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Enhancement of Water Unit use Efficiency under Modified Surface Irrigation Conditions

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ABSTRACT

This study was conducted in Assiut Governorate, Upper Egypt. The objectives of this work were to study the performance of the developed surface irrigation system and comparing it with the traditional surface irrigation system. The performance indicators were hydraulic evaluation of irrigation systems, amount of applied water, water application efficiency, filed water use efficiency and crop yield. The results revealed that the amounts of water applied for wheat crop were 1123, 1168 and 1515 m^3/fed under buried pipes, lining mesqas and earthen mesqas respectively. While they were 1180, 1216 and 1521 m^3/fed of maize crop for the previous mesqas respectively. It is clear that, the highest values of applied water for all crops, were found at earthen mesqas during winter as well as summer season. Average water application efficiencies were as 39.20 %, 76.70 % and 81.75 % for earthen mesqas, lining mesqas and buried pipes respectively. The productivity of wheat and maize increased 21.74 and 20.83 % under buried pipe respectively. Also, wheat and maize were 16.28 % and 15.56 % respectively under lining mesqas compared with earthen mesqas. The values of field water use efficiency (FWUE) for wheat were 3.07 kg ⁄ m^3, 2.78 kg ⁄ m^3 and 1.78 kg ⁄ m^3 under buried pipe, lining mesqas and traditional surface irrigation respectively. also, it was for maize, 2.85 kg/m^3, 2.59 kg/m^3 and 1.75 kg/m^3 under buried pipe, lining mesqas and traditional surface irrigation respectively.

Keywords: Irrigation evaluation - developed surface irrigation - buried pipes - lined canals - upgrading the level of the water delivery system

INTRODUCTION

Egyptian irrigation system is considered one of the most complicated systems in the world. Water in the River Nile is diverted to agricultural lands through a hierarchy of public canals that comprise carrier, or principal canals, main canals, branch canals and sub-branch canals. The branch canals deliver water into smaller tertiary channels mesqas and water is conveyed from the mesqas, or in some cases directly from canals, to the fields by farm ditches or marwas (IFAD, 2012)

Surface irrigation is the oldest and most common method of applying water to croplands. Also, referred to as flood irrigation, the essential feature of this irrigation system is that water is applied at a specific location and allowed to flow freely over the field surface, and thereby apply and distribute the necessary water to refill the crop root zone. (USDA, 2012)

The field water uses Efficiency (FWUE) has been widely used parameter to describe the efficiency of irrigation in terms of crop yield because of it is the ratio between economic yield and water applied in season (Howell, 2003)

To improve the conventional irrigation systems under old lands of Egypt, one of the most important part is that lining the conveyance lines (tertiary canal and mesqas)

Such lining is extensively used in new development areas but has been limited in the established irrigation areas. The irrigation improvement project plans to use concrete-lined mesqas or low pressures pipelines to deliver water to new water user associations (Aziz, 1993)

Canal lining is a method of augmenting water quantity. It can be done in various ways viz

a-hard surface lining, which includes concrete, stone, ferro cement, bricks and shotcrete (pneumatically applied mortar),

b-exposed and buried membranes such as butyl rubber, polyvinyl chloride (PVC) and polyethylene,

c-soil linings and soil sealants, like silts, clays and some chemicals, can also be used for lining. (Ahmed et. al, 2009)

The major loss of head is due to friction in the pipe. The minor losses are so small as compared with friction losses and they may be neglected. But in case of a short pipe, the minor losses, as compared with the friction losses, are of appreciable amount and thus cannot be neglected. These losses are proportional to the length of the pipeline and vary inversely with the inside diameter. (Khurmi, l982)

The main objective of this trial is to evaluate surface irrigation system performance through using buried pipes and lining mesqas for furrows irrigation lengths of 100 m comparing with earthen mesqas under the same condition of furrows length.

The total water amounts, water application efficiency, yield crops and field water use efficiency for crops wheat and maize were identified.

