EFFECT OF AL HUWAYZA MARSH BOUNDARY CONFIGURATION ON THE VELOCITY PATTERNS AND WATER QUALITY DISTRIBUTION

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ABSTRACT

A two-dimensional depth-averaged hydrodynamic model and a two-dimensional water quality parameters transport model were developed to simulate the characteristics of Al Huwayza Marsh, which is considered the largest and most important marsh in the south of Iraq. The hydrodynamic model for Al Huwayza Marsh was built by using RMA2 model, while the water quality model was built by using RMA4 model. These two models are part of Surface Water Modeling System, SMS, software package.

To investigate the effect of the marsh boundary configuration on the variation of the velocity pattern and the water quality within the marsh, both of the hydrodynamic and the water quality models were applied to three cases of boundary configuration of Al Huwayza Marsh. The first case represents the natural extension of the marsh boundary. The second case represents the existing boundary configuration of the marsh, in which the south west of the marsh is bounded by a dyke. The third case represents the Iraqi part of the marsh bounded by the south west dyke and a dyke along the Iraq-Iranian borders, which when completed will separate the marsh into two parts.

Models runs were based on above cases of Al Huwayza Marsh boundary configuration and topographical survey, hydrological measurements and routing, and water quality measurements carried out by the Center of Rehabilitation of Iraqi Marshlands. Discharges of all feeders and stages of the outlets are considered for wet, normal, and dry years. Feeder's seasonal discharges were averaged. High and low concentrations of three selected water quality parameters of the marsh feeders were adopted in the model runs.

Generally, it was found that the flow velocities are relatively high at the inlets and outlets of the marsh. The construction of the dyke along the Iraqi-Iranian border leads to variation in the direction of water flow in all portions of the marsh and a great reduction in AsSuwayb River discharge. While, a slight effect was noticed in the mixing process of the feeders' water of different concentration in case three compared to other cases

الخلاصة:

تم اعداد نموذج هيدروديناميكي ثنائي البعد ونموذج نوعية المياه لتمثيل خصائص هور الحويزة الذي يعد من اكبر واهم اهوار العراق الجنوبيه. تم بناء النموذج الهيدروديناميكي لهور الحويزة باستخدام نموذج RMA2. أما نموذج نوعية المياه فقد تم بناؤه باستخدام نموذج RMA4 وهما جزء من نماذج النظام البرمجي Surface Water Modeling System.

تم تطبيق النموذج الهيدرولكي ونموذج نوعية المياه على ثلاث حالات من حدود هور الحويزة لبيان اثر حالة حدود الهورعلى تغاير انماط السرع ونوعية المياه داخل الهور. الحالة الاولى تمثل وضع امتداد حدود الهور الطبيعية. والحالة الثانية تمثل الوضع الحالي لحدود الهور وهي حالة وجود سدة جنوب غرب الهور. والحالة الثالثة تمثل وضع الهور ضمن الحدود العراقية بعد اكمال انشاء السدة على امتداد الحدود العراقية الايرانية ضمن هور الحويزة والتي ستقسم الهور الى جزئين.

اعتمدت تطبيق النماذج على وضعية حدود هور الحويزة ونتائج القياسات الهيدرولوجيه وعلى نتائج استتباع الجريان و المسح الطوبوغرافي الذي تم تنفيذه من قبل مركزانعاش الاهوار العراقيه. تم التعامل مع قيم التصاريف للمداخل والمخارج على اساس السنوات الرطبة والمعتدلة والجافه حيث تم اخذ المعدلات الفصليه لتلك التصاريف، اما في نموذج نوعية المياه فقد تم اعتماد اعلى واقل التراكيز لبعض معايير مختارة لنوعية مياه مغذيات الهور.

عموما، تم ملاحظة كون سرع الجريان عالية نسبيا عند مداخل ومخارج هور الحويزة. ان انشاء سدة على امتداد الحدود العراقية الايرانية سيؤدي تغير في اتجاهات جريان الماء في معظم الهور وقلة كبيرة في تصاريف نهر السويب. بينما كان التاثير قليل على عملية الخلط داخل الهور لمياه المغذيات المختلفة التراكيز في الحالة الثالثة مقارنة ببقية الحالات.

KEY WORDS

Al Huwayza Marsh, RMA2, RMA4, Hydrodynamic model, Water quality model.

INTRODUCTION

The Iraqi marshlands are the largest wetland ecosystem in the Middle East and Western Eurasia. These marshes began to decline as a result of the increasing water demand for different uses and dam building upstream Tigris and Euphrates Rivers in Turkey, Syria and Iraq, which attenuated the rivers natural flows. Iraq attempts to restore these marshes through the actions of the Center of Restoration of the Iraqi Marshlands, CRIM, of the Ministry of Water Resources and some of interested international organizations.

Al Huwayza Marsh, which is considered as the largest Iraqi marshland, spreads on the east side of Tigris River within Misan Governorate crossing the Iraqi-Iranian borders. The major part of the marsh lies within the Iraqi borders.

During the eighties of the last century, dykes were constructed west of Al- Huwayza Marsh for flood protection and military purposes. Recently, construction of a new dyke has been started along the Iraq-Iranian borders within the marsh area that will separate the marsh into two parts.

Generally, this study is focused on building both hydraulic and water quality models of Al Huwayza Marsh to investigate the effects of the change in the marsh boundaries, due to the constructed dykes, on the velocity distribution, circulation, and the water quality variations of some selected contaminants.

GENERAL DISCRIPTION OF AL HUWAYZAH MARSH

Al Huwayza Marsh is located to the east of the Tigris River in Misan Governorate and extended to the Iraqi-Iranian borders as shown in **Fig.1.** The total length of Al Huwayza Marsh is about 80*km* measured from the northern bank of the marsh close to Ghzayla-AshSheeb check point road down to Southern bank at AsSuwayb River. The average width of this marsh is about30*km*, measured from the flood protection dykes along its west bank to the Iranian lands at its east bank.

Al Musharah, Al Ka'hla River, Al Karkheh River, and AsSanna'f Marsh are the main feeders, while Al Kassara and AsSuwayb Rivers are the main discharge outlets of the marsh.

The total area of Al Huwayza varies between 2350 and 3500km^2 in the flood season, and it is reduced to the half during the dry season, Mohamed, 1999. Only the deep parts of marsh that remain forming water ponds such as Al Huwayza, Um -Elniaj and Al Adhaim, these water ponds are connected to each other by water paths that pass through dense areas of Weeds, Reeds, Papyrus and other water bushes types, Al Furat Center, 2003.

The water level elevations during autumn vary between 1 to 2*m* a.m.s.l. then increase to about 4.5*m* at the western part of the marsh in the end of spring and the early summer. The deepest part of the marsh is at its northern part, including permanent lakes were the depth of water exceeds 6-8*m*, the depth of water reduce going towards the south. However, in major parts of the marsh, particularly that at the Iranian part of the marsh, the depth of water is less than 3*m*, allowing the growth of reed.

Fig.1. General view of Al Huwayza Marsh.

THE MATHEMATICAL MODELS

The Surface Water Modeling System, SMS, RMA2 is a two-dimensional, finite element hydrodynamic modeling code that supports subcritical flow analysis. It computes a finite element solution of the depth-integrated equations of fluid mass and momentum conservation in two horizontal directions. Friction is calculated with the Manning's or Chezy's formula, and eddy viscosity coefficients are used to define turbulence characteristics **Donnell, 2004 a.** RMA2 model was used to compute the water surface elevation and velocity variation over Al Huwayza Marsh.

The Surface Water Modeling System, SMS, RMA4, is a companion model to RMA2, is a finite element water quality transport numerical model. RMA4 is applied to represent the transport of a contaminant, salinity intrusion in a system. RMA4 was used to investigate the movement of some of the water quality parameters inside Al Huwayza Marsh.

THE BOUNDARY CONDITIONS

Fig. 2 shows a schematic diagram of the boundary conditions of Al Huwayza marsh that were applied in the hydraulic analysis. Feeders flow assigned values were used at the upstream boundary and the marsh outlets stage hydrographs were used as downstream boundary.

