Modeling Of Micro Hydroelectric Power Plants Utilizing Artificial Falls (Weirs) On Reach of Tigris River-Iraq

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ABSTRACT
Weirs are one of the world wide water resources management structures, which are beside their activity in rising water surface to become important source for electricity by using low head hydropower turbines, it improve the hydraulic and the environment of the river reach.140,000m long of Tigris River reach between Al-Fatha and Samraa cities at Salahaldeen province in Iraq was selected to evaluate the usefulness of constructing system of weirs series by calculating the range of improvements in the hydraulic properties, in the environment and estimating the hydroelectric power potential of the study reach. GIS, Global Mapper (Ver.11) and DEM (digital elevation model) combined with surveyed cross-sections of the river bed were used for the delineation and knowing the number of cross – sections and its area. 30 cross sections were used for river reach in this study. One dimensional and steady flow HEC-RAS model was used .It was calibrated to estimate water surface profiles through a group of equations and to calculate the suitable hydraulic conditions along the study reach. The optimum value of manning coefficient was 0.027. The study area was evaluated and the system of five weirs with heights of (3.7 – 6.0 m) was proposed along the river reach. Their locations depend on trial and error process, geometric of the cross – sections and the ratio of the height of the weirs to the design head. The simulated results by using HEC-RAS model were tested to know the reach behavior against three different discharge values (200, 1242, 8616 m3/s), with return period of 1, 1.15 and 42.50 years respectively, and to compare the hydraulic changes in the study reach before and after installing the weirs and to know the net heads for running the low head hydropower turbines. The results illustrate improvement in the reach hydraulic properties of the river reach. According to the criteria of hydro – power system classifications, the type of hydro – power in this case study was small and the suitable turbine was Kaplan turbine with flow rate of 30m^3/sec and with ranges of net heads of (3.29 – 6.08 m). 7 and 41 turbines were chooses for the flow rates of 200 and 1242 m^3/sec respectively. The Kaplan turbine is running with very high efficiency below the design flow and with suitable runner diameter. The total estimated capacity of one turbine was (5.38 –7.60 MW) and for seven units, it was (37.66 - 53.20 MW) at one weir. These capacities will cover some of the growth in demand to the electricity in Iraq. It covers about (300, 000) capita of population in the study area. It was found that the maximum cost of the electromechanical equipment for hydro project was 42.91 million US$.
Keywords: Micro-Hydro-Electric Power, Hec-Ras Model, Tigris River

INTRODUCTION:

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Fresh water supplies, energy and environmental preservation are three of the most pressing issues facing humanity. Planning for development of reservoir and hydropower on the rivers of the world can be improved by the use of powerful tools to analyze the natural hydrologic supply of water and determine the most effective management that balances human and ecosystem needs.(Chowdhury, S. (2010)) stated that the hydro power is recognized as a renewable source of energy, which is economical, nonpolluting and environmentally benign. Small and mini hydel projects have the potential to provide energy in remote and hilly areas where extension of grid system is un- economical. A Hydel Power Project has been proposed to be constructed on Tiljuga Dhar (a perennial stream of Kosi River basin flowing from Nepal). The basic infrastructural need of this hilly terrain is low cost and environment friendly source of power. It has been found that if a dam with a storage capacity of 7.05 MCM be constructed, a set of three hydel units with capacity of 610, 180 and 81 KW may be run in unison or alternately to generate power of 4.88 MW annually.

Kucukali, S.(2011), reviewed in details the hydropower has the highest share among the renewable energy sources of Turkey by 94% with a total installed capacity of 14,553 MW for the year 2009. Turkish government has based its energy policy on maximizing hydropower potential to be evaluated in next 15 years. In this sector is expected to build hydroelectric power plants having a total capacity of 27,500 MW. There is also a considerable hydropower potential in existing water supply systems. The most convenient locations for hydropower generation in water supply systems are water supply lines located before the water treatment or distribution network. In water supply lines, the excess pressure is dissipated by creating water jet in the pressure reduction tank. However, the excess pressure can be removed from the system by installing a hydro-turbine and it can be converted into useful energy by means of electricity. For a case study, the hydropower potential of the water supply system of Edremit in Turkey has been analyzed. There are 12 pressure reduction tanks along the water supply line of the city and the system has an electric energy potential of 4.08 GWH/year. Kunwor , A. (2012), discussed about the technical specifications and design parameters required to design a working micro hydro power system. After review of the theory and principles of (MHS) design; these principles are applied to the real case of Lamaya Khola micro hydro project in Pangrang Village of Nepal. The field data required to design the civil components of the micro hydro project was derived from secondary data sources such as the study conducted by the village development committee as well as other independent project surveys. The micro hydro designed was of "run-of-the river" type. Similarly, system components designed are intake structure, headrace canal to divert the water from the source, forebay tank, sedimentation basin and the penstock assembly.