MATERIALS AND METHODS

A field experiment was carried out during growing two successive seasons of winter 2015/2016 and summer 2016 in Upper Egypt at Assuit governorate - El fath city at

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Arab El-atawlah branch canal (27° 15'/ N, 31° 13' / E). Fig (1) Shows the general of developed surface irrigation.

To evaluate the performance of developed surface irrigation in the land area of 43 feddan from fields that has been irrigated by developed surface irrigation under supervisor Ministries of Agriculture and Irrigation at Assuit governorate were selected.

Three areas were irrigated by three systems. The first area (115×12 m) was irrigated by buried pipe 180 mm diameter. The field experimental work covered the evaluation of the buried pipes system performance for outdoor pipe diameter 180 mm, pumping unit discharge rate 216 m3/h, buried pipes system length 100 meter and distance between the valves is 25 m having 4 valves struggling head inlet 6 m. The second area (115×12 m) was irrigated by lining mesqa, (0.6 m width and 0.6 m height). and the third area (115×12 m) irrigated by earthen mesqa is usually ranged from 20 to 100 feddan (0.35×1.20m).

Three fields were selected for two crops wheat (Seds12) in winter season and maize (Giza 15) in summer season where, wheat and maize are considering principle crops in the study area.

The soil texture of the experimental site according to (Black, and Hartage, 1986) is classified as clay soil as shown in table (1).

From the actual experimentally measured of pumping pressure head (h_p), 6 m with pumping unit discharge rate (Q_p) of 216 m^3/h, measured flow rates from each valve along the buried pipes system (q_m), l/s and the actual valve pressure head (h_m) along the buried pipes system measured by using piezometers. The flow rate passing before any valve (q_n), l/s was computed according to equation $Q_n = \sum_{m}^{N} q_n$. The average flow velocity inside the buried pipes system just before any outlet (V_n), m/s computed according to equation $Vn = 0.001Q_n / A$. The accumulative head losses due to friction just before any valve along the buried pipes (h_{ft}), m, computed according to equation $hft = \sum_{m}^{N} h_{fn}$ the superimposed pressure head (H_{sn}) shows the pressure head generated due to the decreasing in the flow velocity inside the buried pipes system computed according to equitation $Hsn = \frac{(V_{max}^2 - V_n^2)}{2g}$. Also, the theoretical discharge rate of any valve could be calculated according to equation q =Cv Cc a $\sqrt{2gh}$ and considering (C_d) unity computed according to equation *Cd=0.83 (h/d)–0.13*. On the other hands, the behavior of flow through the buried pipes system was described by determining the pipe Reynold's number value just before any valve computed by equation $RNRN = \frac{vd}{\upsilon}$. The actual experimentally measured of valves flow rate along the buried pipes system (q_m), l/ s measured by using direct method. Also, the original, pressure head was measured using a pressure gauge and piezometers. The results of the actual experimentally measured of the buried pipes system performance are shown in Table (3). The results of Table (3) was expressed respectively to facilitate the discussion

Amount of applied water consists of pump discharge (applied water from the pump). Applied water from the pump was calculated based on pump discharge and operating time. the pump discharge and operating time during both seasons for different mesqas. The values of pump discharge for mesqas in were 28, 28 and 36.1 L/s, respectively. It is clear that, the pump discharges are varied due to maintenance of the pumps from the previous years, worker experience and operating time of each pump.

