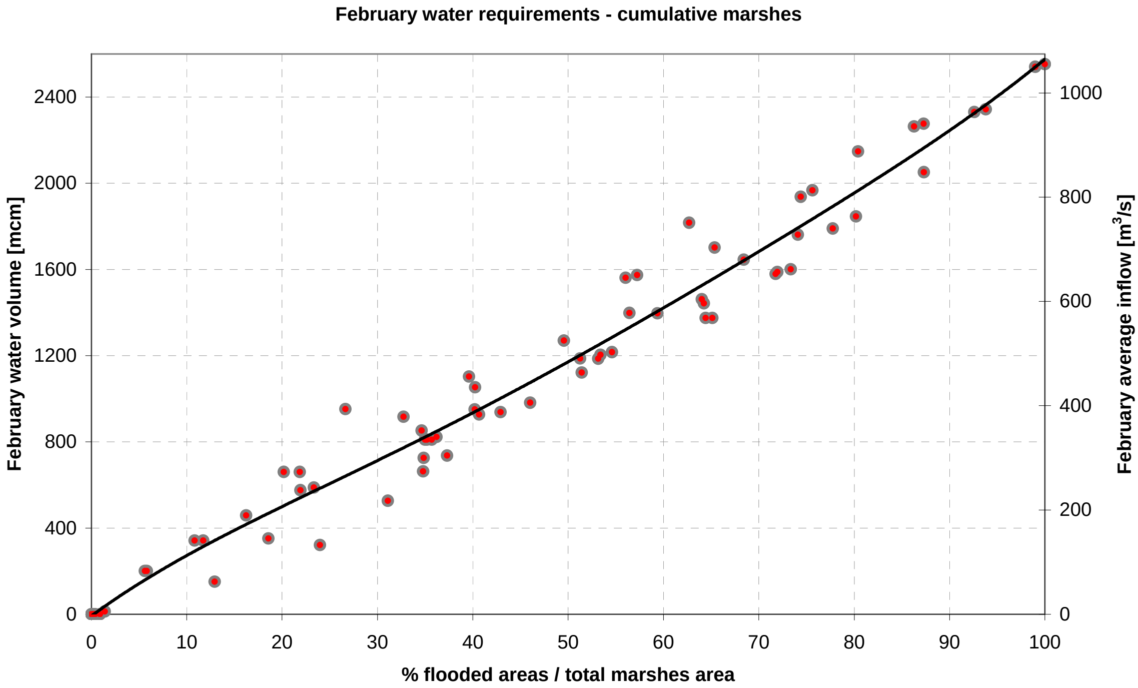


Figure 111: February water requirements for total marshlands area

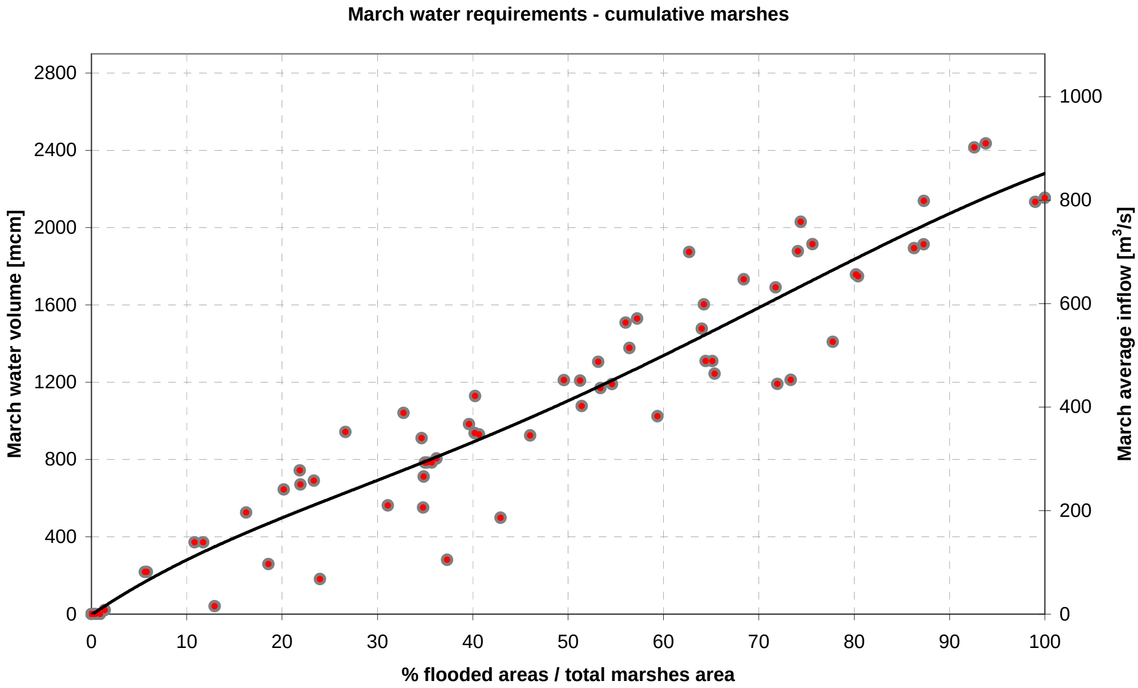


