HYDROLOGICAL MODELING OF ASSANNA'F MARSH

Riyadh Z. Al Zubaidy, Ph. D.
Department of Water Resources Engineering, University of Baghdad
Hayder A. Al Thamiry, Ph. D.
Department of Water Resources Engineering, University of Baghdad
Mahmoud S. Al Khafaji, M. Sc.
Department of Building and Construction, University of Technology

ABSTRACT

AsSanna'f Marsh is one of the southern Iraqi Marshes. It is considered as a seasonal marsh. During rainy season, the marsh feeders start to fill the nearly empty region of the marsh and the water levels start to increase gradually. After the water level reaches a specific value, it starts to flow toward Al Huwayza Marsh.

Studies on the hydrological properties of AsSanna'f Marsh are rare and there is a lack of hydrological data of AsSanna'f Marsh feeders. Generally, this paper was prepared to predict missing hydrological data, a procedure was developed and applied for this purpose, and to be used with the available hydrological and topographical data for modeling and analysis the hydrological properties of AsSanna'f Marsh.

The topographical survey and the hydrological field measurements for a period of six months, which were carried out by the Center for Restoration of Iraqi Marshlands, CRIM, of the Ministry of Water Resources, MOR, were used in the hydrological analysis carried out by this paper.

The area and storage elevation curves were computed in two different methods satisfying the existing behavior of the flow condition through the marsh. Relations between the inflow, out flow with the water level elevation, and storage and losses within the marsh were obtained.

The hydrological routing showed the dykes surrounding AsSanna'f Marsh must be at least 11m.a.s.l to increase the Marsh outflow into Al Huwayza Marsh. especially at the south east boundary of the marsh near Al Msharah River. Maximum and minimum storages and the extended wetted area of the marsh were specified. The required inflow and outflow of AsSanna'f Marsh was studied, taking in consideration the wet, normal, and dry years. The maximum allowable AsSanna'f Marsh inflow into Al Huwayza Marsh is specified for flooded year satisfying different the design criteria of the control structures of the outlets of Al Huwayza Marsh and Kmait Flood Escape. A control structure was suggested at the outlet of AsSanna'f Marsh to ensure the full restoration of Al Huwayza Marsh.

الخلاصة

هور السناف احد اهوار العراق الجنوبية الموسمية. يبدأ الماء بالتجمع في هذا الهور من مغذياته خلال موسم الامطار الى ان تصل مناسيب المياه فيه الى حد محدد عندها يبدا الماء بالانسياب باتجاه هور الحويزة.

الدراسات الهيدرولجية التي تمت لهور السناف محدودة كما ان البيانات المطلوبة لانجاز الدراسات الهيدرولوجية قليلة وما متوفر منها يقتصر على فترة محدودة. عموما، اعدت هذه الدراسة لاستنباط البيانات الهيدرولوجية الناقصة وفق سياق اعد في هذه الدراسة لهذا الغرض ومن ثم وبالاعتماد على هذه البيانات وما متوفر من بيانات هيدرولوجية وطوبوغرافية تم نمذجة وتحليل الخواص الهيدرولوجية لهور السناف.

اعتمد في هذا البحث المسح الطوبوغرافي والقياسات الحقلية الهيدرولوجية المنجزة من قبل مركز انعاش الاهوار العراقية التابع لوزارة الموارد المائية لمدة ستة أشهر.

تم في هذا البحث حساب العلاقة بين منسوب الماء مع الخزين والمساحة السطحيةفي هور السناف والتي اعتمدت على اسلوبين مختلفين لتحقيق واقع حال الماء الجاري ضمن الهوركما وتم الاستفادة من القياسات الحقلية في منطقة هور السناف في ايجاد العلاقة بين الماء الداخل والخارج مع مناسيب المياه والخزن والضائعات ضمن هذا هور . ان الاستنتاجات المستحصلة من خلال استتباع الجريان خلال موسم الفيضان بان منسوب التكتيف المحيط بالهور يجب ان لا يقل عن 11م فوق مستوى سطح البحر وخصوصا الجزء الجنوبي الشرقي من هورالسناف قرب نهر المشرح لزيادة تصريف الهور باتجاه هور الحويزة وكذلك تم تحديد اقصى تصريف ممكن اطلاقه من هور السناف باتجاه هور الحويزة محققا مختلف المعايير التصميمية لمنشأت السيطرة على مخارج هور الحويزة ومهرب كميت الفيضاني اضافة لاستعراض اسلوب التشغيل الامثل للمنشأ المقترح على مخرج هور السناف لضمان الانعاش الكلي لهور الحويزة..

KEY WORDS
Flow routing, Hydrological modeling, Hydrological routing, Iraqi Marsh Lands.

INTRODUCTION

Fig. 1 shows a schematic diagram of AsSanna'f Marsh and its feeders, the marsh area reaches 360km^2 during rainy seasons. The marsh area lies along left hand side of Am'arah-Msharah main road. Flood protections dykes lie along the south boundary of the marsh started from Ghzayla Bridge until the dykes of Sa'ad Drain River. Al Fakka–Ghzayla road is the north-east boundary of the marsh. The north boundary of the marsh is a varying boundary that depends on the levels of the stored water within the marsh. The average ground level is around 5m.a.s.l at its southern part and increases gradually in north and north-west directions. The maximum recorded water level in the marsh was 6.5m.a.s.l at Ghzayla Bridge in March of 1988.

The main feeders of AsSanna'f Marsh are: AtTeeb, Dwayreach, Kmait Rivers, the Drain water of Sa'ad River irrigation project, and the surface runoff of AshShmasher catchment area. The catchments area of AtTeeb and Dwayreach Rivers are 2670km^2 and 3270km^2, respectively. These catchment areas lie within the Iranian borders and discharging into AsSanna'f Marsh. AtTeeb River has a length of 500km; its peak discharge is about 1100m^3/sec. While Dwayreach River has a length of 202km, its peak discharge is about 930m^3/sec. These two rivers are seasonal rivers they have flow during January to March. There is no hydraulic structure that can be used to control the inflow from these feeders, Al-Furat Center for studies and designs of irrigation projects, 2003.

Kmait River was designed as a flood escape, its intake has a design discharge of 400m^3/sec and a crest level of 8m.a.s.l, which is located at north of Al Am'arah Barrage. The river is extended from Tigris River towards AshShmasher dykes with a length of 3.4km, then its

direction is changed to the right along these dykes, and this part of river is known as AshShmasher channel, Al-Furat Center for studies and designs of irrigation projects, 1993.

Sa'ad River irrigation project area is about 90000Donams which is located between Al Msharah and Kmait Rivers. This project is served by a drain system in which the drain water is collected by a main collector draining called Sa'ad River irrigation project drain which is finally pumped at a rate of 11m^3/sec to the Kmait River and at a rate of 4 m^3/sec directly to AsSanna'f Marsh by another pump station.

The catchment area of AshShmasher surface runoff is 1300km^2, its surface runoff of about 600m^3/sec is discharge along AsSanna'f Marsh west dyke, between Ghzayla Bridge and AshShmasher dykes. The water passes this dyke through groups of pipes, Al-Furat Center for studies and designs of irrigation projects, 2003, General Directorate of Water Resources Management, Center of hydrology, 2004.

During rain season, water from AsSanna'f Marsh feeders starts to fill empty region of the marsh and the levels are increased gradually. Then water of this marsh is directed to Al Huwayza Marsh after it reaches a specified level.

Fig. 1. Layout of AsSanna'f Marsh and its feeders, *after CRIM 2006*.

AVAILABLE DATA

Some of the hydrological and topographical data required to carry out the flow routing through AsSanna'f Marsh were available at the CRIM, these data are presented in the following sections.

Topographical Data

A topographical survey of AsSanna'f Marsh area was carried out by CRIM, 2006. **Fig. 2** shows the topographical map of AsSanna'f Marsh.