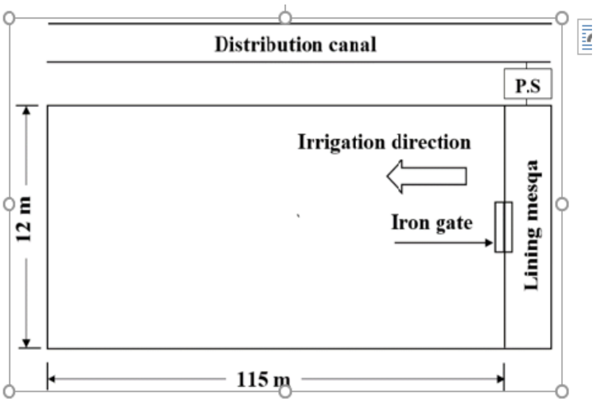

Fig. 1. The general layout of developed surface irrigation

Table 1.The physical and mechanical analysis of the soil

Depth, Cm	Mechanical analysis				Texture Class	F.C %	W.P %	B.D g/cm³
	Sand		Silt	Clay				
	C.S%	F.S%	%	%				
0 – 15	7.51	15.20	22.77	54.52		35.3	18.1	1.18
15 – 30	6.23	16.30	20.32	57.15	Clay	37.2	19.2	1.19
30 – 45	5.16	15.11	22.88	56.85		35.6	21.1	1.20

Developed surface irrigation

UPVC pipelines

In developed surface irrigation the field received irrigation water from the branch canal through electric and diesel pumping unit to the main and branch buried UPVC pipes instead of traditional Mesqa and Marwa. The main line (Mesqa) diameter ranged from 225mm to 280mm and branch line (Marwa) diameter was 180 mm. The UPVC pipes were connected together using faucet rubber ring jointing system. On branch line there is risers ended by 160 mm hydrant valve. Fig (2) Shows general layout for buried pipelines Mesqa (lateral canal).

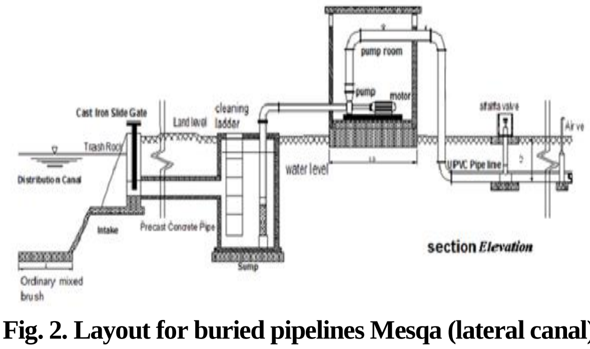

Fig. 2. Layout for buried pipelines Mesqa (lateral canal)

Lining Mesqa (U- Section):

In the present work, one U-section Mesqas were used. It is about lifted Mesqas under the ground surface Mesqas aspects and its base of bricks U-section height 60 cm and width 60 cm. The water is lifted to the Mesqas using pumps. The irrigation water come through holes located at the head of each Marwa. Fig (3) Shows general layout for lining Mesqa (lateral canal).

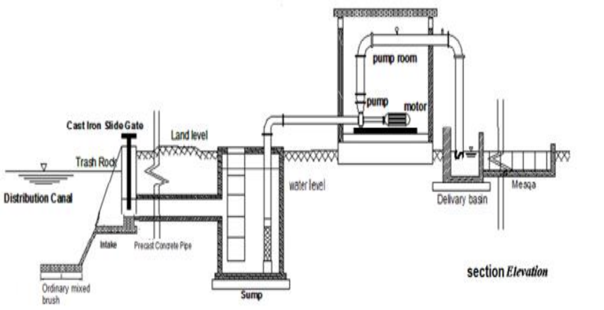

Fig. 3. Layout lining Mesqa (lateral canal)

The buried pipes system calibration and test procedure

The water uniformity distribution through valves outlets along pipes along its hole length was experimentally tested under field condition through the variation of flow (q_{var}) using equation (1). On the other hands the pressure head variation (H_{var}) could be determined by equations, (2) under the same condition.