Jaehyouk, L. et al, (2013), reviewed in detail about the small hydro-power plants are commonly constructed and operated in many countries like United States of America, Canada, Japan, and China as the reliable and economical renewable power source. For instance, Japan has been utilizing rubber weirs as the intake-dam in many hydro-power plants extending its height up to 6 meters high in Kurotani River in Fukushima Prefecture in South Korea. The objective is to make assessment of small hydro-power generation capacity and its economical value of the selected five existing sites constructed with movable weirs in streams. These various sites have the small hydro-power generation's effective inflows range from (0.92 to 73.30CMS); effective heads from 0.7 to 3.0 meters in height; designed generation capacities were(9.3 to 1,724kWh) and annual generation capacities were estimated at (73~14,755 MW/year). There are approximately 36 small hydro-power plants existing in South Korea. As results of our initial studies we are determined with a numerous potential and possibility to develop the optimized solution for utilizing these rubber weirs to produce clean energy and provide sustainability near the water sources in our country. Selection of an appropriate turbine to a large extent is dependent upon the available water head and to a lesser extent on the available flow rate. In general, impulse turbines are used for high head sites, and reaction turbines are used for low head sites. Kaplan turbines with adjustable blade pitch are suitable for wide ranges of flow or head conditions, since their peak efficiency can be achieved over a wide range of flow conditions. Small turbines (less than 10 MW) may have horizontal shafts and even fairly large bulb-type turbines up to 100 MW or so may be horizontal. Very large Francis and Kaplan machines usually have vertical shafts because this makes best use of the available head, and makes installation of a generator more economical. Pelton turbines may be installed either vertically or horizontally (Gatte, M.T. et al, (2012)).

The objectives of this study are: use HEC–RAS Model to simulate steady state flow in the study reach of the Tigris river-Iraq; calibrate the model by using manning coefficient parameter for the water surface profile; generate the hydroelectric power as clean energy and environmental
friendly from low water heads utilizing artificial falls (Weirs) on a river reach; select the best choice of various types turbines to produce energy; provide hydroelectric power to far areas (villages and rural areas) that have not available energy and reduced its transition cost.

Study area:

The selected reach of Tigris river is 140 km in its length .It lies at north of Baghdad city between Al- Fatha and Samraa cities at Salah Al-Din province in Iraq, Fig.(1). It was selected to evaluate the usefulness of constructing system of weirs series as artificial falls in river by calculating the range of improvements in the hydraulic properties and estimating the hydroelectric power potential of the study reach. This area had been selected because it has better slope of a river which can be used for modeling micro hydro power plants.

Figure(1): Study area of Tigris river reach (google earth).

Theoretical Basis:

1-One Dimensional Steady Flow

Hec-Ras model is capable of performing one dimensional water surface profile calculations for steady gradually varied flow in a river. Subcritical, supercritical and mixed flow water surface profiles can be calculated. Water surface profiles are computed from one cross section to the next by solving the energy equation with an iterative procedure called the standard step method **(USACE (2002))**. The energy equation is:

$$Y_1 + Z_1 + \alpha_1 {V_1}^2/2g - h_e = Y_2 + Z_2 + \alpha_2 {V_2}^2/2g \qquad \ldots..(1)$$

Where: Y_1, Y_2=depth of water at cross sections; Z_1, Z_2=elevation of the main river inverts; V_1, V2=average velocities; α_1, α_2=velocity weighting coefficients; g=gravitational acceleration and h_e=energy head losses. The energy head loss h_e between two cross sections is computed of friction losses and contraction or expansion losses. The energy head loss eq. is:

$$h_e = L * S_f + C(\alpha_2 {V_2}^2/2g - \alpha_1 {V_1}^2/2g) \quad \ldots\ldots(2)$$

Where: L=discharge weighted reach length; S_f=friction slope between two sections; C=expansion or contraction loss coefficient. The distance weighted reach length, L, is calculated as:

$$L = (L_{lob} * Q_{lob} + L_{ch} * Q_{ch} + L_{rob} * Q_{rob}) / (Q_{lob} + Q_{ch} + Q_{rob}) \quad \ldots\ldots(3)$$

Where: L_{lob}, L_{ch}, L_{rob}=cross section reach lengths for flow in the left overbank, main river and right overbank, respectively; Q_{lob} , Q_{ch}, Q_{rob}=average flow between sections for the left overbank, main river and right overbank, respectively. The friction slope, S_f is calculated in Hec-Ras model by the following eq.:

$$S_f = \left(\frac{Q_1 + Q_2}{K_1 + K_2}\right)^2 \quad \ldots.(4)$$

Where: K=conveyance for subdivision (from Mannings eq.).For the calculation of C, the model assumes that a contraction is occurring whenever the velocity head downstream is greater than the velocity head upstream. When the velocity head upstream is greater than the velocity head downstream, the model assumes that a flow expansion is occurring. The velocity weighting coefficient α is calculated using the following eq.:

$$\alpha = \frac{Q_1{V_1}^2 + Q_2{V_2}^2 + \cdots + Q_N{V_N}^2}{QV^2} \quad \ldots.(5)$$

The main objective of the HEC-RAS program is to compute water surface elevations at cross-section locations of interest along a river or stream, for given flow values. Data requirements include flow regime, starting elevation, flow rate, loss coefficients, roughness, cross-sectional geometry, and reach lengths. Profile computations begin at a cross section with known or assumed starting conditions and proceed upstream for subcritical flow or downstream for supercritical flow. Subcritical profiles are constrained to critical depth or above, and supercritical profiles are constrained to critical depth or below **(Bedient, P.B. *et al.*(2008)).** The following assumptions are implicit in the equations and procedures used in the HEC-RAS model: flow is steady; flow is gradually varied; flow is one dimensional; river channels have small slopes (less than 1:10). If any of these assumptions are violated, the results from the HEC-RAS program may be in error.