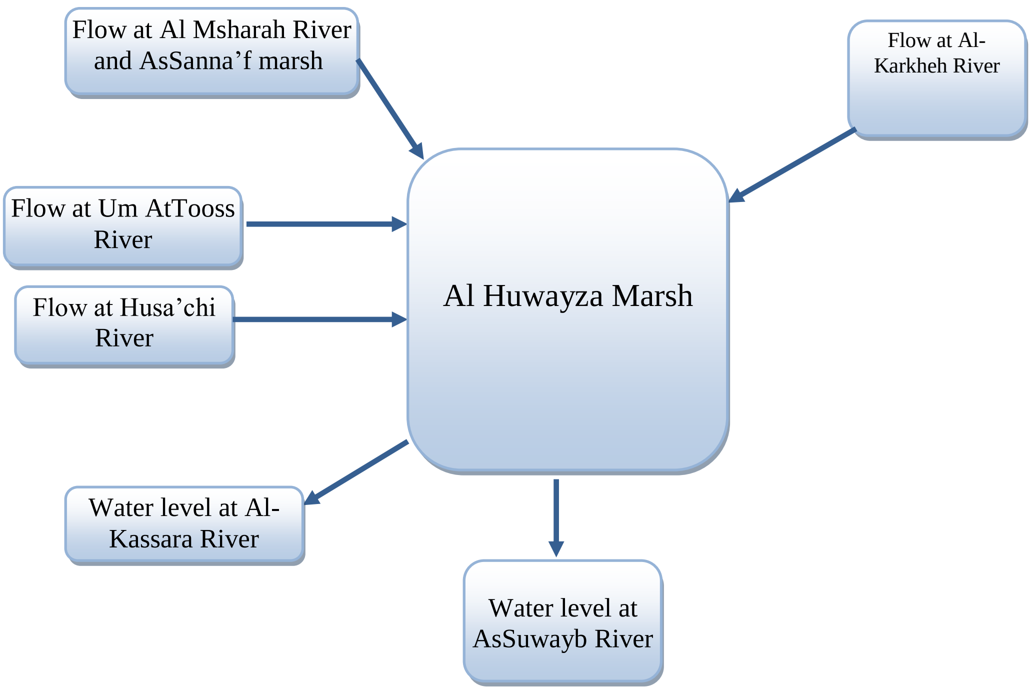


Fig.2. Boundary conditions schematic diagram of Al Huwayza Marsh.

CASES STUDIES

Three cases were taken into consideration, which depend on the Al Huwayza Marsh boundaries configuration. The first case represents the natural extension of the Al Huwayza Marsh boundaries, the second; represent the present situation of marsh boundaries where the south-west dykes limiting the natural extension of the marsh, and the third case represents the Iraqi part of the Al Huwayza Marsh only after completion of the east dyke along the Iraqi-Iranian borders.

Case One

In this case study, Al Huwayza Marsh extends beyond the current existing south-west dykes as shown in **Fig. 3,** which represents the natural extension of the marsh. The south-west dykes were constructed for military purposes during the first gulf war The maximum surface area of Al Huwayza Marsh for this case, when the water level at 7m a.m.s.l., is about 1800km^2 with a storage capacity of about 5896 million m^3. Al Huwayza Marsh with this boundary configuration was studied by CRIM in year 2006. The study carried out hydrologic and hydraulic investigations and water quality field measurements. Discharges were estimated to be assigned for the marsh, this estimation depending on the results of the hydrological routing scenario for wet, normal, and dry years.

Case Two

In this case study, Al Huwayza Marsh is bounded by the south-west dykes as shown in **Fig 3.** This case represents the existing boundary configuration of the marsh. The maximum surface area of Al Huwayza Marsh for this case is about 1240km^2 with a storage capacity of about 4400 million m^3.

Case Three

This case study includes the Iraqi side of Al Huwayza Marsh only because of Iran has planned and started constructing a dyke along its borders with Iraq within the marsh area, which when will be completed will separate the marsh into two parts. The total area of Al Huwayza Marsh within the Iraqi borders is about 1013km^2 with a storage capacity of about 3735million m^3.

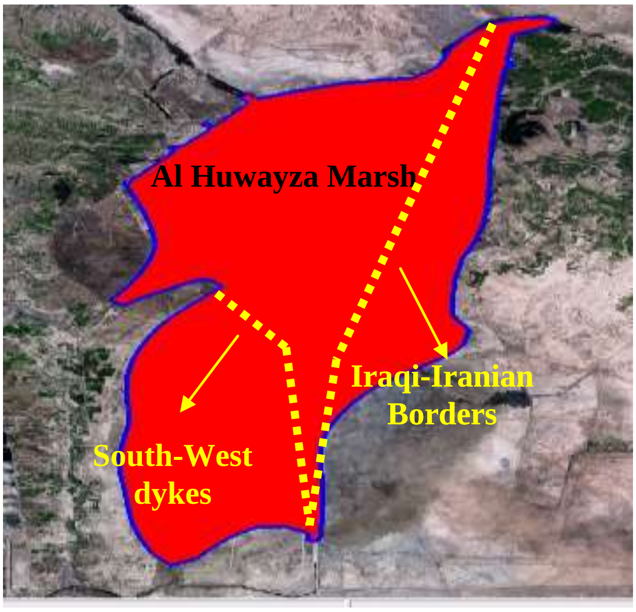


Fig.3. Sketch to define Al Huwayza Marsh boundaries.

REQUIRED DATA

Discharge of all feeders and stages at the outlet were considered for for wet, normal and dry years. The discharges of all feeders are presented in **Table 1**. The averaged inflow from the Karkheh River into the marsh has been obtained from the Azadegan Environmental Baseline studies, Iranian Ministry of Environment 2004, where the maximum flow entering the marsh was 220m^3/sec during April and the minimum value of flow during October was 19m^3/sec. The stages at the outlets were considered from the hydrologic routing achieved in the study of CRIM, 2006

Water quality analysis was based on the highest and lowest concentrations of the water quality measurements at the marsh feeders that were carried out by CRIM during the period from January to July 2006, which are presented in **Table 2**.

Table 1. The averaged seasonal discharges in m^3/sec of each feeder during wet, normal and dry years, *after CRIM, 2006*.

Season		Feeder			
		Al Husachi	**Um AtTooss**	**Al Msharah and AsSanna'f Marsh**	**Al Karkheh**
Wet year	Winter	96	60	184	130
	Spring	75	53	37	207
	Summer	38	25	18	55
	Autumn	77	51	32	30
Normal Year	Winter	56	37	72	83
	Spring	25	19	17	145
	Summer	18	12	9	32
	Autumn	27	18	13	20
Dry Year	Winter	6	4	3	45
	Spring	4	3	5	68
	Summer	5	3	4	19
	Autumn	7	4	5	12

Table 2. High and low concentrations of contaminants , after CRIM, 2006.

River	Contaminant									
	High Concentrations					Low Concentrations				
	PH	TDS (mg/l)	NO_3 (mg/l)	TURB. (NTU)	SO_4 (mg/l)	PH	TDS (mg/l)	NO_3 (mg/l)	TURB. (NTU)	SO_4 (mg/l)
Al Msharah	8.2	2670	9.8	145	280	7	430	2.8	1.02	90
Um AtTooss	8.3	1310	10	3136	260	7.4	540	0.88	26.69	165
Al Husachi	8.3	1390	8.86	359	280	7.3	530	3.24	14.17	110
Al Karkheh	8	1400	0.5	50	290	7.2	900	0.28	7	200

Topographical survey of the Al Huwayza Marshwas carried out by CRIM, 2006, and is presented in **Fig. 4.** Based on the topographical survey, the area elevation and storage elevation relations for case one and two were computed and presented by CRIM, 2006. While, the area elevation and storage elevation relations for case three was computed and presented in **Figs 5** and **6**, respectively.