Discharage of flow variation through buried pipes system (q_{var})

The flow variation along the line can be determined by:

$$q_{var} = \frac{q_{max} - q_{min}}{q_{max}} \quad \text{.................. (1)}$$

Where:

q_{var} = The outlet flow variation %,
q_{max} = The maximum outlet flow along the lateral line. m3/h
q_{min} = The minimum outlet flow along the lateral line. m3/h

2.3.2. The pressure head variation through buried pipes system:

The pressure head variation can be determined by:

$$H_{var} = \frac{H_{max} - H_{min}}{Hmax} \quad \text{................ (2)}$$

Where:

H_{var} = pressure variation along the pipe, as a percentage,
H_{max} = maximum head in sub-main, m, and
H_{min} = minimum head in sub-main, m

The irrigation water amount

The amount of irrigation water received by wheat plants of 5 irrigation for different mesqas were measured actually by flow meter during the winter season. Also, the amount of irrigation water received by maize plants of 6 irrigation for different mesqas were measured actually by flow meter during the summer season.

Water application efficiency (WAE)

Water application efficiency was calculated from the formula (3) according to (FAO, 1989)

$$WAE = \left[\frac{WDZ}{WT}\right] \times 100 \quad \text{.................. (3)}$$

Where:

WDZ = Depth of water stored in the root zone, cm.
WT = Gross depth of applied water, cm.

Soil moisture distribution "SMD" was determined according to Liven and Rooyen (1979). For each treatment, six locations were taken along the field. The soil moisture content was determined using the gravimetric method. SMD was identified at six points along field and three depths at root zone (0-15, 15-30 and 30-45) before and after irrigation. Soil samples were collected by soil auger. Moisture content for each treatment was measured directly before irrigation and 48 hours after irrigation. Soil moisture content percentage (S.M.C, %) was determined as a dry method according to the equation (4):

$$S\,M\,C = \left[\frac{(W_1 - W_2)}{W_2}\right] \times 100 \ \text{.......................... (4)}$$

Where:

W_1 = mass of the wet soil sample, g.
W_2 = mass of the oven dried soil sample, g. at 105 ^{0}C for 24 hours.
Equation (5) was used to find the depth of water that entered to root zone (WDZ) during irrigation.

$$W.D.Z = \left[(SMC2 - SMC1) * p * D / 100\right] \quad \text{...... (5)}$$

Where:

P = is the specific gravity of soil.
S.M.C2 = soil moisture content in the Field 48 hours after irrigation, %.
S.M.C1 = is moisture content in the field before irrigation, %.
D = root depth, mm.

Field Water use efficiency (FWUE).

After determining the amount of water applied to crop in the season. Water use efficiency was calculated according to equation (6) according to (Howell, 2003).

$$\text{FWUE (kg/m}^3\text{)} = \frac{Yield,(\frac{kg}{fed})}{water\ applied,(\frac{m^3}{fed})} \times 100 \ \text{.... (6)}$$

$$Q = \frac{V}{T} \ \text{........................ (7)}$$

Where:

Q = discharge m3/ h.
V= the volume m3.
T= time (hour) h.

RESULTS AND DISCUSSION

Hydraulic evaluation of irrigation systems

The value of both velocity and discharge they are control the engineering design of the channels in terms of water passing through the channels. The results of Table (2) were graphically expressed to facilitate the discussion. showed that the average values of the velocity through different type of mesqas were 0.16, 0.09, 0.42 and 0.194 m/s for Ordinary, Roughness, Lining mesqas and Buried mesqa respectively. showed that the average values of water discharge through different type of mesqas were 153.6, 45, 151.2 and 5.62 l/s for Ordinary, Roughness, Lining mesqas and Buried mesqa respectively.

Table 2. The value of both velocity and discharge through different types of mesqas.

Type mesqas	Area of flow, m^2	wetted perimeters, P, m	hydraulic radius, m	velocity, V m/s	Discharge , Q l/s
Ordinary breadth, bO	0.96	2.64	0.36	0.16	153.6
Roughness breadth, bR	0.56	2.04	0.25	0.09	50.4
Lining breadth, bL	0.36	1.8	0.20	0.42	151.2
Pipe line	0.029	0.60	0.048	0.194	5.62

Evaluation of the buried pipes system performance.