Hydrological Data

The monthly Evapo-transpiration, evaporation and water used by plants, are essential factor in estimating the water losses. **Table 1** presents the calculated monthly Evapo-transpiration for Al Huwayza Marsh and was adopted in AsSanna'f Marsh hydrologic routing, Ministry of Water Resources, et. al. 2006.

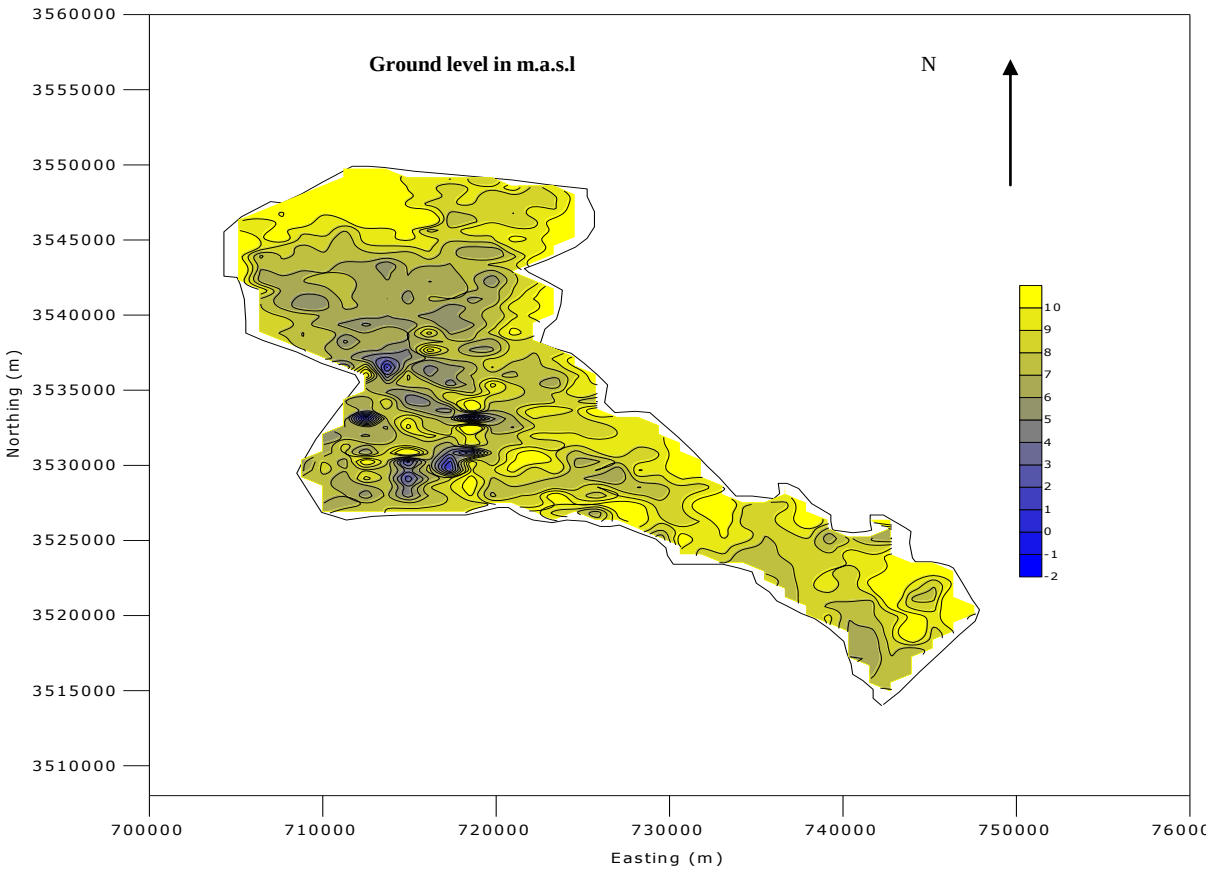


Fig. 2. Topographical map of AsSanna'f Marsh, *after CRIM 2006*.

Table 1. Monthly evapo-transpiration in Al Huwayza Marsh, ***after Ministry of Water resources et. Al. 2006.***

	Month												
	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Total
Evapo-transpiration mm/month	53.5	76.8	126.1	199.9	278.4	375.2	423.2	390.9	279.1	174.4	99.1	59	2536.3

Hydrological Field Measurements

Twelve discharge and stage measurements at four measurement stations, two measurements every month, were carried out during the period from January 2006 to July 2006 by the CRIM. These stations are shown in **Fig. 3.**

The discharge and stage measurements records in all stations are presented in **Table 2.** The recorded discharge at Kmait station is zero during the study period, since there is no inflow water from Kmait flood escape. The stage within this station is approximately constant and equal to 6m.a.s.l.

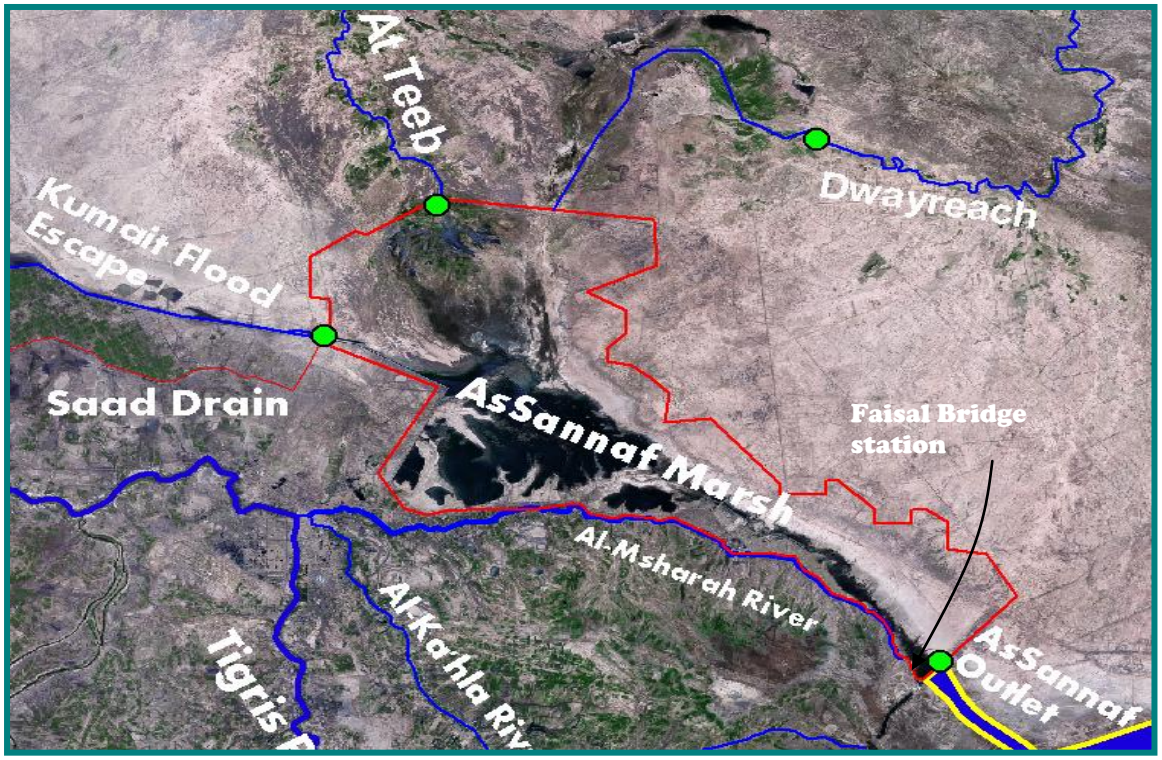


Fig. 3. Hydrological field measurements Stations.