Figure 112: March water requirements for total marshlands area

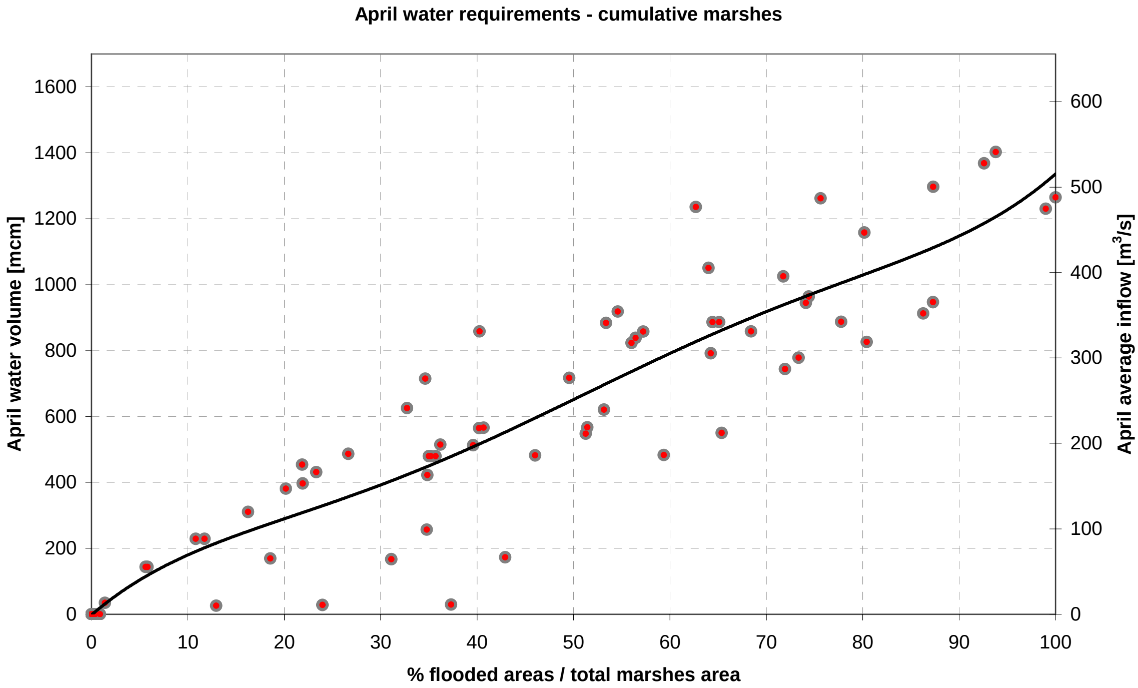


Figure 113: April water requirements for total marshlands area

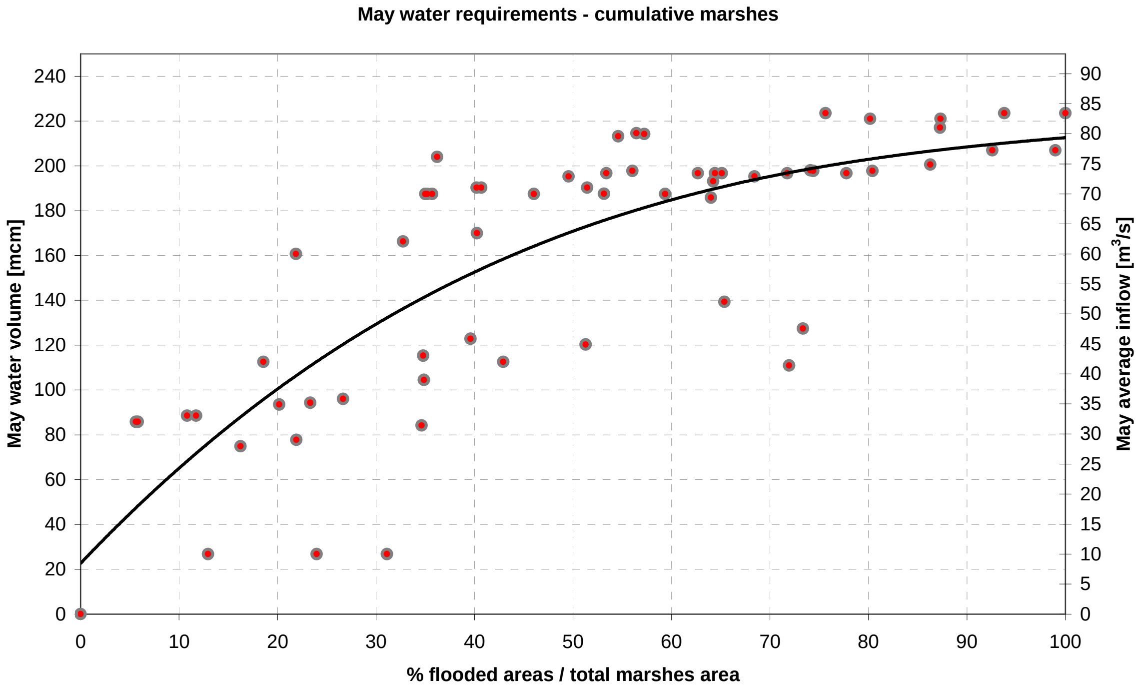