2-Overflow Spillway

Overflow spillway behaves as weir and if the spillway is not submerged the flow will pass through critical depth over the crest. One of the most common crest shapes is the ogee. The discharge over ogee crest (without gates) is given by the following eq.:

$$Q = C * L * {H_e}^{\frac{3}{2}} \quad \ldots(6)$$

where: Q=discharge; C=discharge coefficient; L=effective crest length; H_e=total head on the crest (design head plus velocity of approach head H_a).The discharge coefficient C, is influenced by many factors: the depth of approach; slope of upstream weir face ; submergence in the down stream and the ratio of the height of weir to the design head of flow. The discharge coefficient for vertical faced ogee crest ranges between 3.8 and 3.9 for values of P/H_d ranging from 0.5 to 3.0 where p is the weir height and H_d is the design head,(USBR(1977)).The discharge coefficient is also vary for heads other than the design head. The ratio of C to design head C varies from 0.85 to 1.07 as the ratio of head to design head varies from 0.2 to 1.6.

3-Micro-Hydro-Power:

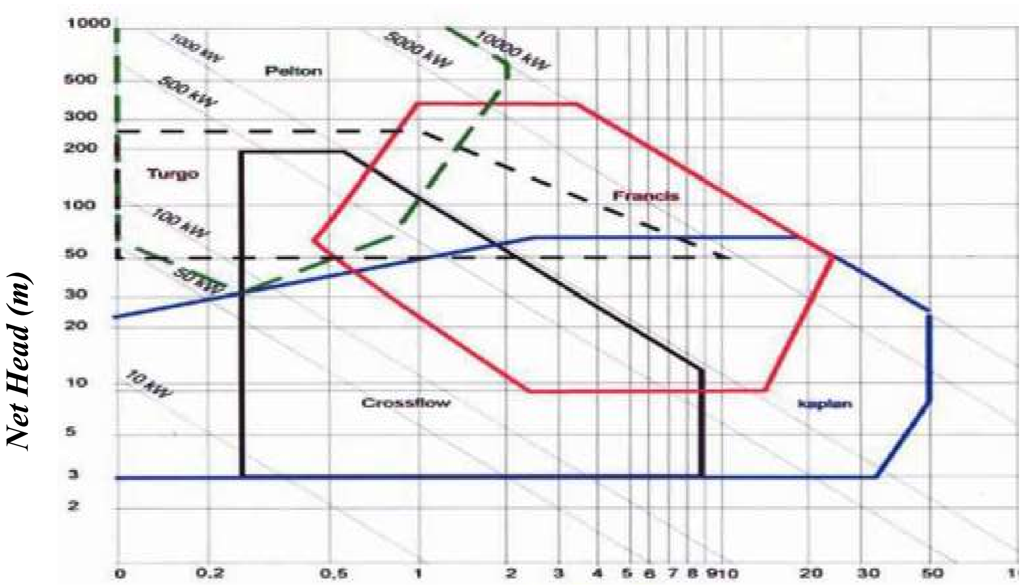
Turbine is the main piece of equipment in the hydro power scheme that converts energy of the falling water into the rotating shaft power. The selection of the most suitable turbine for any particular hydro site depends mainly on two of the site characteristics – head and flow available (Gatte, M.T. *et al*, (2012)). In micro hydro system, there are two factors determine the power potential of the water flowing in a river or stream flow and the head. The potential power can be determined as:

$$P = Q * H * \gamma * \acute{\eta} * n \qquad \ldots\ldots(7)$$

Where: P = Power (KWH/year); H = Head (m); Q = Water flow (m^3/s); γ = Weight density (9.81 KN/m^3); ή =Turbine and generator efficiency; n= Number of hours per a year.

Hydro turbines can be broadly categorized into either impulse or reaction turbines**.** Impulse turbines convert the kinetic energy of a jet of water in air into movement by striking buckets or blades. By comparison, the blades of a reaction turbine are totally immersed in the flow of water, and the angular as well as linear momentum of water is converted into shaft power **(**Tamburrini, M. (2004)**).** Selection of an appropriate turbine to a large extent is dependent upon the available water head and to a lesser extent on the available flow rate. In general, impulse turbines are used for high head sites, and reaction turbines are used for low head sites. Kaplan turbines with adjustable blade pitch are suitable for wide ranges of flow or head conditions, since their peak efficiency can be achieved over a wide range of flow conditions. Small turbines (less than 10 MW) may have horizontal shafts and even fairly large bulb-type turbines up to 100 MW or so may be horizontal. Very large Francis and Kaplan machines usually have vertical shafts because this makes best use of the available head, and makes installation of a generator more economical. Pelton turbines may be installed either vertically or horizontally. Some impulse turbines use multiple water jets per runner to increase specific speed and balance shaft thrust. Turbine type, dimensions and design are basically governed by the following criteria (Gatte, M.T. et al, (2012)): net head; variation of flow discharge through the turbine; rotational speed; cavitation problems (quality of water available from penstock); cost.