Table 2. Measured discharge and stage at the measuring stations. ***After CRIM, 2006*****.**

Measurement date	Discharge Q ,m^3/sec- Stage m m.a.s.l.					
	Dwayreach Station		AtTeeb Station		Faisal Bridge station	
23/1/2005	202.00	21.90	154.00	17.40	210.00	7.64
08/2/2005	94.50	20.86	55.20	15.99	152.00	6.89
16/3/2005	0.18	18.75	1.55	13.44	94.80	6.14
30/3/2005	0.16	18.50	1.55	13.44	17.20	6.06
13/4/2005	0.15	18.75	1.40	14.19	3.55	6.16
27/4/2005	0.06	18.78	1.38	13.87	3.78	6.13
01/5/2005	0.06	18.82	1.31	13.78	9.48	6.17
25/05/2005	0.00	18.50	0.74	13.71	7.23	6.09
08/06/2005	0.00	18.50	0.51	13.69	6.07	6.09
22/06/2005	0.00	18.50	0.72	13.71	3.23	6.04
06/07/2005	0.00	18.50	0.74	13.71	0.00	5.64
20/07/2005	0.00	18.50	0.71	13.72	0.00	5.64

PREDICTED HYDROLOGICAL DATA

There is a lack of hydrological data of AsSanna'f Marsh feeders. The discharge hydrographs of these feeders have been estimated by utilizing the hydrological field

measurements during the period of the study. An accurate estimation of the surface runoff of AshShmasher catchment area is very difficult because of the absence of the accurate historical data and the interface between this runoff and the water of AtTeeb and Dwayreach Rivers before the entrance of this runoff into AsSanna'f Marsh. Prediction of AshShmasher catchment area surface runoff was carried out depending on the topographical and climatologically similarity. The catchment area of AtTeeb and Dwayreach Rivers lies within the same region of AshShmasher area and have approximately same conditions. By assuming a linear relation between catchment area and runoff, the surface runoff of AshShmasher area surface runoff hydrograph is approximated to be the runoff of AtTeeb and Dwayreach runoff multiplied by area ratio. The catchment area of AshShmasher area, AtTeeb, and Dwayreach Rivers are 1300, 2670, and 3270 km^2, respectively, General Directorate of Water Resources Management, Center of Hydrology, 2004, UNEP, January 2004

The average ratio of AshShmasher catchment area to AtTeeb River catchments area is (0.49), and Dwayreach River catchments area, (0.4), is 0.44. This ratio, 0.44, has been adopted as the ratio of AshShmasher area surface runoff from the average of AtTeeb and Dwayreach Rivers discharges. Predicted data of AshShmasher catchment area surface runoff is presented below in **Table 3**.

The discharges of AsSanna'f Marsh feeders, AtTeeb River, Dwayreach River and AshShmasher surface runoff, during the dry and wet years were estimated by making use of the measured discharges during the study period. These measured discharges have been considered as AsSanna'f Marsh feeders' discharges during a normal year.

Table 3. Predicted surface runoff (m^3/sec) of AshShmasher Catchments Area.

Months	Surface Runoff (m^3/sec)		
	AtTeeb River	Dwayreach River	AshShmasher Area
Oct.	0.73	0.00	0.16
Nov.	0.73	0.00	0.16
Dec.	0.73	0.00	0.16
Jan.	154.0	202.0	78.3
Feb.	55.2	94.5	32.9
Mar.	1.55	0.17	0.38
Apr.	1.39	0.11	0.33
May	1.03	0.03	0.23
Jun.	0.62	0.00	0.14
Jul.	0.73	0.00	0.16
Aug.	0.73	0.00	0.16
Sept.	0.73	0.00	0.16

The ratio of discharge of each feeder to AsSanna'f Marsh outflow, at Faisal bridge station, was calculated for normal year. The calculated ratios have been considered as the amount of share of each feeder from the marsh outflow for the dry and wet years. The predicted discharges of AsSanna'f Marsh feeders, AtTeeb River, Dwayreach River and AshShmasher catchment area surface runoff, during the dry, normal, and wet years are shown in **Figs. 4, 5 and 6.**

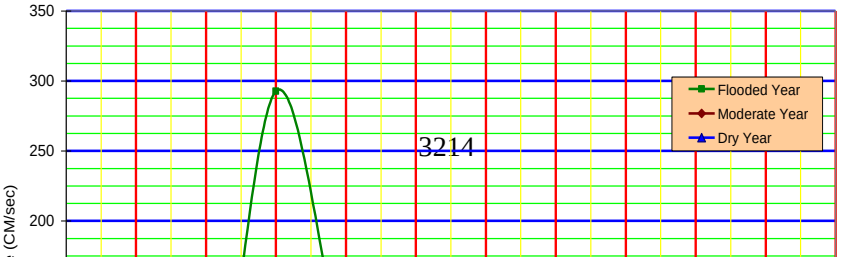


Fig.4. Averaged monthly flow of AtTeeb River averaged.

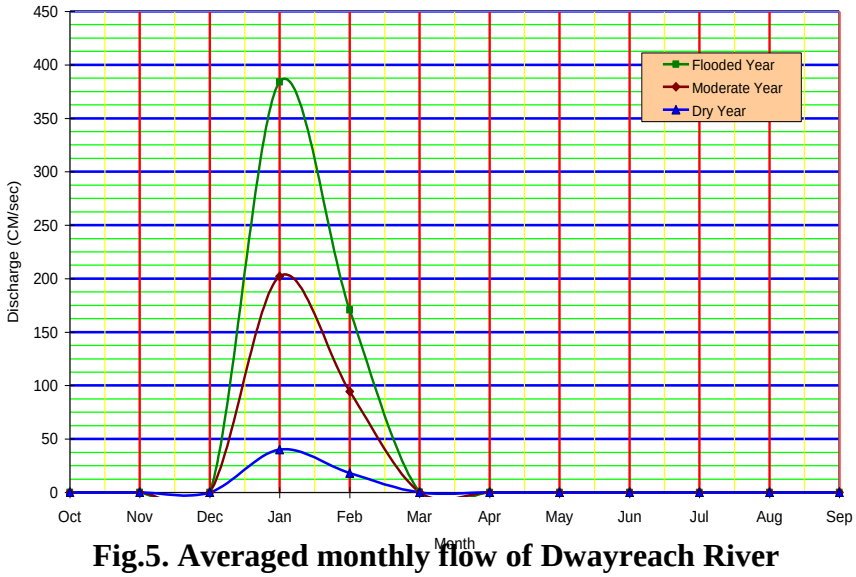


Fig.5. Averaged monthly flow of Dwayreach River

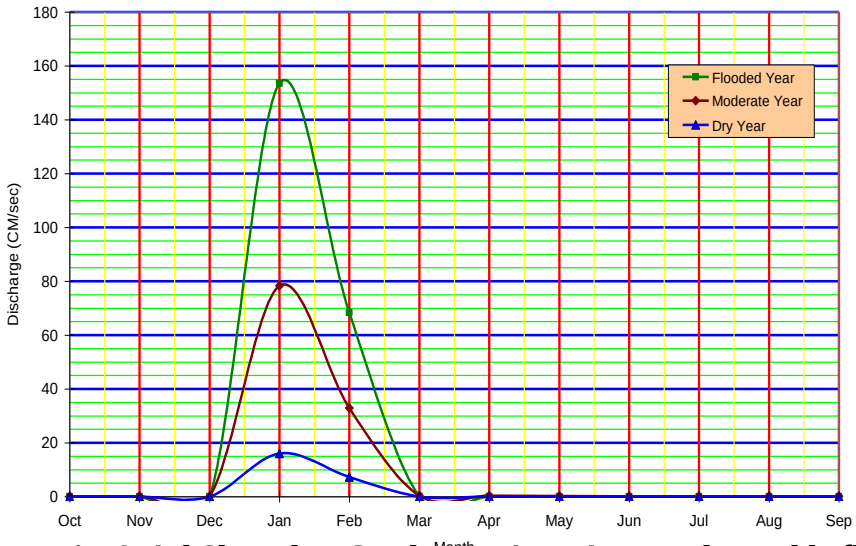


Fig. 6. AshShmasher Catchment Area Averaged monthly flow.

STORAGE CAPACITY RELATION

AsSanna'f Marsh extension is decided depending on the actual height of the marsh dykes. The minimum dykes level is about 9 m.a.s.l at the south boundary of the marsh near Al Msharah River. Therefore, the marsh boundary is the within the contour of 9 m.a.s.l. if 1m is considered as a free board, then the maximum allowable water level within the marsh is 8m.a.s.l.