Figure 114: May water requirements for total marshlands area

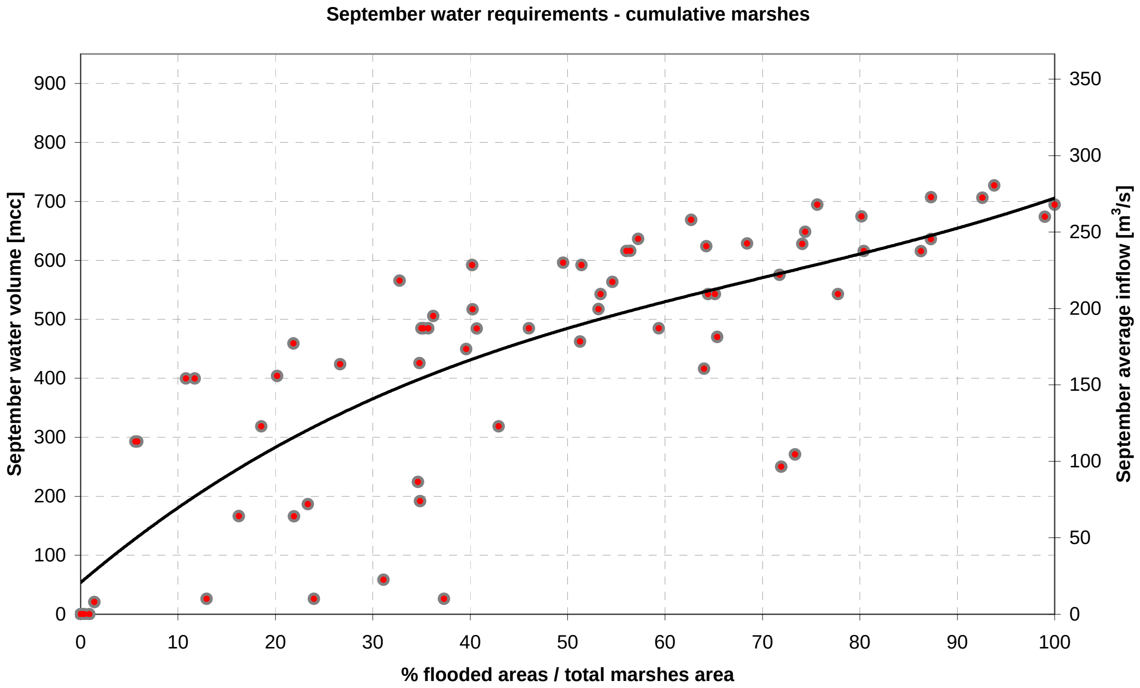


Figure 115: September water requirements for total marshlands area