Table (3) shows that the measured resultant of pressure head (h_m). dropped gradually in the buried pipes and this dropping trend ended about 28.30 percent of the buried pipes length due to the accumulative friction head losses greater than the superimposed pressure head and thus overcome its effect. The minimum values of the measured pressure heads (h_m) was about 53.33 percent of the original pressure head at the buried pipes inlet. After that, the measured pressure head decreased gradually until it reached the buried pipes end and its values were about 38.33 percent of the original pressure head at the buried pipes inlet because the gradual increased in superimposed pressure head.

Table 3. The actual experimentally measured of buried pipes system

Valve No.	q_r, l/s	Q_m, l/s	V_m,m/s	Re	h_{sn}, m	h_{ft}, m	h_m, m	h_p, m
1	15	16.1	2.36	$4.2x10^5$	0	2.65	3.2	6
2	15	15.3	1.77	$3.1x10^5$	0.124	3.97	2.8	6
3	15	14.5	1.18	$2.1x10^5$	0.213	4.57	2.5	6
4	15	14.1	0.59	$1.1x10^5$	0.266	4.73	2.3	6

Amount of applied water

Amount of applied water consists of pump discharge (applied water from the pump). Applied water from the pump was calculated based on pump discharge and operating time. the pump discharge and operating time during both seasons for different mesqas. The values of pump discharge for mesqas in were 28, 28 and 36.1 L/s, respectively. It is clear that, the pump discharges are varied due to maintenance of the pumps from the previous years, worker experience and operating time of each pump.

The data indicated that the operating time for the pumps on the mesqas increased during summer season due to increase period between irrigation. The lowest value of operating time was obtained with improved mesqas, while the maximum value was recorded with earthen mesqa, due to different of pumps discharges and type of mesqa Fig. (4) and (5) show the effect of mesqa type on applied water for during two seasons. The results indicated that the amount of water applied for wheat crop were 1123, 1168 and 1515 m^3/fed under buried pipes, lining mesqa and earthen mesqa respectively. While they were 1180, 1216 and 1521 m^3/fed of maize crop for the previous mesqas respectively.

The recorded data revealed that increased amount applied water for crops with undeveloped mesqa as compared to developed mesqas. And this may be due to proven that the average decrease overall irrigation efficiency. Most of water losses occur in mesqas and marwa.

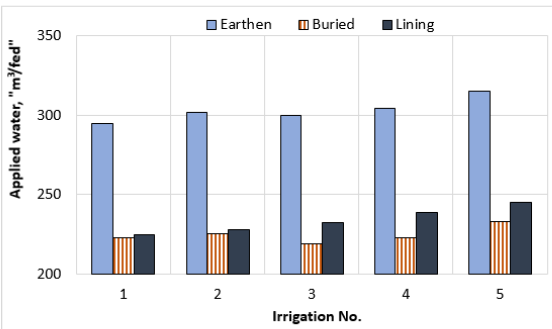

Fig. 4. mesqa types on Applied water for irrigation number for winter crops under different mesqas types

Water application efficiency (WAE)

The average depths of the irrigation water stored in the root zone under buried pipe and lining mesqas irrigation compared with earthen mesqas depending on soil moisture content before and after each irrigation were 35.7, 34.7 and 31.90 cm for different mesqas respectively in winter while,it was 44.00, 43.57 and 39.12 cm for buried pipe, lining mesqas and earthen mesqas respectively in summer season.

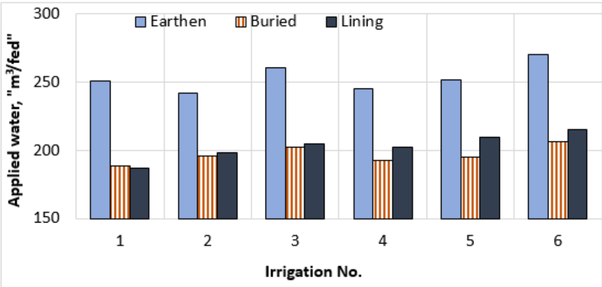

Fig. 5. Effect of mesqa type on applied water for summer crops.