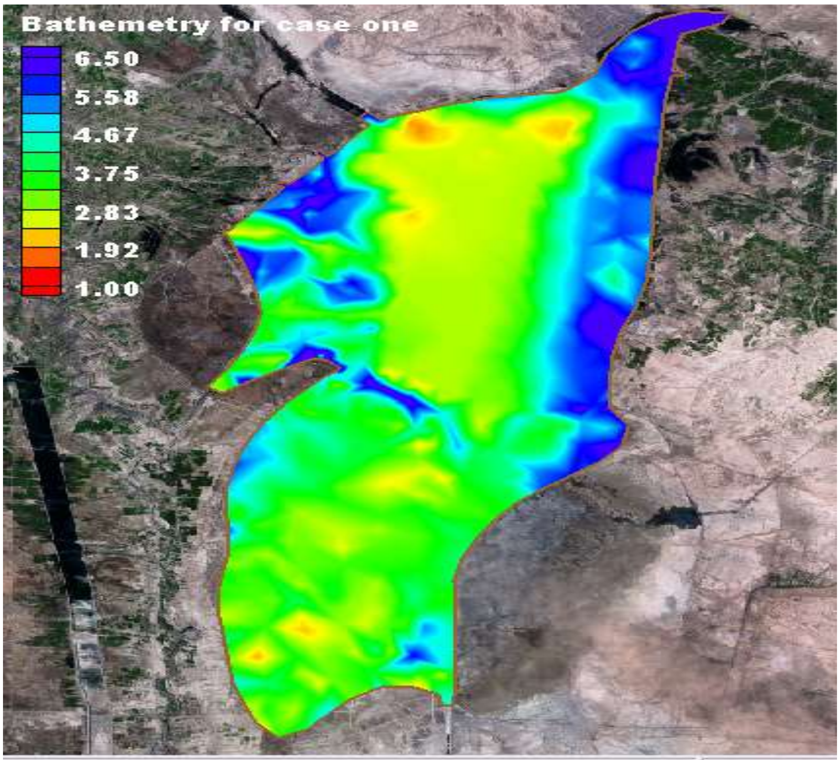


Fig. 4. Bed elevation of Al Huwyzah Marsh, *after CRIM, 2006*.

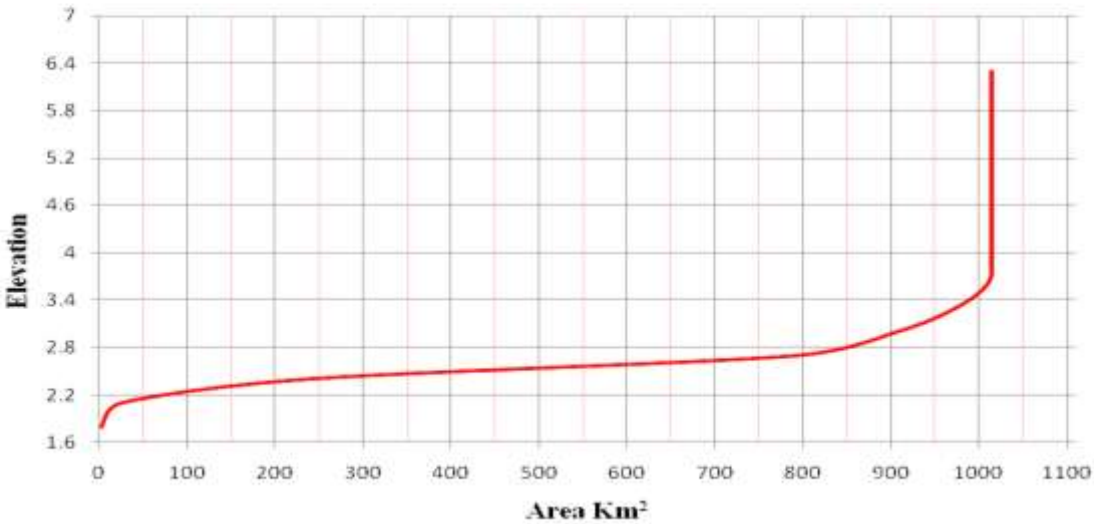


Fig 5. Computed Area- Elevation curve of Al Huwayza Marsh, case three.

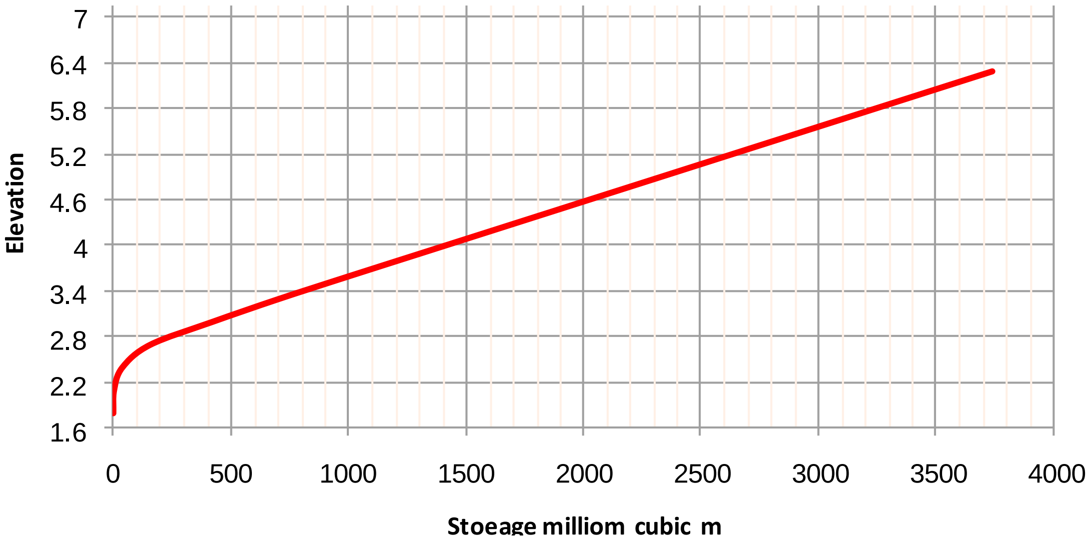


Fig 6. Computed storage- Elevation curve of Al Huwayza Marsh, case three.

Manning roughness coefficient was used to define the bed friction of marsh and a value of 0.045 were used for shallow non vegetated part and 0.07 for shallow vegetated part of the marsh. Typha and reed are the major aquatic plants within the marsh, theses aquatic plants cannot grow when the water depth is greater than 2m. This is the criteria used to separate the vegetated from non vegetated zones within the marsh. The Manning roughness coefficient as a function of depth that was obtained from RMA2 model is shown in **Fig. 7**.

The eddy viscosity is an addition coefficient that must be specified in the implementation of the model. The value of eddy viscosity affects stability and turbulent fluid characteristics. More than one technique was adapted in the definition of the eddy viscosity number.

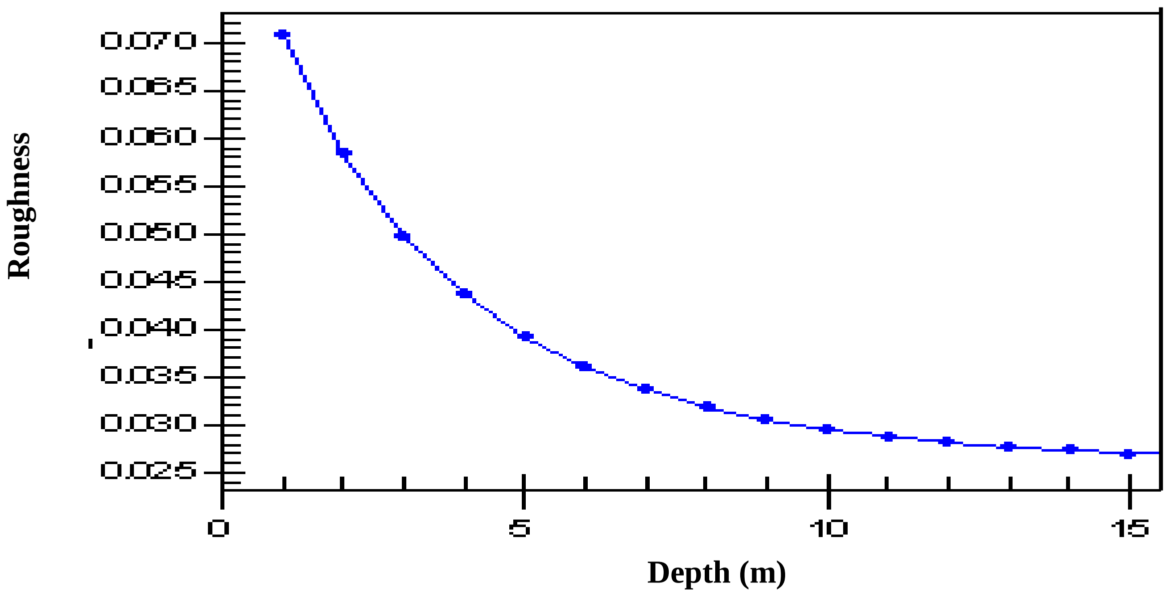
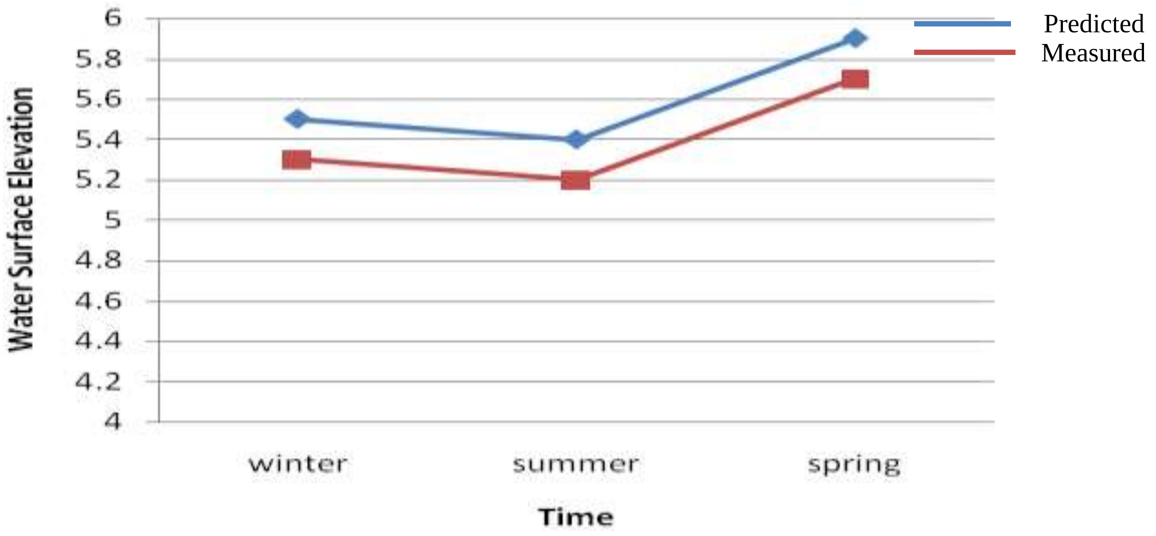