Turbine selection chart below, Fig.(2) permits the user to select turbines for a available of flow rate (m3/s) and net head (m).A significant factor in the comparison of different turbine types is their relative efficiencies both at their design point and at reduced flows. Typical efficiency curves are shown in Fig. (3). An important point to note is that the Pelton and Kaplan turbines retain very high efficiencies when running below design flow; in contrast the efficiency of the Crossflow and Francis turbines falls away more sharply if run at below half their normal flow. Most fixed-pitch propeller turbines perform poorly except above 80% of full flow.



Flow (m^3/s)

Figure (2): Turbine Selection Chart.

4. Empirical Hydro Cost Equations:

Gordon J. L. is the pioneer who made remarkable contributions to cost estimating techniques for hydro projects. Early in 1979, correlations of electromechanical equipment cost and overall project cost to the net head and capacity were developed for projects below 5 MW at existing dams (Gordon and Penman 1979):

$$C_{em} = 9000 * \frac{P^{0.7}}{H^{0.35}} \qquad \ldots.(8)$$

where, C_{em} = cost of electromechanical equipment in US$, P = installed capacity in kW, H = hydraulic head in meters. Limitations are recognized for using Gordon's empirical equations today, because (1) the project data were consolidated from different countries, assuming no cost variations for equipment among countries, (2) the data are out of date (1956–1986), and (3) the effects of project schemes and turbine types on the overall plant cost were not considered. Papantonis (2001), based on the Europe data, developed cost estimate formulae for different components and project cost equations differentiated for different turbine types. The cost of electromechanical equipment confirmed Gordon's equation with an inflation rate adjustment:

$$C_{em} = 29000 * \frac{P^{0.7}}{H^{0.3}} \qquad \ldots \ldots(9)$$

Where: P (in kilowatts) and H (in meters) are the same as defined earlier.

Methodology and Data Requirements:

-Digital Elevation Model (DEM) is the data files that contain the elevation of the terrain over a specified area, usually at a fixed grid interval over the surface of the earth. The intervals between each of the grid points will always be referenced to a geographical coordinate system. For the purposes of flood mapping, it is essential

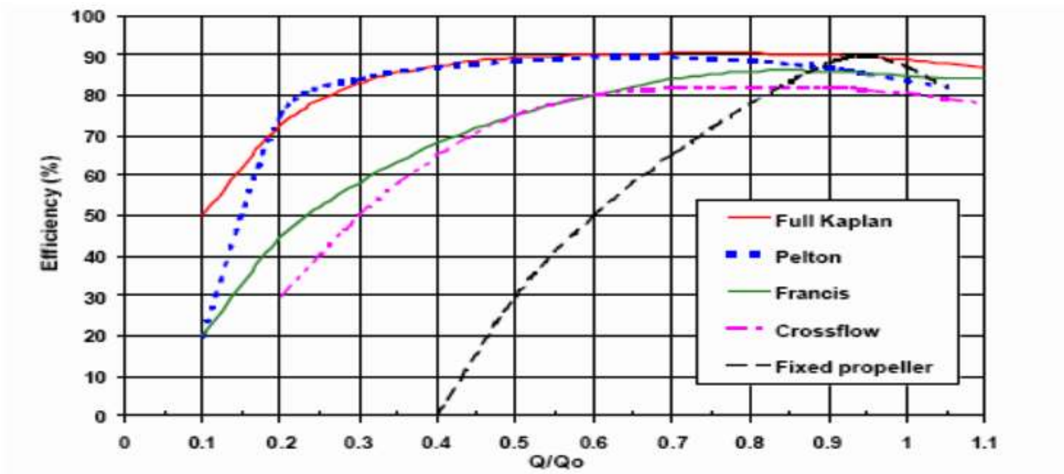


Figure (3): Efficiency of Various Turbines based on Discharge rate.

that the DEM represents accurately all the important topographical features of the floodplain show in Fig. (4).The elevation accuracy of the floodplain DEM is also important. The accuracy of any generated flood map will only be as good as the accuracy of the base DEM data. Global Mapper-11, has a capability of identifying the elevation of any point and delineation of cross-section at any given location, but unfortunately the digital elevation model did not include information about water covered surfaces and it considers the water surface as the ground surface, so on site surveying process for the stream bed on the specified locations of the cross-sections is required to establish relatively accurate geometry of the study stream.