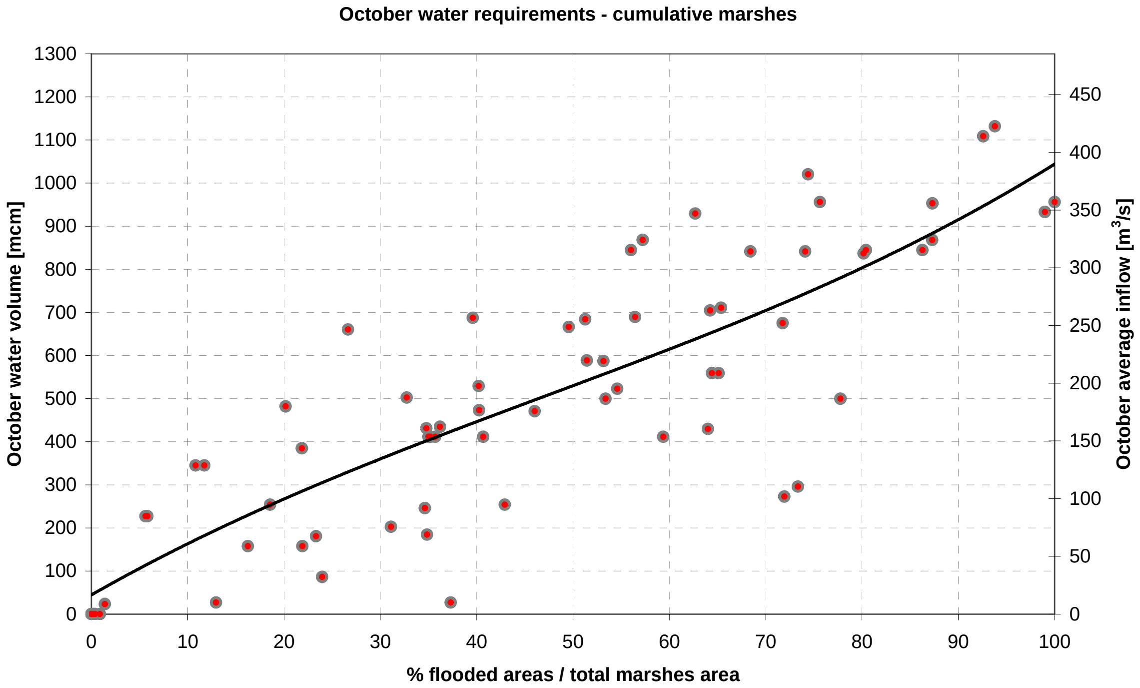


Figure 116: October water requirements for total marshlands area

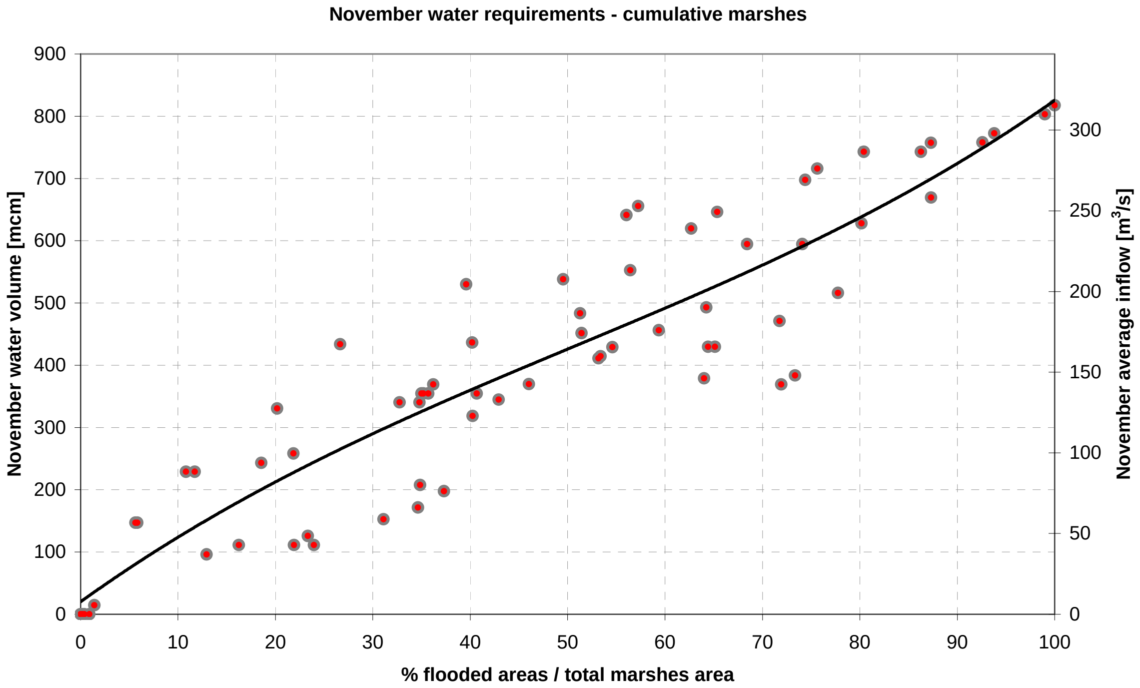