The area and storage elevation curves were computed for two different cases satisfying the existing behavior of the water flowing through the marsh. The first case, when there is inflow and no outflow from the marsh toward Al Huwayza Marsh, or there is no inflow and there is outflow from the marsh or there is no inflow and no outflow. This case occurs when the marsh is starting store water or when the feeders are depleted at the end of the rainy season. In this case the water level within AsSanna'f Marsh is approximately horizontal and the Arc-View GIS software is used to evaluate the area elevation and storage elevation relations.

The second case, when the water level near AsSanna'f Marsh outlet is higher than the 5.65 m.a.s.l, i.e. water is discharged from this marsh towards Al Huwayza Marsh with the existing of upstream feeding. In this case the marsh is treated as a river basin and the water level along the marsh will not be a horizontal. Since the marsh width is not constant a long its length, the water surface elevation will have significant variation along the marsh length. This variation in water levels increases the surface area and storage in the upstream part of this marsh.

A one dimensional steady hydraulic model was developed using the HEC-RAS software in order to estimate the surface area and the storage within the marsh. Development of this model required implementation of the geometrical and hydraulic data. ARC-View GIS Software with DEM of AsSanna'f Marsh is used in the construction of the geometrical data. Layout of the implemented cross sections is shown in **Fig. 7.**

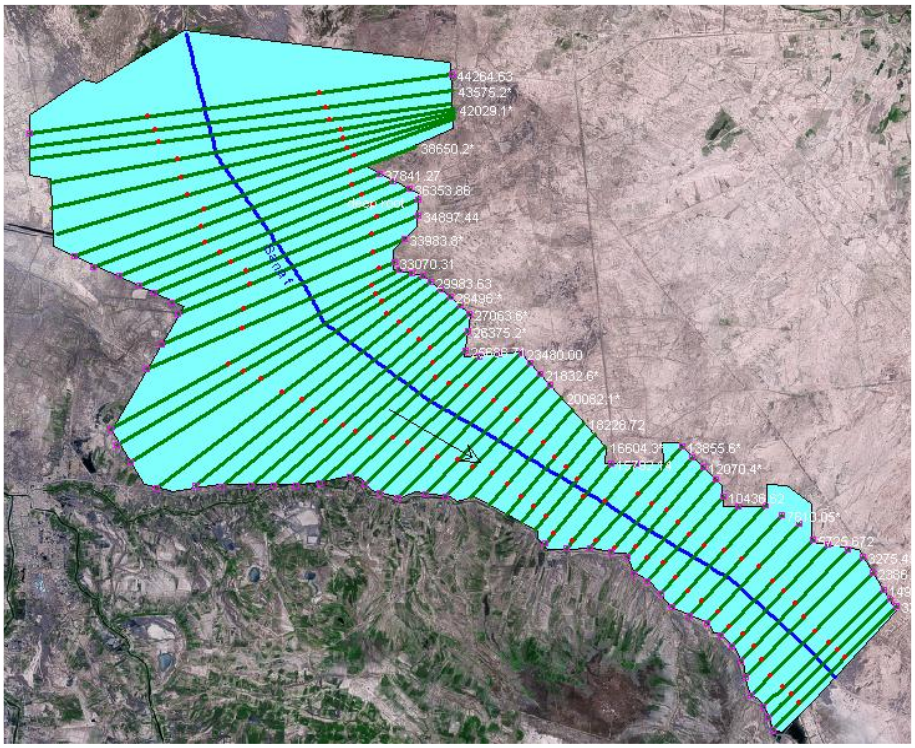


Fig.7. Implemented cross sections along AsSanna'f Marsh.

The upstream boundary condition is a known range of flow rates while the downstream boundary condition is rating curve, according to the filed measurements at Faisal Station during the study period. According to each computed water level, the surface area and storage are evaluated from the developed model. The constructed area-elevation and storage–elevation curves

for the two cases are shown in **Fig. 8** and **9**. The constructed area-elevation curves and storage elevation curves for the flow conditions are based on the water elevation at location of Faisal station. The maximum surface area of AsSanna'f Marsh with 8m.a.s.l is 360 km^2 with storage capacity of 750 million m3. It is to be noticed that, the dykes surrounding the marsh are equal or higher than 9m.a.s.l.

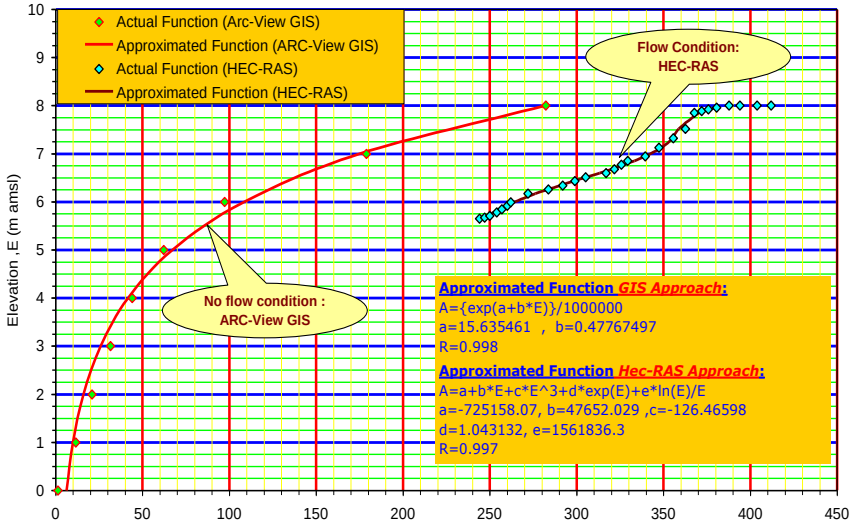


Fig. 8. AsSanna'f Marsh area-elevation curves.

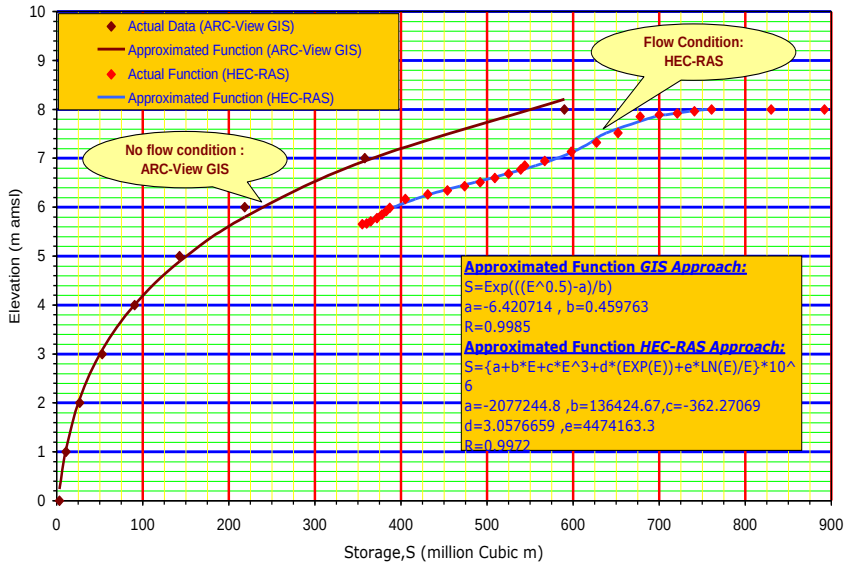


Fig. 9. AsSanna'f Marsh storage-elevation curves.

HYDROLOGICAL ROUTING

There is some uncertainty in the flow routing of AsSanna'f Marsh arising from its behavior and the lack of infiltration losses data within the marsh. To take these two points into account, the following methodology was adopted in the hydrological study. A hydrological routing for normal year is presented by the period of this study using the twelve measured discharges that were carried out at all feeders and outlet of the marsh and comparing of the resulting storage within the marsh with the existing storage according to the recorded stages at Faisal station. The effect of the infiltration losses is considered as a part of the required storage in the first period of storing water, when there is inflow and no outflow from the marsh. These infiltration losses are considered with the calibration of the model.