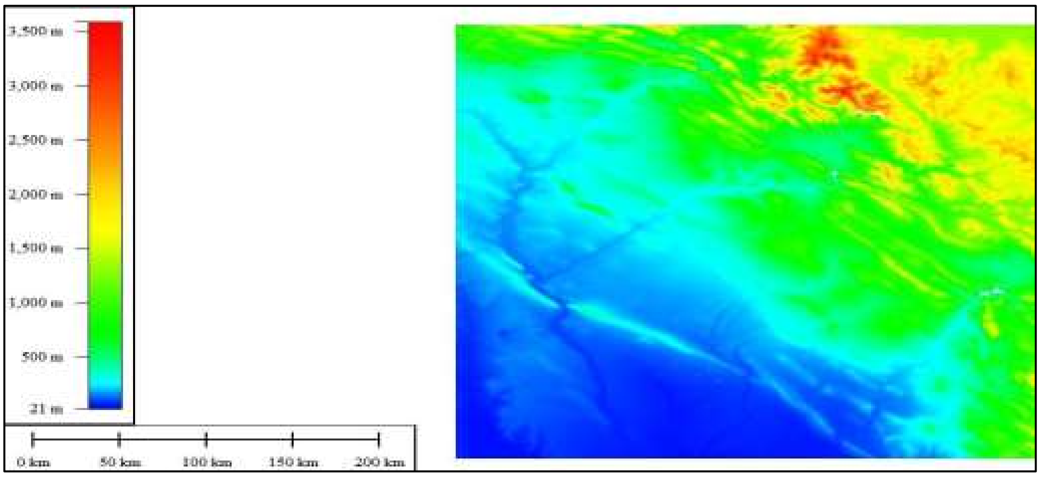


Figure (4): DEM model picture for study area (Global Mapper Program).

-The newest cross-sections can be invested in this study for the stream bed surface to be a part of available 30 cross-sections which were survived along the Tigris River between Al Fatha city and Sammara Barrage. The study reach starts at station 100 in Sammraa Barrage to station 3000 in Al-Fatha city that represent end of the river reach. Fig.(5) below shows the river reach for case study area, draw by HEC-RAS model. All cross-sections were described by entering the station and elevation (X-Y data) from left to right, with respect to looking in the downstream direction. Most of the 30 cross sections contain at least 50 pairs of X-Y coordinates. Figs.(6) and (7) showed two cross sections of the Tigris river, the first one represent the starting reach of river at Al-Fatha station(St-3000) and the second is near to the Samaraa Barrage station(St-100).

-To enter bridge data the first requirements were to select the reach of river and two cross sections which the structure placed between its. After this, all data which specialized for design of bridge in upstream and downstream of bridge station represent an input data, these are: place of bridge, inter outer border of bridge (Deck/Roadway) data, slope of abutment, dimensions and elevations of piers to model the bridge approach by model. In this study two bridges data were introduced (Tikrit and Al-Fatha bridges).

-To achieve the greatest benefit from using series of weir within reach of river which worked as artificial falls to rise water surface, best location must be selected that will be improved a hydraulic conditions requirement for high efficiency operation to small sizes of turbines.Weir height and design energy head must be known in the model. The total head is equal to the energy grade line elevation minus the elevation of the weir crest. Indeed weirs locations have been depended upon availability hydraulic condition limitation and nature of area where the rural and village area is favorable on urban area. So five weirs were added within river reach to achieve the objectives of this study and get the best hydraulic conditions in this area of case study. Numbering for upstream and downstream river station Table (1) is according to numbering of model which limited the cross sections between (100 – 3000) to configuration 30 river stations of case study.

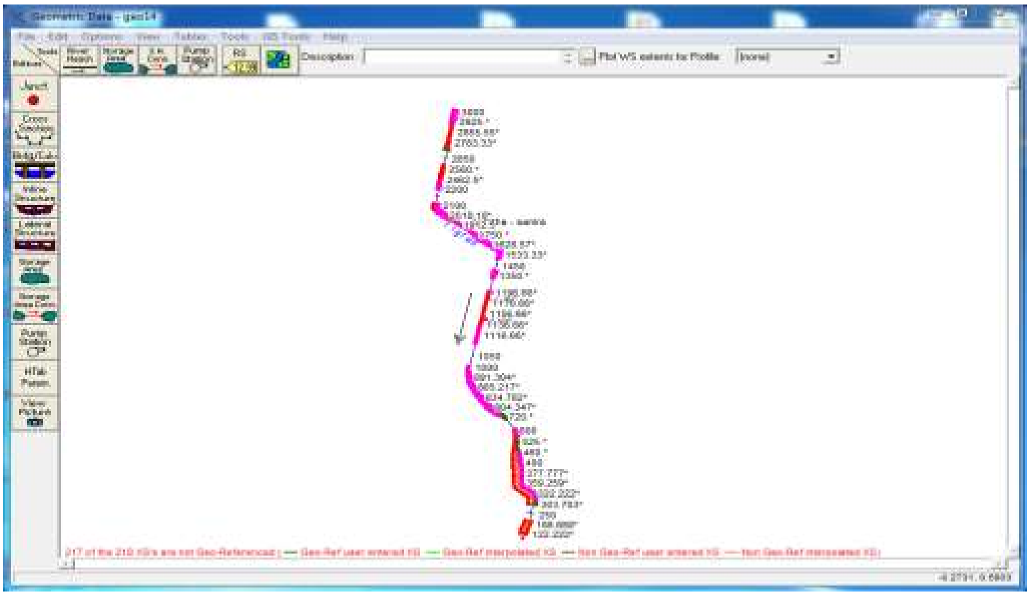
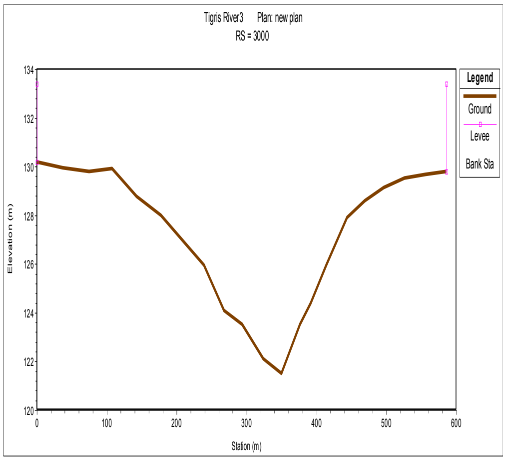
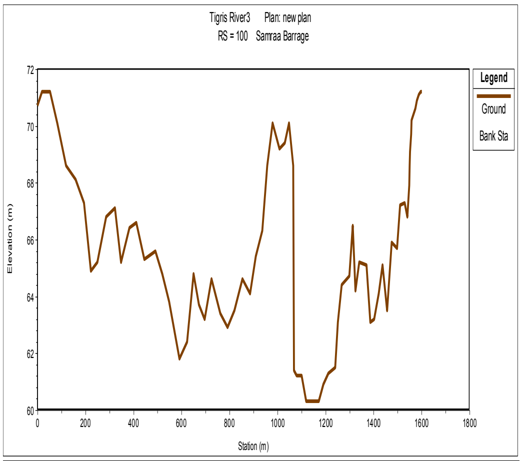