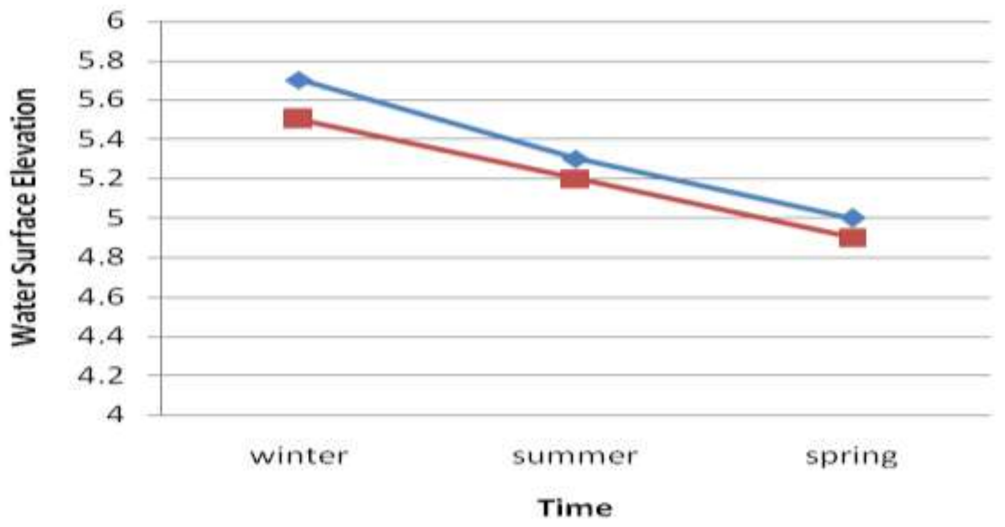
Fig. 7. Roughness values of Al Huwayza Marsh.

VERIFICATION OF THE HYDRAULIC MODEL

The verification consists of comparing field water surface elevation at two locations in Al Huwayza marsh which are Al-Adhaim and AsSodda bridge. **Fig. 8** shows a good satisfactory between the model predicted data and field measurement data at the two gauge stations.



a- at AsSodda Bridge station



b- at Al Adhaim station.

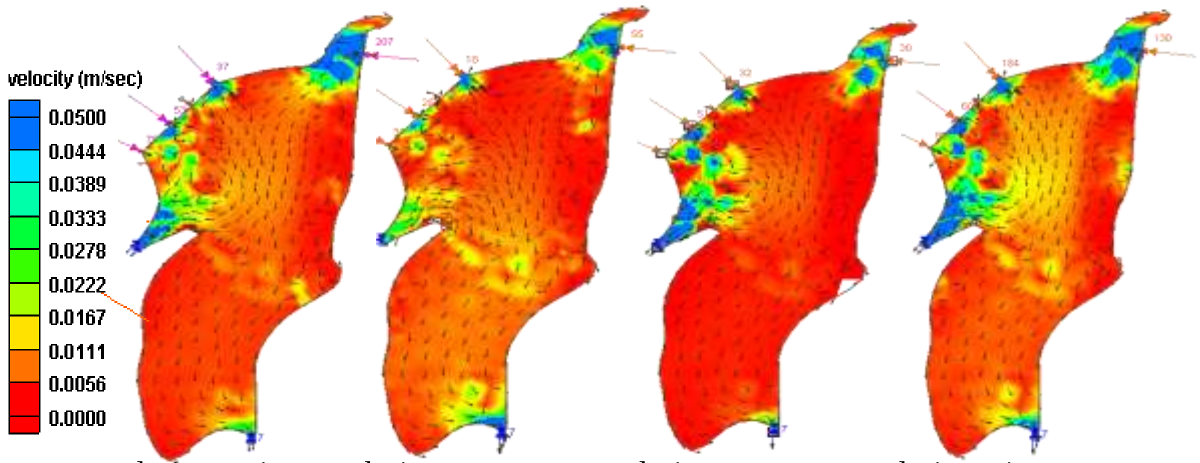
Fig. 8. Water surface elevation comparison at selected measuring stations.

ANALYSIS OF THE CASE STUDIES

The velocity pattern and the water quality distribution of the three cases of boundary configuration of Al Huwayza Marsh were analyzed as follows:

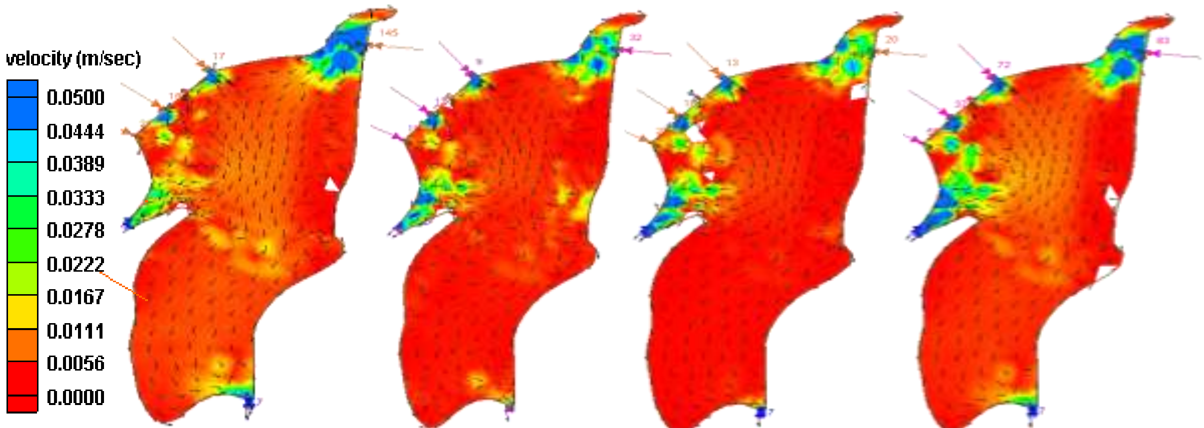
Case one

The flow velocity patterns were analyzed for wet, normal and dry years as shown in **Figs. 9** to **11**, respectively. It is clear that the topographic of the marsh bed (refer to **Fig. 4**), inflow (season) and the outlets capacities affecting the velocity profiles. The velocities are higher at the inlets and outlets of the marsh than that at the interior part of the marsh. The maximum velocities are at the outlets of the marsh, Al Kassara and AsSuwayb.