The implementation of the hydrologic routing model for calibration purposes depends on the inflow into AsSanna'f Marsh, measured at: AtTeeb, Dwayreach, and Kmait hydrological measuring stations, the outflow, measured Faisal bridge hydrological measuring station, the area – elevation curves, storage –elevation curves, and evapo-transpiration of the study area. It was noted, during the period of the study that there is no inflow towards AsSanna'f Marsh from the Kmait Flood Escape at Kmait station. The recorded water levels at Kmait station is approximately constant and is about 6m.a.s.l. The outflow form AsSanna'f Marsh was measured at Faisal Bridge station. These data were used as an input for the hydraulic mathematical model to verify the flow and obtain the relation between the inflow and out flow with the water level elevation, storage and losses within the marsh. The resulting marsh storage for normal year is shown in **Fig. 10.**

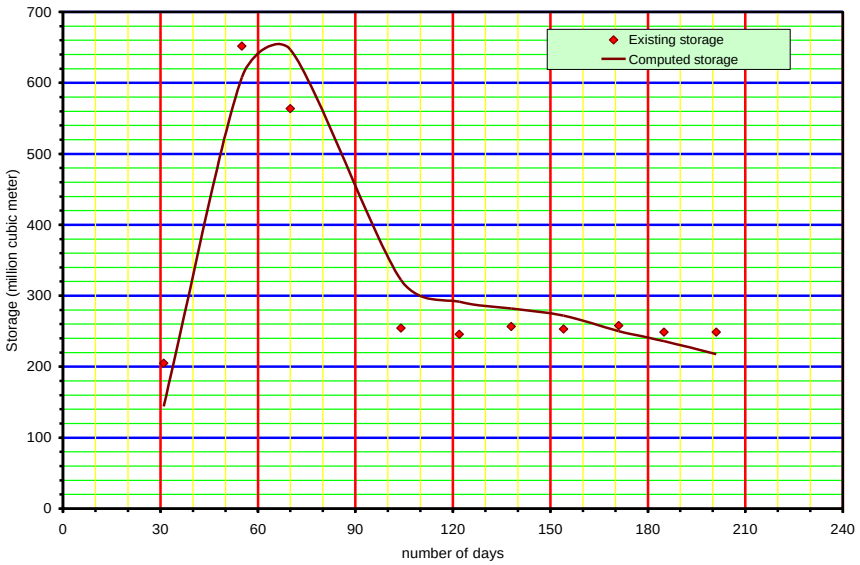


Fig.10. Computed and existing storage within AsSanna'f Marsh during January to October, 2006.

Additional important results from the hydrological routing are the total volume of inflow, outflow and the losses within the marsh are 11012.10, 8810.67 and 2201.43 million m^3 respectively. The evaporation and infiltration losses within the marsh are about 21% from the total inflow. All above results are considered for normal years only

Due to the lack of data records concerning the wet and dry years, the constructed stage-outflow curve for normal year, **Fig. 11**, (it is constructed according to the existing field measurements) will be adopted in the implementation of the hydrological routing for the two situations.

Hydrological Routing During Wet and Dry Years

Two individual hydrological routing were made for wet and dry years, to predict the storage, outflow, and the water levels within the marsh. AsSanna'f Marsh starts its depletion at the end of the rain season and starts its restoration in sequent new rain season. So, this marsh starts its hydrological cycle as a dry marsh. The main limitations that are considered in the construction of the hydrological routing are:

- The maximum storage within the marsh is considered with water level of 8 m, dykes are considered to be at 9 m.a.s.l. The surrounding dykes must be raised to the safe height and new area-elevation and storage elevation curves must be achieved when levels are higher than 8 m.a.s.l.
- The minimum water level is 5.65m.a.s.l, which is the ground level at AsSanna'f Marsh outlet.

- The wet year data of all feeders and the required outflow are considered as detailed in **Table 4**.

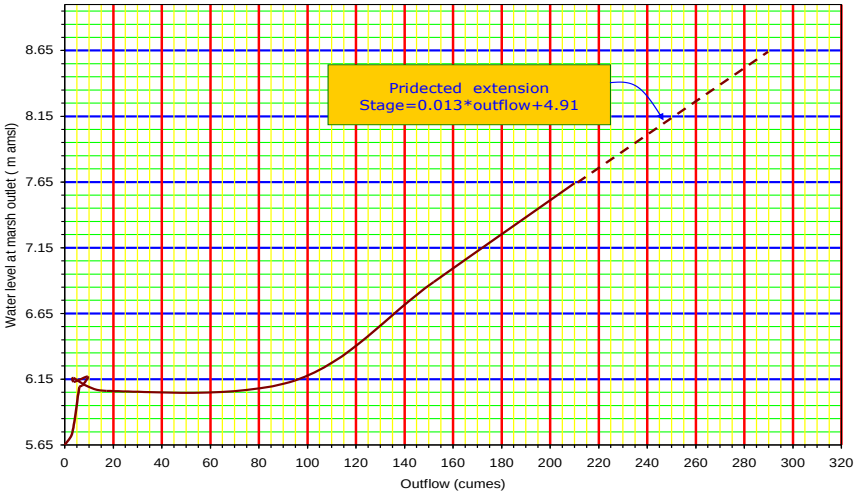


Fig. 11. AsSanna'f Marsh outflow-stage curve.

Table 4. Monthly discharge, m^3/sec, into AsSanna'f Marsh from all feeders during wet years.

Month	Feeder				Total Outflow[b]	The required Outflow[c]
	AshShmasher Run off [a]	Dwayreach River[a]	AtTeeb River[a]	Total Inflow		
Oct.	0	0	1	1	0	0
Nov.	0	0	1	1	0	0
Dec.	0	0	1	1	0	0
Jan.	154	384	293	831	388	264
Feb.	68	171	100	339	367	170
Mar.	0	0	2	2	240	33
Apr.	0	0	2	2	103	33
May	0	0	1	1	67	8
Jun.	0	0	1	1	0	6
Jul.	0	0	1	1	0	0
Aug.	0	0	1	1	0	0
Sept.	0	0	1	1	0	0

a:predicted **b:**hydrologic routing **c:** CRIM, 2006.

According to the hydrological routing and the predicted outflow from the marsh the maximum water level within the marsh reaches 10.15m.a.s.l during January at Faisal bridge station.. The stored water, the surface area and water level variations during the flood season are shown in **Figs. 12, 13** and **14** are respectively.

The dykes of AsSanna'f Marsh must be at least 11m.a.s.l surrounding the marsh especially at the south east boundary of the marsh near Al Msharah River. The maximum expected outflow into Al Huwayza Marsh is 388m^3/sec. Additional routing is needed for Al Huwayza Marsh during flooded year, since the required inflow from this feeder into Al Huwayza Marsh is 264m3/sec at January. The capacity of Al Huwayza Marsh and its outlet designed structures must be able to carry the surplus inflow of 124m^3/sec**,** CRIM, 2006. When the dykes surrounding AsSanna'f Marsh become equal to (or higher than) 11 m.a.s.l, the maximum storage and surface area of the marsh will be 1480 million m^3 and 426km^2, respectively.

The maximum allowable inflow into Al Huwayza Marsh from AsSanna'f Marsh for flooded year is listed in **Table 5**. The Kmait flood escape structure must be a gated control structure with maximum capacity of 250m^3/sec.This control structure must be operated according to the maximum allowable inflow from Kmait Escape**.**

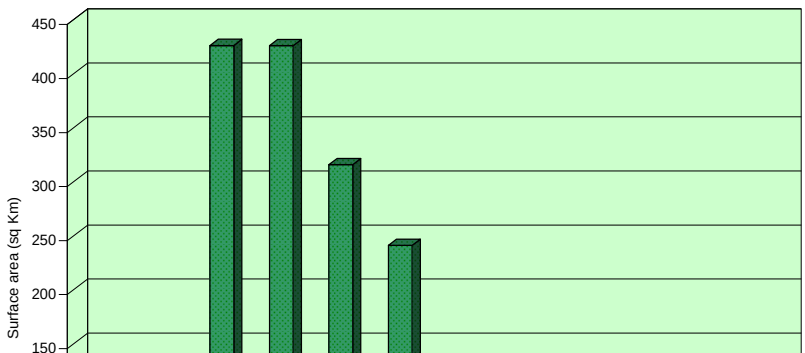


Table 5. Maximum allowable inflow into Al Huwayza Marsh from its feeders during wet year with Al Huwayza Marsh outlets is

Fig.12. The Surface area variation within AsSanna'f Marsh.