Figure 117: November water requirements for total marshlands area

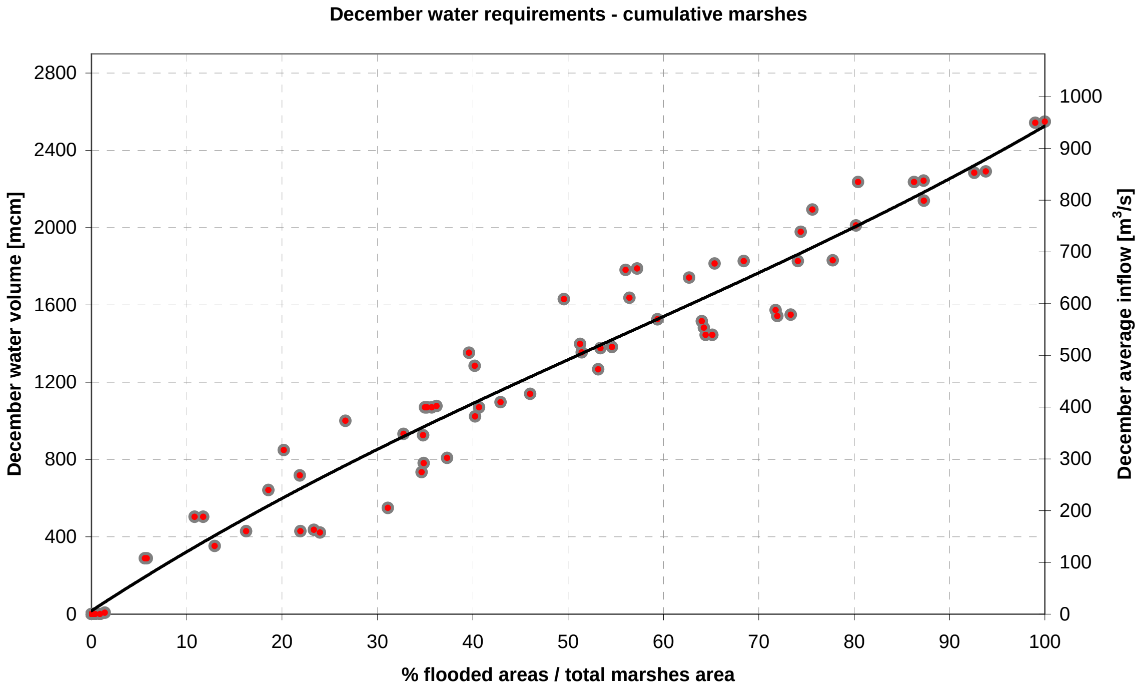


Figure 118: December water requirements for total marshlands area