Fig. (6) show the effect of mesqas types on application efficiency for during two planting seasons. the average values of water application efficiency during two seasons through using buried pipes and lining mesqas compared with mesqas earthen. Generally, the results showed that increased the average values of the water application efficiency (WAE) in case of using buried pipe and lining mesqas by 42.42 and 37.00 % than irrigation earthen mesqas respectively for winter season.it was by 40.74 and 38.46 % of using buried pipe and lining mesqas for summer season. The maximum value of water application efficiency (WAE) was achieved in case of buried pipe and its determination of 82.50 %.

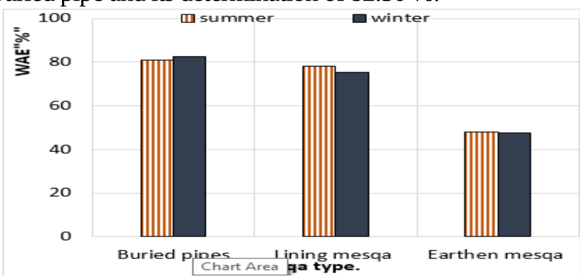

Fig. 6. Application efficiency during winter and summer seasons

Yield of crops

The grain yields (kg/fed) for wheat and maize crops obtained for the developed and traditional surface irrigation were shown in Table (4). The yield of crops was affected by using developed surface irrigation as it is high compared with traditional surface irrigation. The yield of maize was 3360 kg/ fed under buried pipes and it was 2660 kg / fed under traditional surface irrigation. In wheat the yield was 3450 kg/ fed under developed surface irrigation and it was 2700 kg/ fed under traditional surface irrigation. The lowest value of wheat and maize was under traditional surface irrigation condition. The percentage of increase in yield of wheat and maize under buried pipes was 21.74 % and 20.83 % respectively compared with traditional surface irrigation. Also, the yield of maize was 3150 kg/ fed under lining Mesqa and it was 2660 kg / fed under traditional surface irrigation. In wheat the yield was 3225 kg/ fed under developed surface irrigation and it was 2700 kg/ fed under traditional surface irrigation. The lowest value of wheat and maize was under traditional surface irrigation condition. The percentage of increase in yield of wheat and maize under lining Mesqa was 16.28 % and 15.56 % respectively.

Table 4. Effect of developed surface irrigation on productivity of crop.

Types of Mesqas		Yield of crops (kg/fed)	
		Wheat	Maize
Developed	Buried pipes.	3450	3360
	Lining Mesqas.	3225	3150
Traditional	Earthen Mesqas.	2700	2660

Field water use efficiency

Field water use efficiency (FWUE) considered as an indicator of the capability of irrigation system to converting irrigation water to crop. The (FWUE) was considered a tool for maximizing crop production per each unit of water applied. So, values of (FWUE) for wheat and maize were calculated under developed and traditional surface irrigation. The value of (FWUE) in buried pipes was 3.07 kg ⁄ m^3 for wheat and it was 1.78 kg ⁄m^3 under traditional surface irrigation. The value of (FWUE) for maize under buried pipes was 2.85 kg ⁄ m^3 and it was 1.75 kg ⁄m^3 under traditional surface irrigation. Also, it found that the value of (FWUE) in lining mesqas was 2.78 kg ⁄ m^3 for wheat and it was 1.78 kg ⁄m^3 under traditional surface irrigation. The value of (FWUE) for maize under lining mesqas was 2.59 kg ⁄ m^3 and it was 1.75 kg⁄m^3 under traditional surface irrigation. Fig. (7) show the Field water use efficiency affected by type crop for different of season.

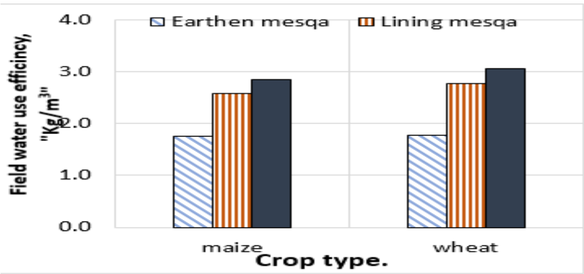

Fig. 7. Field water use efficiency affected by type crop for different of season

From previous results the (FWUE) under developed surface irrigation is higher than that under traditional surface irrigation because of the volume of water applied per feddan in developed surface irrigation

less than the traditional surface irrigation and productivity per feddan in developed surface irrigation higher than the traditional surface irrigation so, the (FWUE) under developed surface irrigation is higher than traditional surface irrigation.