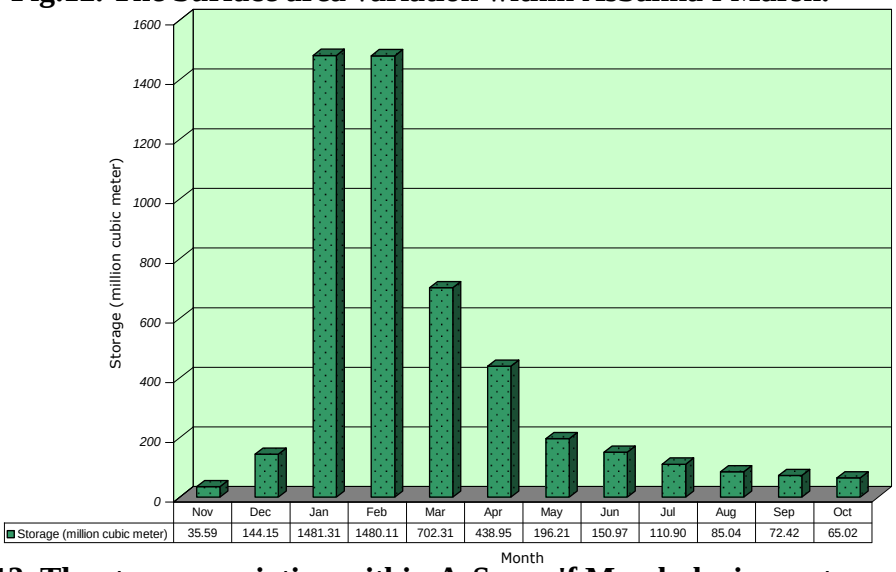


Fig. 13. The storage variation within AsSanna'f Marsh during wet year.

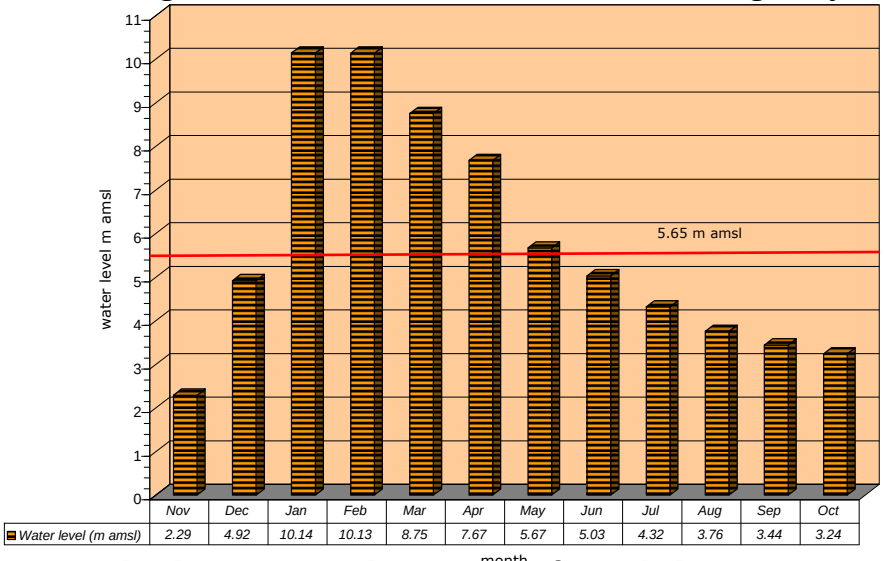


Fig.14. Water level variation within AsSanna'f Marsh during wet year.

Month	Max. allowable inflow into Al Huwayza Marsh	The total required inflow Into Al Huwayza Marsh	Max. surplus inflow into Al Huwayza Marsh	Available inflow from AsSanna'f Marsh	Required inflow from AsSanna'f Marsh	Surplus inflow from AsSanna'f Marsh	Max. allowable inflow From Kmait Escape	Max allowable inflow from AsSanna'f Marsh
Oct.	459	144	315	0	0	0	315 = 250	315
Nov.	528	218	310	0	0	0	310= 250	310
Dec.	519	209	310	0	0	0	310= 250	310
Jan.	799	494	305	388	264	124	181	388*
Feb.	755	447	308	367	170	197	111	388 *
Mar.	751	449	302	240	33	207	95	335
Apr.	850	550	300	103	33	70	230	333
May	608	372	236	67	8	59	177	244
Jun.	311	206	105	0	6	-6	111	335
Jul.	249	144	105	0	0	0	105	333
Aug.	357	132	225	0	0	0	225	244
Sept.	445	130	315	0	0	0	315= 250	335

There is no flood risk, so the maximum allowable discharge must be limited by the proposed Kmait escape control structure maximum capacity , 250 m^3/sec.

*** Maximum capacity of AsSanna'f Marsh outfall.**

e maximum allowable inflows from Kmait flood escape were 181 m^3/sec, 111 m^3/sec, 95m^3/sec, 230 m^3/sec and 177 at Jan., Feb., Mar., Apr. and May, respectively. While the design capacity of this escape is 400m^3/sec. According to the hydrological routing of AsSanna'f

Marsh, refer to **Table 4,** the outflow of AsSanna'f Marsh into Al Huwayza Marsh will 388m^3/sec, 367m^3/sec, 240m^3/sec, 103m^3/sec, and 67m^3/sec during Jan., Feb., Mar., Apr. and May respectively. An additional safe inflow from Kmait Escape can be discharged into Al Huwayza Marsh through AsSanna'f Marsh considering the maximum capacity of AsSanna'f Marsh outlet. The maximum safe additional inflow from Kmait escape is 223m^3/sec which occurred at May.

According to the hydrological routing of Al Huwayza Marsh, CRIM, 2006, the designed discharges of Al Huwayza Marsh outlets control structures must be increased to 550m^3/sec in order to safely discharges this surplus inflow into Tigris river and Shat Al Arab River, the client recommendation for the maximum capacity of Al Huwayza Marsh outlets is 325m^3/sec, The New Eden group, 2005. The design capacity of the Al Huwayza Marsh outlets must be 200m^3/sec of Al Kassara River and 350m^3/sec of AsSuwayb River hydraulic structures. The maximum allowable inflow into Al Huwayza Marsh from AsSanna'f Marsh for flooded year is listed in **Table 6.** The Kmait flood escape structure must be a gated control structure of 400m^3/sec maximum capacity. This control structure must be operated according to the maximum allowable inflow from Kmait escape, **Table 6.**

The dry year data of all feeders are considered as detailed in **Table 7**.The required outflow into Al Huwayza marsh routing is considered to be zero as a worst case, refer to CRIM, 2006**,** for more details.

The results of the hydrological routing were based on the achieved routing in the normal year and the related relations. The maximum water level at Faisal station will be 6.44 m.a.s.l with storage and surface area of 289.8 million m^3 and 133.7 km^2, respectively. The outflow is predicted by trail and error process where, the main constrain is the water level at Faisal bridge station and the losses within the marsh. The monthly variation in storage, surface area and water levels are shown in **Figs. 15, 16** and **17** respectively. According to the hydrological routing and the predicted outflow from the marsh that is listed in **Table 7**.