Figure (5):The reach of river by HEC-RAS model.



Figure(6) :Cross section at Al-Fatha city.



Figure(7) :Cross section at Samaraa Barrage.

Table (1): Stations of Weirs and its distance from the nearest cross-section.

Weir no.	Area name	Weir river station	Downstream Distance* (m)	Lu**
1	Tal-Althahab	2650	116,167	2000
2	Al-Bojoary	1450	79,722	1743.75
3	Al-Baaj	1250	74,446	1582.75
4	Al-Mahzam	650	32,254	1631.75
5	Owainat	250	6,574.5	2191.25

*Represent distance between every weir and zero point (at samara) station.
**Represent distance between weir and nearest station at upstream direction.

-Due to changes in the cross section area, the contraction or expansion of flow is important in calculation of energy losses within a reach (between two cross sections). Whenever this occurs, the loss is computed from the contraction and expansion coefficients specified on the cross section data editor. The coefficients, which are applied between cross sections, are specified as part of the data for the upstream cross section. The coefficients are multiplied by the absolute difference in velocity heads between the current cross section and the next cross section downstream, which gives the energy loss caused by the transition. Where the change in river cross section is small, and the flow is subcritical, coefficients of contraction and expansion are typically on the order of 0.1 and 0.3, respectively (Bedient ,P.B. et al.(2008)).

-By using the records of flow rate which obtained from the Ministry of Water Resources – Iraq (2014) for (84 years), Fig. (8), which represent the flow rate of Tigris River at Beiji for the period (1930-2013), were drawn. By using the statistically analyzed (probability), the minimum, average, maximum discharges and flood flow were estimated, Table (2).

- Figs. ((9) and (10)) show the rating curves at Beiji and Samraa stations according to the observed data. As rating curves for several river stations were known, the initial water surface profile can be drawn to estimate the different between the observed and the compute profile for several discharges also the energy and critical depth can be plotted. This process represents a calibration for HEC-RAS model. At the first time, a single value of Manning's Roughness will be used for the calibration of water surface profile. After this process, different values will be used to justify their adequacy for simulation of the water surface profile Fig.(11). The results show obviously that the value (0.027) of Manning coefficient is the optimum and represents the average n value for the same reach and for the main channel, as previously referred to the research of (Khayyun, T.S.(2006)).

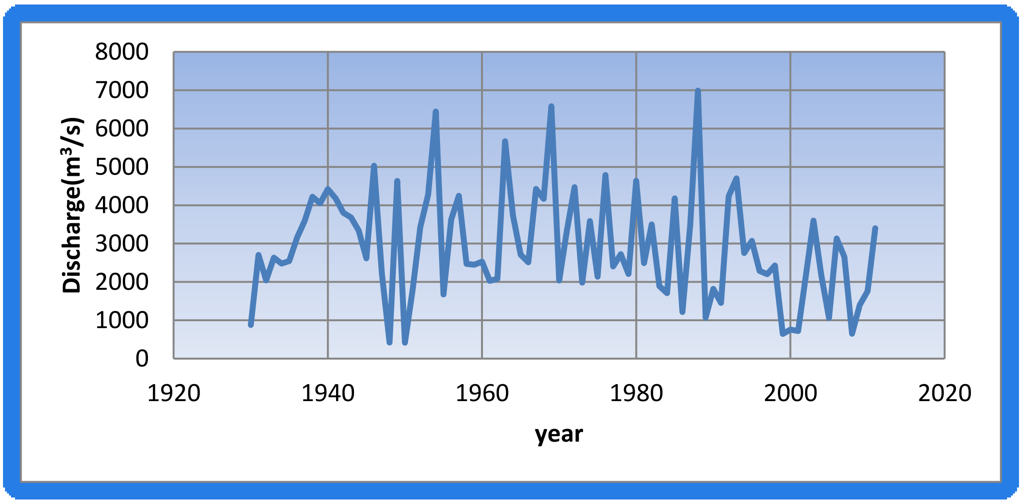
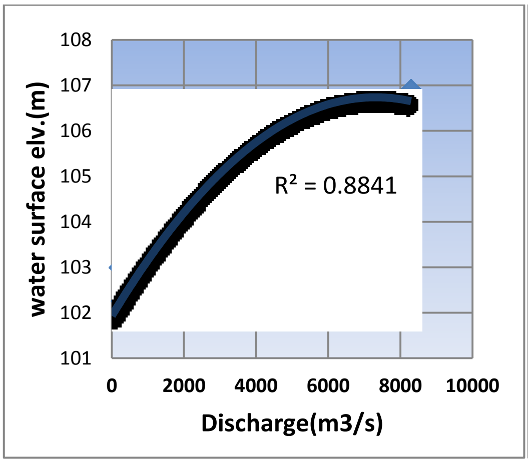
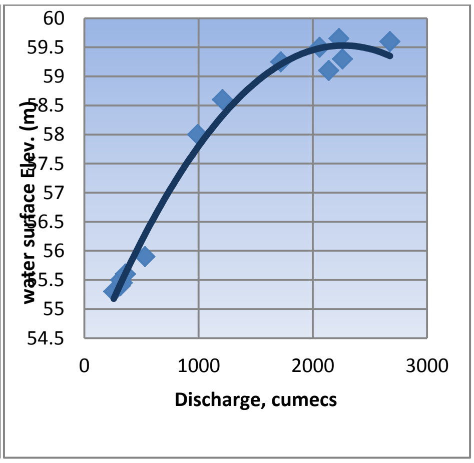