CONCLUSION

1. The buried pipes and lining mesqa have many advantages such as: Saving irrigation Water, hence minimize the drainage problems. improve the usage efficiencies equity of water distribution and high crop yields.
2. Utilization of buried pipes and lining mesqa has increased the saved amount water, application efficiency, irrigation water efficiency and high remarkable crop yield. Therefore, it is recommended to utilize the developed canals in the upper Egypt region, especially the buried pipes.

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تحسين كفاءه استخدام وحدة المياه تحت ظروف الرى السطحي المطور

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[2] قسم الرى الحقلي ، معهد بحوث الهندسه الزراعيه.

تم اجراء هذة الدراسة بمنطقة عرب الأطاولة مركز الفتح بمحافظة أسيوط، وذلك بهدف تقييم أداء نظام الري السطحي المطور، من أجل رفع كفاءة استخدام المياة وزيادة إنتاجية المحاصيل وذلك من خلال تقدير كمية المياة اللازمة للمحاصيل طوال الموسم،وكفاءة إضافة المياة، وكفاءة استخدام المياة الحقلية.ومعدل الزيادة في إنتاجية الفدان كما تم إجراء دراسة هيدروليكية لتحديد التصرف التصميمي للقنوات المطورة وكذلك سرعة المياة بها. اظهرت النتائج ان ميل منحنى الضاغط المقاس فعليا على طول خط الرى بالانابيب المدفونة تركز على تأثير طول الانابيب على التغير فى الضواغط المحسوبة بلغت قيمتها حوالي 53.33 %. التغير فى التدفق خلال الرى بالانابيب المدفونة 12.42 % كما بلغت انتظامية المياة في نظام الرى بالانابيب المبوبة طول 100 متر وقطر180 مم حوالي 87.58 %. كميات المياه المستخدمة لري محصول القمح بلغت حوالي 1123 و 1168 و 1515 م3/فدان باستخدام المواسير المدفونة، والمساقي المبطنة، والمساقي التقليدية على التوالي. بينما وصلت الى 1180 و 1216 و 1521 م3/ فدان عند ري محصول الذرة للمساقي السابق ذكرها على التوالي. وأوضحت النتائج زيادة كمية المياه المضافة لمحصولي تحت الدراسه في حاله المساقي التقليدية بالمقارنة مع المساقي المطورة. وجد ان نسبه كفاءة إضافة المياة حوالي 39.20 % في المساقي الترابية ، 76.70 % في المساقي المبطنة ، 81.75 % في المواسير المدفونة. في حين كانت نسبة الزيادة في إنتاجية الفدان باستخدام المواسير المدفونة 21.74 و 20.83 % للقمح والذرة علي التوالي، نبينما باستخدام المساقي المبطنة كانت الزيادة 16.28 و 15.56 % للقمح والذرة علي التوالي، مقارنة بالمساقي الترابية.زادت كفاءة استخدام المياة لمحصول القمح الى حوالي 1.78 كجم/م3 في المساقي الترابية ، 3.07 كجم/م3 و 2.78 كجم/م3 في المواسير المدفونة والمساقي المبطنة علي التوالي، ولمحصول الذرة زادت الى حوالي 1.75 كجم/م3 في المساقي الترابية ، 2.85 كجم/م3 و 2.59 كجم/م3 في المواسير المدفونة والمساقي المبطنة علي التوالي.

الكلمات الدالة: تقييم الرى - الري السطحي المطور- المواسير المدفونة - المساقي المبطنة - تطويرمستوى نظام توصيل المياه