Table 6. The maximum allowable inflow into Al Huwayza Marsh from its feeders for wetyear with Al Huwayza Marsh outlets is

Month	Max. allowable inflow into Al Huwayza Marsh	The total required inflow Into Al Huwayza Marsh	Max. surplus inflow into Al Huwayza Marsh	Available inflow from AsSanna'f Marsh	Required inflow from AsSanna'f Marsh	Surplus inflow from AsSanna'f Marsh	Max. allowable inflow from Kmait escape	Max allowable inflow from AsSanna'f Marsh
Oct.	684	144	540	0	0	0	400	388*
Nov.	741	218	535	0	0	0	400	388*
Dec.	743	209	535	0	0	0	400	388*
Jan.	1024	494	530	388	264	124	264	388*
Feb.	980	447	530	367	170	197	191	388*
Mar.	973	449	530	240	33	207	181	388*
Apr.	1078	550	525	103	33	70	318	388*
May	834	372	461	67	8	59	329	388*
Jun.	536	206	330	0	6	-6	336	336
Jul.	473	144	330	0	0	0	330	330
Aug.	582	132	450	0	0	0	400	402*
Sept.	670	130	540	0	0	0	400	402*

Table 7. Monthly feeders discharges, m^3/sec, into AsSanna'f Marsh during dry years.

Month	AshShmasher Run off [1]	Dwayreach River[1]	AtTeeb River[1]	Total Inflow	Total Outflow[2]	Required Outflow[3]
Oct.	0	0	1	1	0	0
Nov.	0	0	1	1	0	0
Dec.	0	0	1	1	0	0
Jan.	16	40	31	87	0	0
Feb.	7	18	11	36	13	13
Mar.	0	0	1	1	28	28
Apr.	0	0	1	1	0	0
May	0	0	1	1	0	0
Jun.	0	0	0	0	0	0
Jul.	0	0	1	1	0	0
Aug.	0	0	1	1	0	0
Sept.	0	0	1	1	0	0

1: Predicted, 2:Resulting from the hydrological routing, 3: CRIM, 2006.

*** Maximum capacity of AsSanna'f Marsh outfall.**

The stored water, the surface area and water level variations in the marsh during the rainy months are shown in **Figs. 18,19** and **20**, respectively.

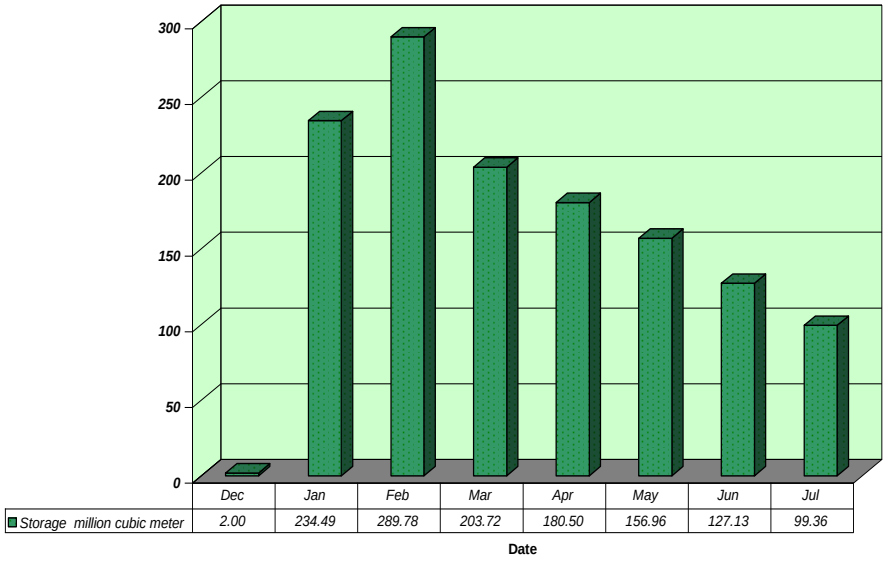


Fig. 15. Storage variation within AsSanna'f Marsh.

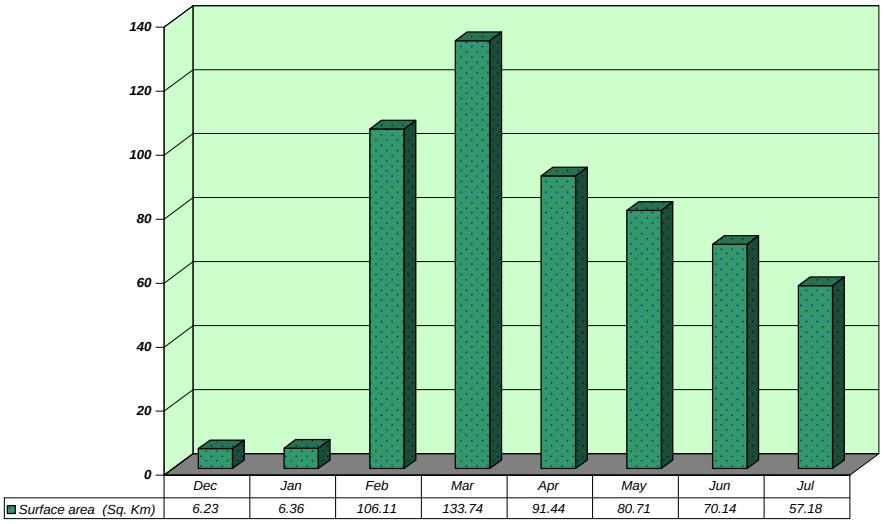


Fig. 16. AsSanna'f Marsh surface area variation during dry year.

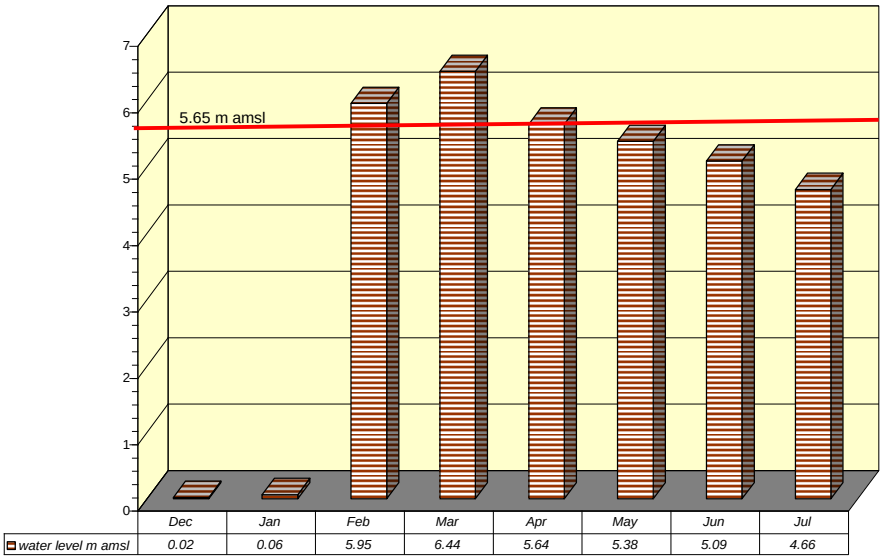
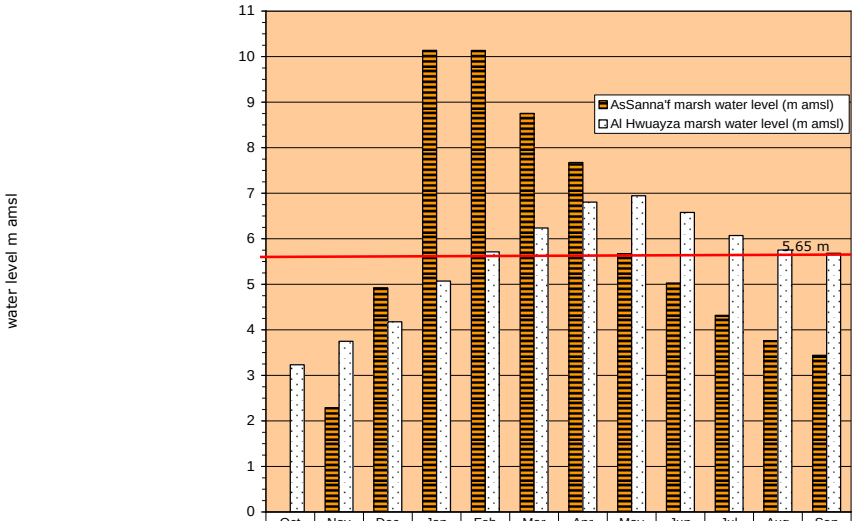


Fig. 17. AsSanna'f Marsh water level variation during dry year.