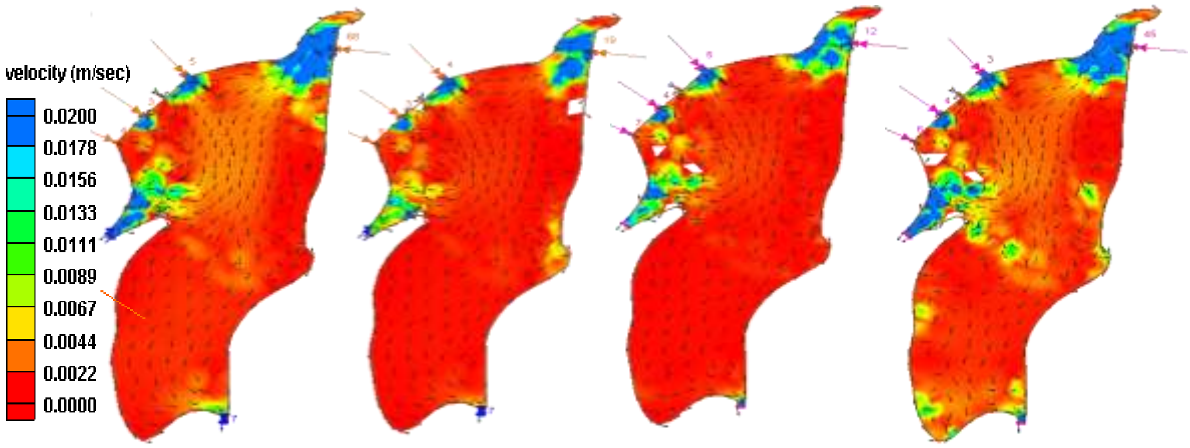
during spring during summer during autumn during winter

Fig.9. Velocity pattern within the marsh during a wet year, case one.



during spring during summer during autumn during winter

Fig.10. Velocity pattern within the marsh during a normal year, case one.

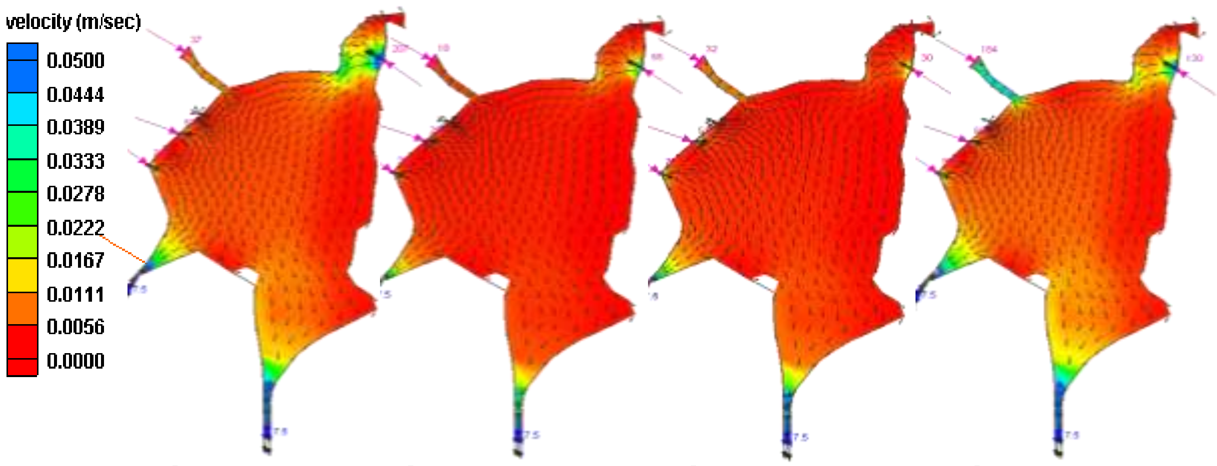


during spring during summer during autumn during winter

Fig.11. Velocity pattern within the marsh during a dry year, case one

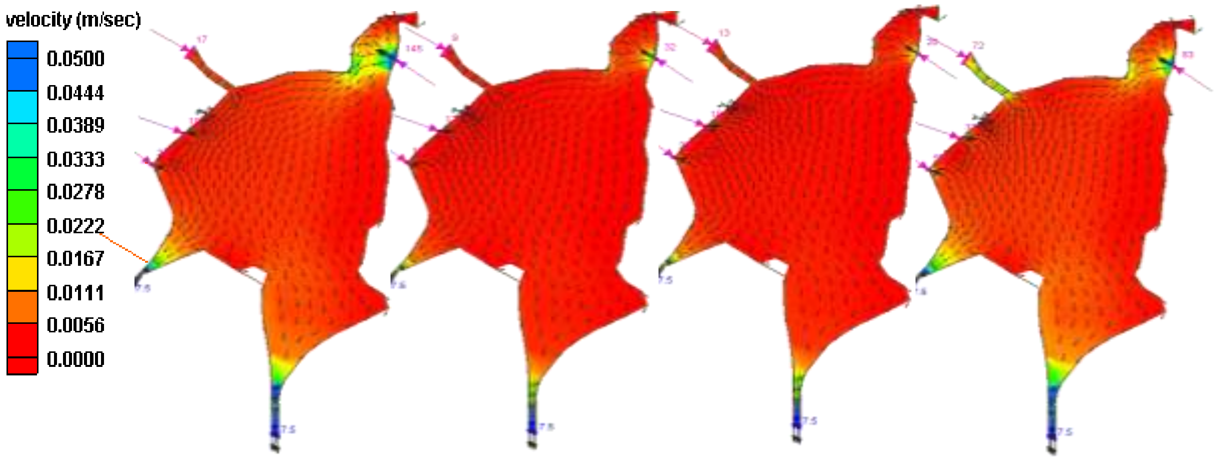
Case Two

Fig. 12 to **14** shows the flow velocity pattern for wet, normal and dry years of case two, respectively. In addition to the above mentioned factors affecting the velocities within the marsh the marsh boundary configuration is an additional factor that affects the velocity variation within the marsh. Velocities of water are relatively high at outlets of the marsh but the velocities at some of the inlets are reduced compared to that of case one. This reduction may be referred to the increase in water level elevation within and the overall change in the velocity patterns within the marsh.



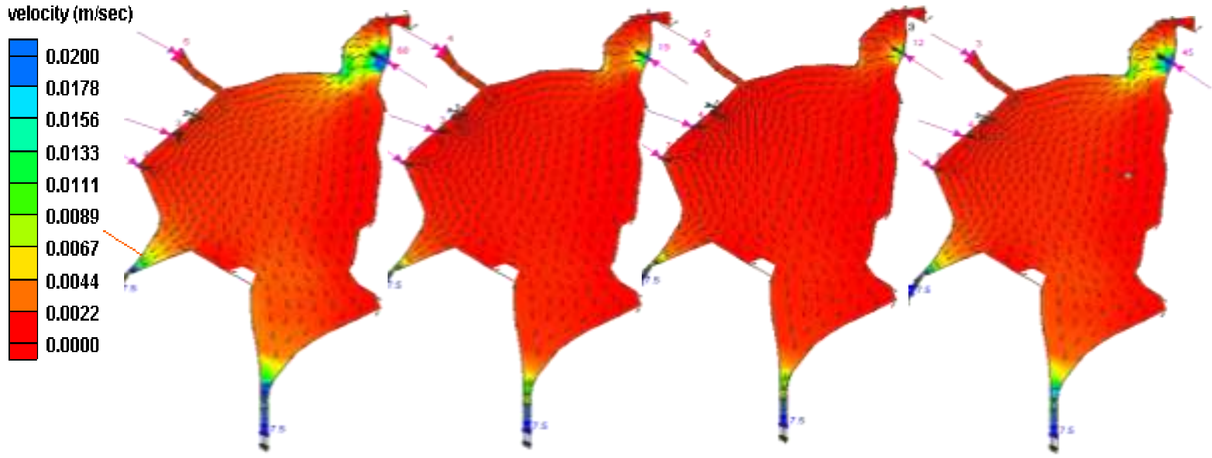
during spring during summer during autumn during winter

Fig.12. Velocity pattern within the marsh during a wet year, case two.



during spring during summer during autumn during winter

Fig.13. Velocity pattern within the marsh during a normal year, case two.