Figure (8): Flow rates of Tigris river for period (1930 – 2013)(Ministry of Water Resources-Iraq).

Table (2): Values of flow rates of Tigris River for period (1930 – 2013).

Type of flow	***Q (m^3/s)***	***Return period T(years)***
Minimum flow	200	1
Average flow	1242	1.15
Maximum flow	8616	42.50
Flood flow	16380	85





Figure(9):Rating Curve at Biji station. **Figure(10): Rating Curve at Samraa station.**

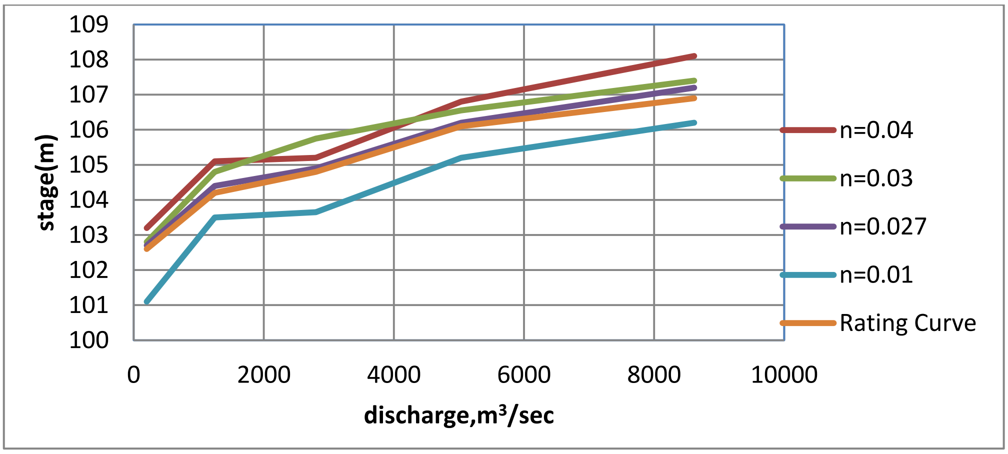
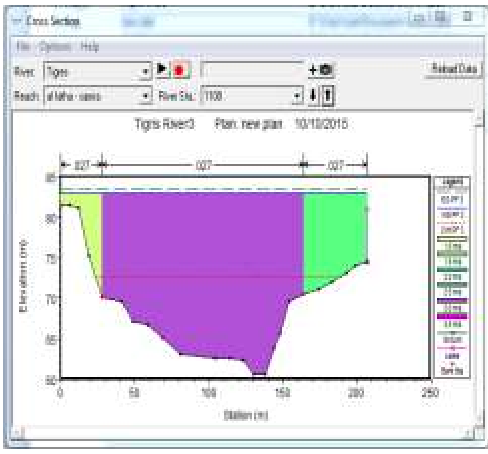


Figure (11): Calibration process for n values by HEC-RAS model.

Results and Discussions:

- One of e the important results that can be got it by applying HEC-RAS model is a plot of the velocity distribution for every cross section as one of the hydraulic conditions of the river reach after installed series of weirs. Figs (12 and 13) show