Water levels within AsSanna'f Marsh

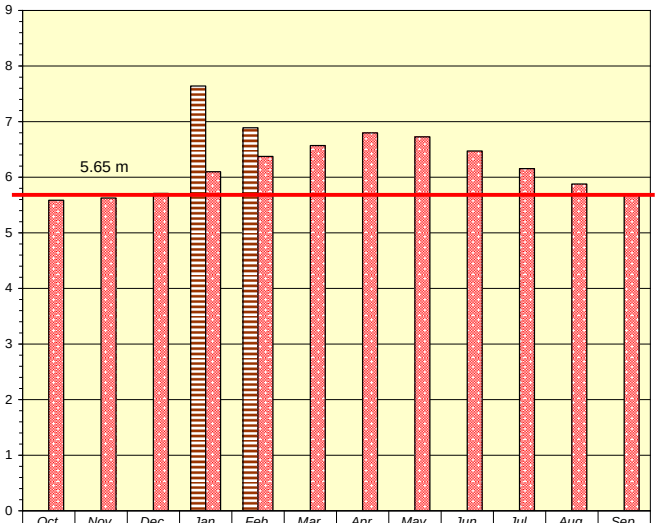
The water levels within AsSanna'f Marsh are affected by the fluctuations of the water levels within Al Huwayza Marsh. if Al Huwayza Marsh water levels or AsSanna'f Marsh water level were higher than 5.65m, AsSanna'f Marsh outlet bed level, there will be an interface between these marshes. When the amount of flow from AsSanna'f toward Al Huwayza Marsh will be varied according to the head difference and type of flow, free or submerged. Comparison of Al

Huwayza Marsh water levels which computed in the hydrological routing of this marsh, CRIM, 2006, with AsSanna'f Marsh water levels which computed in the hydrological routing of this marsh show that Al Huwayza Marsh water levels are higher than that of AsSanna'f Marsh and AsSanna'f Marsh outlet bed level during the period from March to September for flooded and moderate years, as shown in **Figs. 18** and **19**. The flow rates due to the head difference are estimated according to the suitable open channel hydraulic formula. These flow rates are shown in **Table 8**. The yearly stored water in AsSanna'f Mash according to the estimated inflow is 1118 million m^3 and 680 million m^3 for flooded and moderate years respectively.



	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
AsSanna'f marsh water level (m amsl)		2.29	4.92	10.14	10.13	8.75	7.67	5.67	5.03	4.32	3.76	3.44
Al Hwuayza marsh water level (m amsl)	3.23	3.75	4.18	5.07	5.71	6.23	6.80	6.94	6.58	6.07	5.75	5.68

Fig. 18. Al Huwayza Marsh and AsSanna'f Marsh water levels during wet year.



	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
AsSanna'f marsh water level m amsl	0.00	0.00	0.00	7.64	6.89	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Al Huwayza marsh water level m amsl	5.58	5.63	5.71	6.10	6.37	6.57	6.80	6.73	6.47	6.15	5.88	5.70

Fig.19. Al Huwayza Marsh and AsSanna'f Marsh water levels during normalyear.

Table 8. Al Huwayza Marsh flow, m^3/sec, into AsSanna'f Marsh during wet and normal years.

Month	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
Wet year	0	0	0	0	0	44.2	122.7	145.4	88.3	27.0	3.3	0.5
Normal year	0	0	0	0	0	53.6	87.0	76.7	44.1	0.6	0.2	0

These storages represent about 149 % from the maximum allowable storage of AsSanna'f Marsh when the minimum dykes level is 8 m.a.s.l, so AsSanna'f Marsh will be flooded due to this rate, and 91 % from the maximum allowable storage of AsSanna'f Marsh when the minimum dykes level is 8 m.a.s.l, so AsSanna'f Marsh will be flooded in the next year due to inflow of AtTeeb and Dwayreach rivers to AsSanna'f Marsh. While, these storages represent about 76 % and 46 % from the maximum allowable storage of AsSanna'f Marsh when the minimum dyke's level is raised to 11m.a.s.l, so AsSanna'f Marsh will be flooded in the next year due to inflow of AtTeeb and Dwayreach rivers to AsSanna'f Marsh. According to the above conclusions, a control structure at Faisal bridge station must be constructed at AsSanna'f Marsh outlet to satisfy the positive operation of AsSanna'f Marsh. The design discharge of the suggested control structure is 425m^3/sec with the spillway crest level of 7m.a.s.l. This control structure must be operated according to **Table 9**.

Table 9. Operation of the proposed control structure at AsSanna'f Marsh outlet.

Month	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
Flood year												
Moderate year												

Fully opened , **Fully closed**

CONCLUSIONS

1- The dykes surrounding the marsh must be at 11 m.a.s.l.
2- Ghzayla Bridge width must be increased 30m in order to develop its discharge capacity.
3- A control structure at Faisal bridge station must be constructed at AsSanna'f Marsh outlet to satisfy the positive operation of AsSanna'f Marsh. The design discharge of the suggested control structure is 425m^3/sec with the spillway crest level of 7m.a.s.l. This control structure must be operated according to **Table 9.**
4- In order to use Kmait flood escape during the flooded years to discharge 400m^3/sec into Al Huwayza Marsh through AsSanna'f Marsh, the design capacity of Al Huwayza Marsh outlets hydraulic structures must be: 200m^3/sec of Al Kassara River and 350m^3/sec of AsSuwayb River and Kmait flood escape structure must be a gated control structure with maximum capacity of 400m^3/sec and the operation of this escape must be based on **Table 6**.
5- The suggested maximum design discharges of Al Huwayza Marsh outlets, 550 m^3/sec may not be adopted if a new gated hydraulic structure is a accomplished at Kmait Flood Escape inlet with maximum discharge of 250 m^3/sec instead of that of 400 m^3/sec. The operation of this escape must be satisfying the maximum allowable inflow into Al Huwayza Marsh, **Table 5**.

RECOMMENDATIONS

- The hydrological system of AsSanna'f Marsh requires continuous observations on all its feeders using the existing hydrological stations. Extensive reading is required during rain season.
- The expected outflow from the marsh into Al Huwayza Marsh during flooded and dry years must be calibrated with observation data of more than 6 years.
- Studying the morphological changes within AsSanna'f Marsh area resulting from the sediment transportation from its feeders.
- Studying the ability of controlling AtTeeb and Dwayreach flow discharges into AsSanna'f Marsh.

REFERENCES

- Ministry of Water Resources, Al-Furat Center for studies and designs of irrigation projects, 2003, *Restoration of southern Iraqi Marshlands*, (in Arabic).

- Ministry of Water Resources, General Directorate of Water Resources Management, Center of hydrology, 2004, *Border Rivers between Iraq and Iran*, Translated from Arabic.

- Ministry of Water Resources, Al-Furat Center for studies and designs of irrigation projects, 1993, *Kmait Flood Escape project*, Translated from Arabic

- Ministry of Water Resources, Center of Restoration of the Iraq Marshlands, CRIM, 2006, *Study The Rehabilitation of Al Huwayza Marsh Ecological Syste.*.

- Ministry of Water Resources, Ministry of Environment , Ministry of Municipalities, and Public Works which Prepared in cooperation with the Italian Ministry for the environment and Territory and the Free Iraq Foundation, 2006, NEW *EDEN Master Plan for Integrated Water Resources Management in the Marshlands area.*

- UNEP, January 2004, *Azadegan Environmental Baseline Study*, Iran.

- The New Eden group, 2005, *Design Criteria for Optimum Regulation of Haweizhe Marshes*.