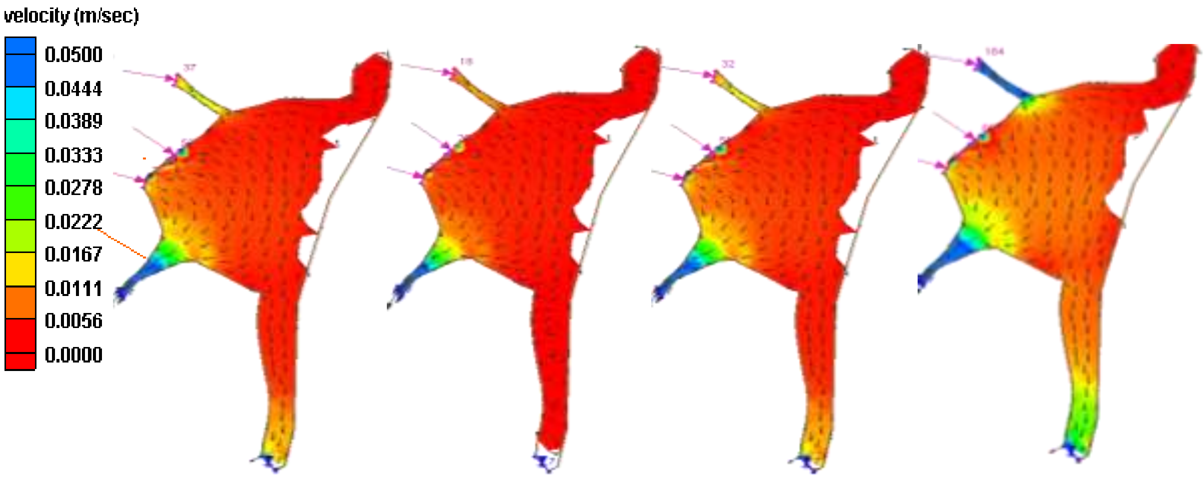
during spring during summer during autumn during winter

Fig.14. Velocity pattern within the marsh during a dry year, case two

Case Three

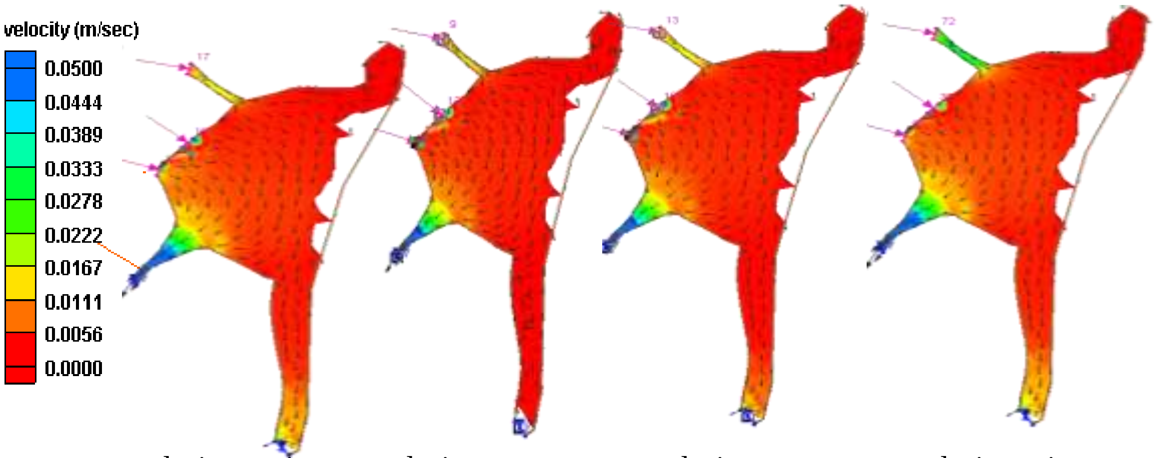
The velocity patterns within the marsh for wet, normal, and dry years are analyzed as shown in **Figs.15 to 17,** respectively. The velocity values Al Kassara River is of the high velocity. Most of the out flow in this case is through Al Kassara River, while the flow towards AsSuwayb River is reduced greatly and is approaches zero flow. The velocities at the north east of the marsh near Al Karkheh River toward AsSuwayb River at the south along the Iraqi-Iranian borders are reduced greatly, the water in this area is considered shallow and of very low level of water because of the construction of the dyke in this area. Some of the marsh areas are left dry.

By comparing the velocity profiles of case three with that of case one and two, a high changes in velocity profiles can be notice at all parts of Al Huwayza Marsh for all of flow conditions as a result of construction of the dyke along the Iraqi-Iranian borders.



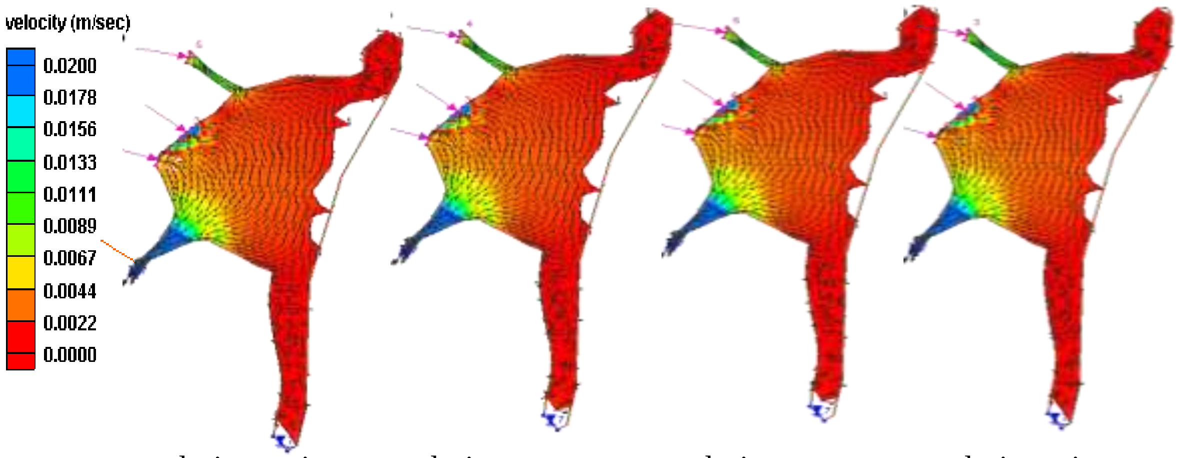
during spring during summer during autumn during winter

Fig.15. Velocity pattern within the marsh during a wet year, case three.



during spring during summer during autumn during winter

Fig.16. Velocity pattern within the marsh during a normal year, case three.



during spring during summer during autumn during winter

Fig.17. Velocity pattern within the marsh during a dry year, case three.

EFFECT BOUNDARY CONFIGURATION ON OUTLETS DISCHARGES

The discharges throughout Al Kassara and AsSuwayb Rivers are affected greatly by the boundary configuration of Al Huwayza Marsh. **Table 3,** shows the discharges through these two outlets for the three cases of boundary configuration. The great impact is in case three because of the construction of dyke along the line of the Iraqi-Iranian borders, in this case the velocities are reduced where the minimum value is at AsSuwayb River and the discharges in this river will reduced greatly.

Table 3. The discharges in m^3/sec of Al Kassara and AsSuwayb outlet during wet, normal, and dry years.

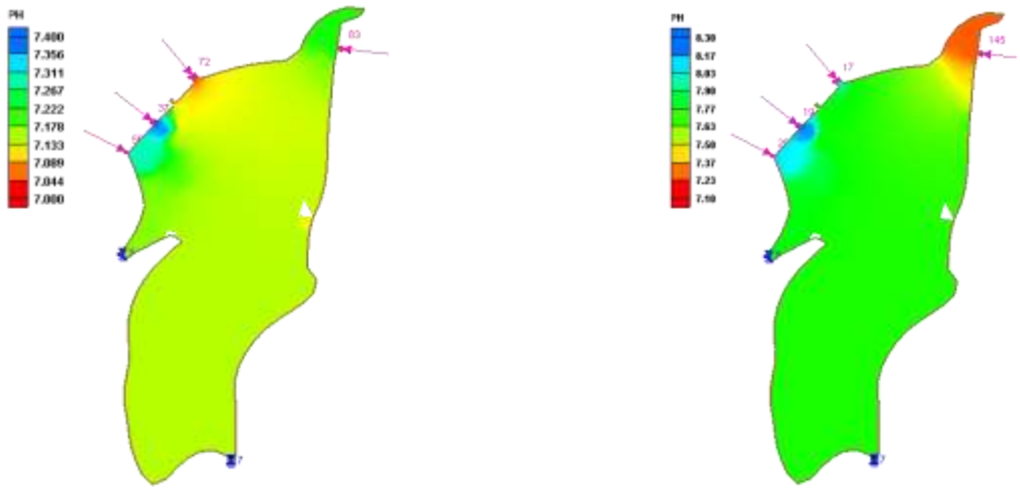
Year		Cases Study					
		Case 1		Case 2		Case 3	
		Al Kassara	AsSuwayb	Al Kassara	AsSuwayb	Al Kassara	AsSuwayb
Wet	Winter	354	116	217.3	253	300	40
	Spring	229	143	174.5	197.5	156.5	8.5
	Summer	50	86	59	77	75	6
	Autumn	71	119	67.5	122.5	153.3	6.7
Normal	Winter	135	113	105	143	157.3	7.7
	Spring	85	121	91	115	56.5	4.5
	Summer	53	22	21	50	35	4
	Autumn	60	18	30	48	55.3	2.7
Dry	Winter	31	24	32	26	12.7	0.35
	Spring	55	25	31	49	12.1	0.89
	Summer	20.7	10	11	20	14	5
	Autumn	17.8	10.4	10	18	15.3	0.61

WATER QUALITY ANALYSIS OF THE CASE STUDIES

Steady state water quality model was applied to the three cases of boundary configuration of Al Huwayza Marsh. This model depends on the hydrodynamic model and advection–diffusion equation to obtain a solution. Based on the set of initial conditions that represent the concentrations at the feeders of Al Huwayza Marsh, **Table 2,** the model used to calculate the variation of the concentration of three water quality parameters, PH, TDS, and NO_3, within the marsh. Flow of a normal year only was used in the model because the actual field measurement for water quality model was during this year and the initial conditions were applied for only the highest concentrations and lowest concentrations to show the variations of the concentrations in these critical cases.

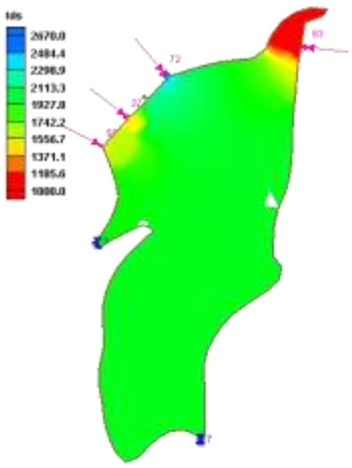
Case one

The PH variation within Al Huwayza Marsh for this case study can be shown in **Fig. 18**. Salinity variation, represented by TDS, within Al Huwayza Marsh is shown in **Fig.19. Fig.20** represents nitrate changes during spring and winter seasons. The concentration of all contaminates within the marsh reaches a common value within short distances from the marsh feeders; this is an indication to a good mixing process take place within the marsh.

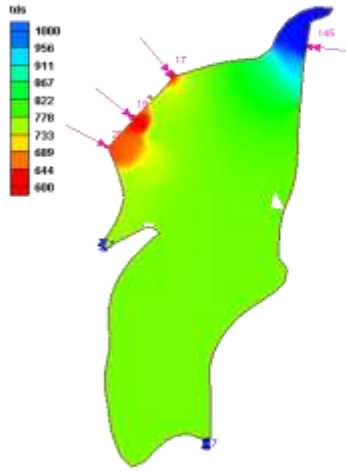


a-during winter b- during Spring

Fig. 18. Variation of PH within the Al Huwayza Marsh.

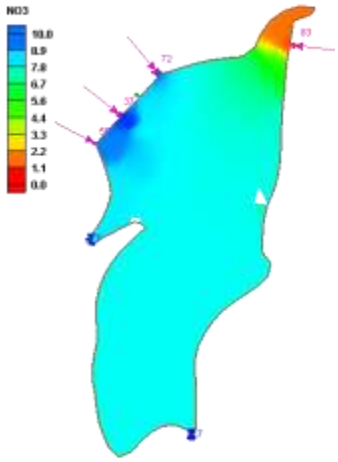


a- during winter

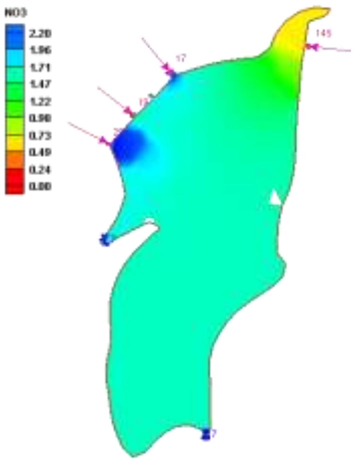


b- during spring

Fig.19. Variation of TDS within the marsh.



a- during winter

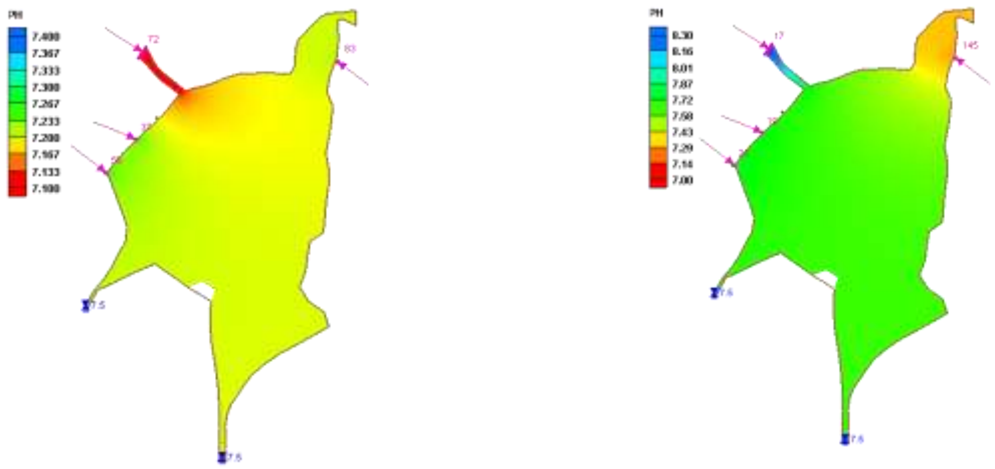


b- during spring

Fig. 20. Variation of NO_3 within Al Huwayza Marsh.

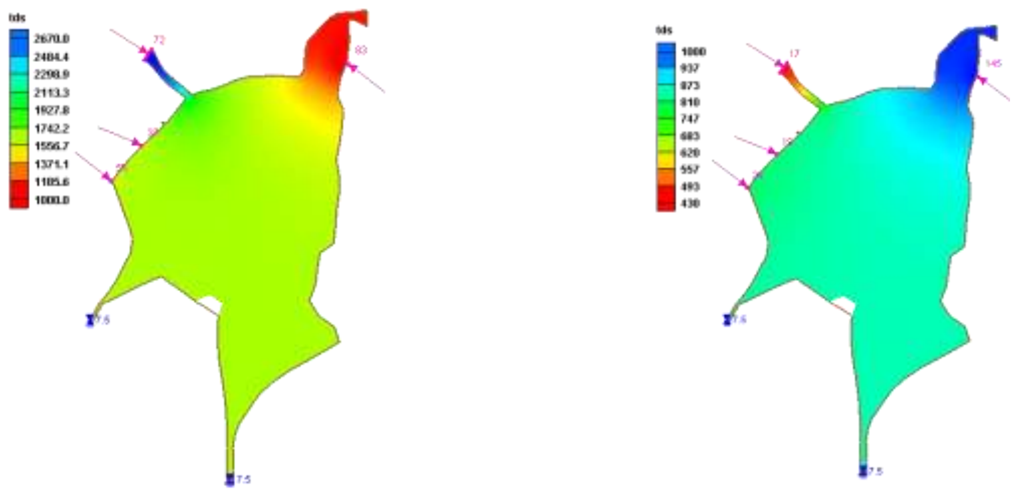
Case Two

Fig.21 shows the values of PH variation within Al Huwayza Marsh. Salinity in Al Huwayza Marsh is shown in **Fig.22.** **Fig.23** shows the nitrate changes for this case study. The mixing process within the marsh still good.



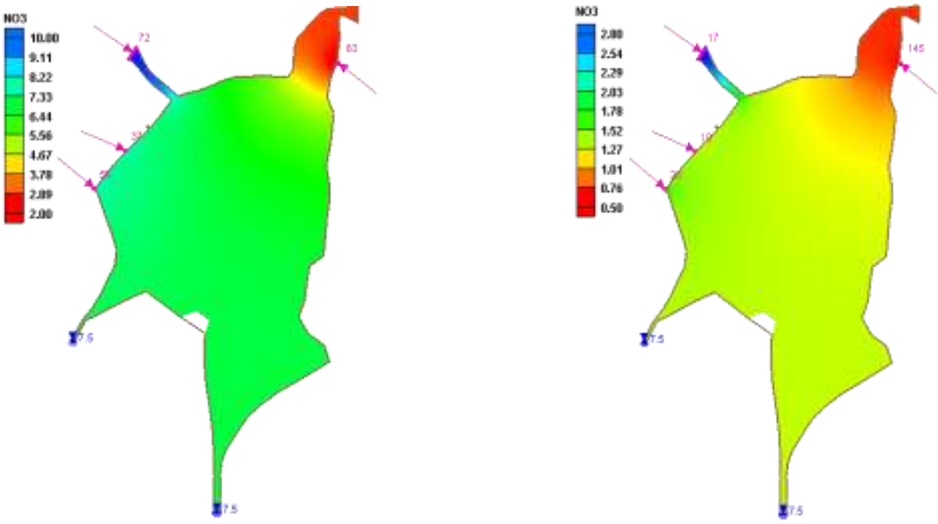
a- during winter b- during spring

Fig.21. Variation of PH within Al Huwayza Marsh.



a- during winter b- during spring

Fig.22. Variation of TDS within Al Huwayza Marsh

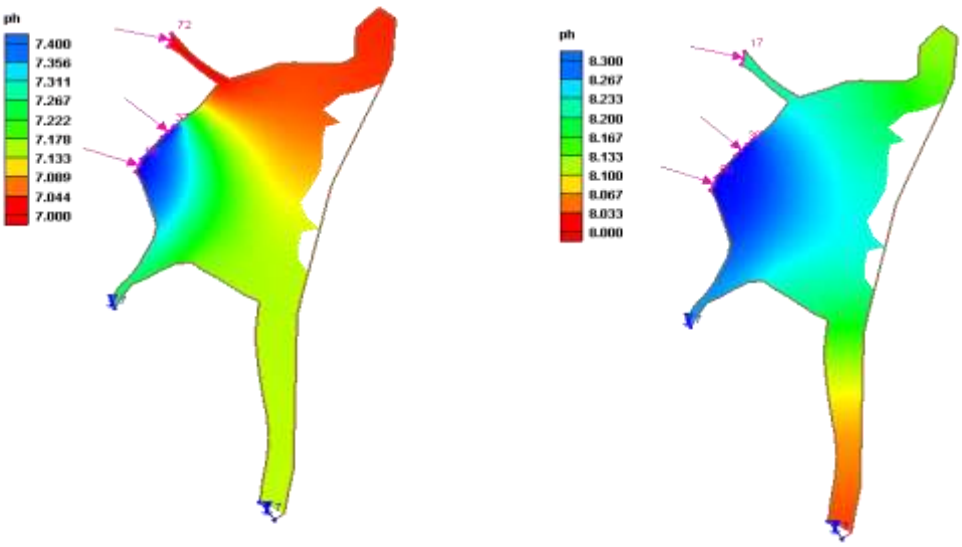


c- during winter b- during spring

Fig.23. Variation of NO_3 within Al Huwayza Marsh

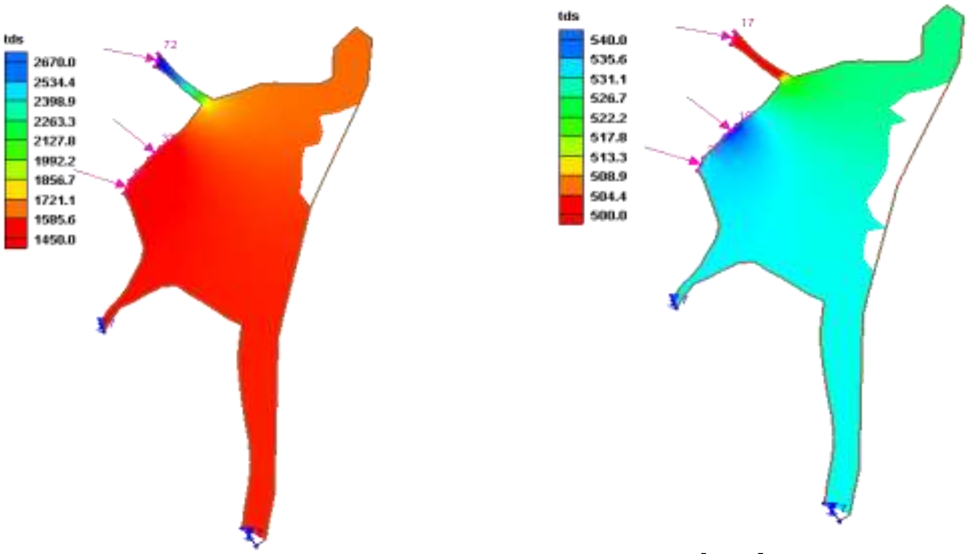
Case Three

The PH variation for this case study is shown in **Fig. 24.** **Fig.25** shows that TDS concentrations in Al Huwayza Marsh. **Fig.26** represents nitrate variation for this case study. A slight effect may be notice in the mixing process of the feeders water of different concentration compared to other cases which may be referred to the change in flow patterns.



a- during winter b- during spring

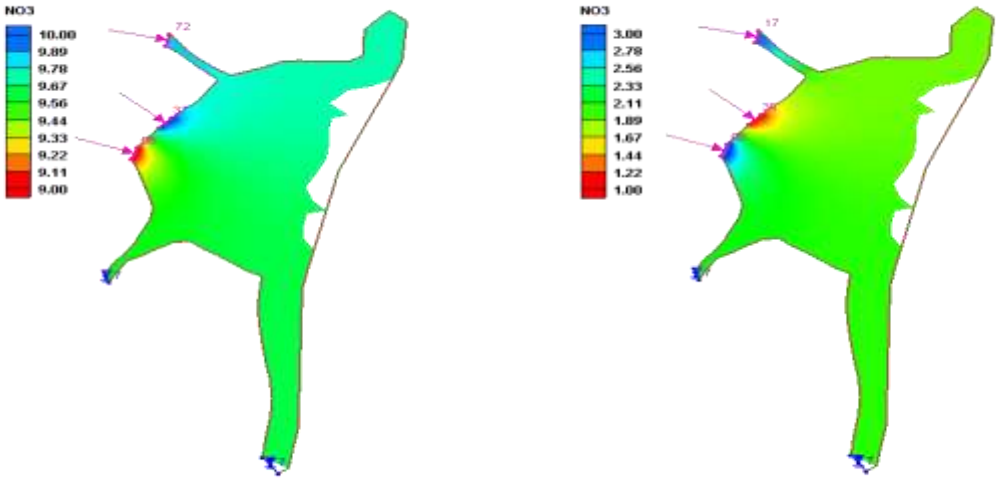
Fig.24. Variation of PH within Al Huwayza Marsh.



a- during winter

b- during spring

Fig.25. Variation of TDS within Al Huwayza Marsh.



a- during winter

b- during spring

Fig.26 Variation of NO_3 within Al Huwayza Marsh.

CONCLUSIONS

The study has come out with the following conclusions:

- The flow velocity is relatively high near the inlets and outlets of Al Huwayza Marsh.
- A high changes in velocity patterns and the overall water circulation was noticed at all parts of Al Huwayza Marsh for all of the flow conditions as a result of construction of the dyke along the Iraqi-Iranian borders within the marsh.
- The discharge values increase at AsSuwayb River outlet of the marsh in case two. While a great reduction in the discharges of this outlet was noticed in case three.
- A slight effect was noticed in the mixing process of the feeders' water of different concentration in case three compared to other cases.
- RMA2 and RMA4 models found to be a powerful tool in simulating the flow and water quality and could be applied to study other Iraqi marshlands.

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