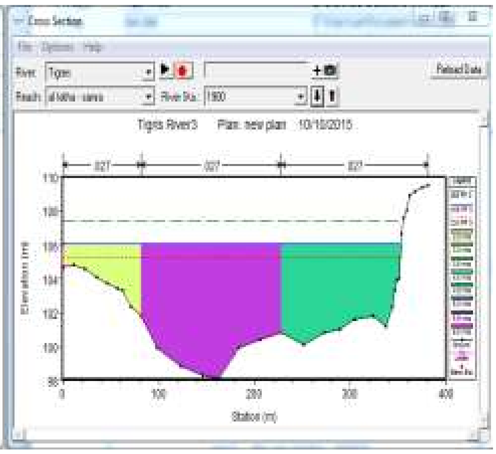


Figure (12): Velocity distributions at St. 1100. **Figure (13): Velocity distributions at St.1900.**

the velocity distribution of the cross section stations (1100 and 1900) respectively. It is clear from these figures below that the velocity distributions of these cross sections change with flow depth along the cross section perpendicular to the flow direction from the left to the right. At station (1100) which represents the cross section at Tikrit city, the velocities vary from 1.24 to 3.11 m/s and the maximum value lies approximately in the middle of the cross section. At the station 1900 (cross section at Beiji city), the velocity changes from 2.5 to 5.5 m/s. These high values of velocities are due to flood discharge of 8616 m^3/s. For low flow rates values, the velocities vary from 0.40 to 0.90 m/s.

-Figure (14) presents a comparison of the rating curve between the curve generated as output data from HEC-RAS model and the actual rating curve for 3000 cross section at Al-Fatha city. It is obviously that there is a little differences between them, this mean that the result of the model is close to the actual data and this difference is dut to some assumptions of the model during analysis process for the case study.

-Figures (15 and 16) show the relationship of energy grad line elevation and critical depth elevation with distance when the HEC-RAS model was simulated with an average discharge of (1242 m^3/s).The energy line has a higher slope in the upstream of the river reach than downstream due to higher slope of the river bed. The bed slope was parallel to the energy slope along the river reach as a result for using a steady flow in HEC-RAS model. The flow regime for the steady reach by using HEC-RAS model was subcritical with average Froude number of (0.25). The average energy slope was 0.00049, which is close to be slope of 0.0005.

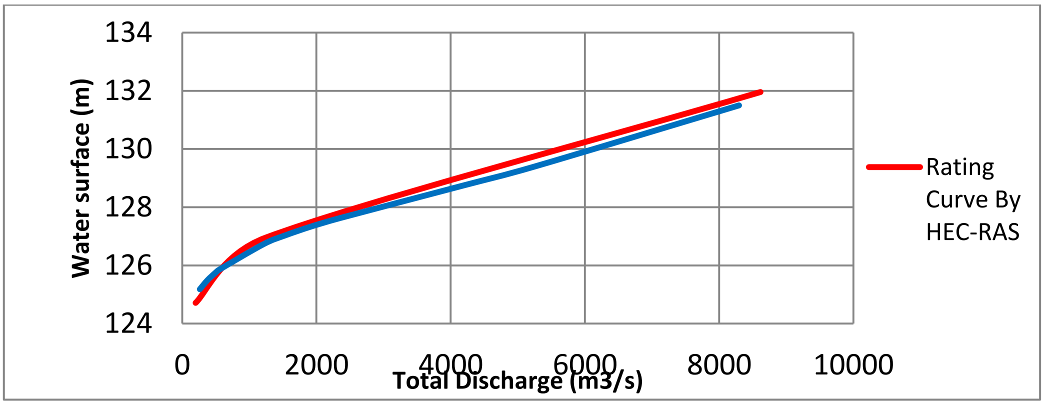
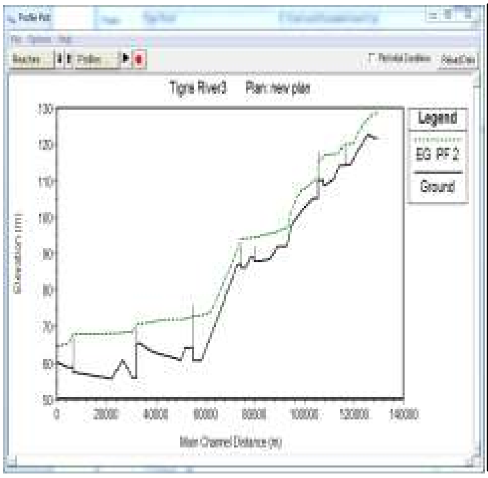
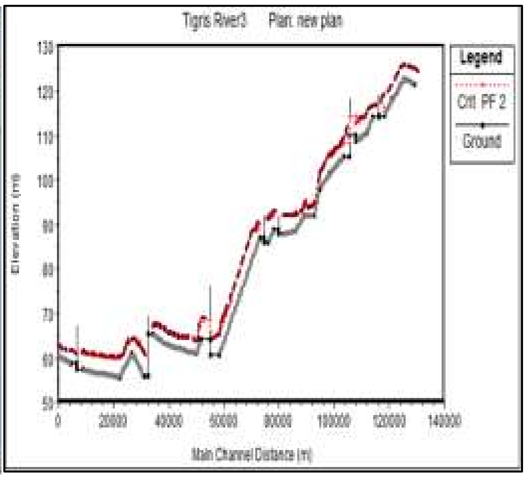


Figure (14): Comparison between two rating curves at 3000 cross section (AL- Fatha city.





Figure(15):Energy grad line elevation for discharge of 1242m^3/s.

Figure(16):Critical depth elevation for discharge of 1242 m^3/sec.

- After installing series of weirs within the river reach and HEC-RAS model has been used the generated water surface profiles showed in Figs. (17,18 and 19) with three discharge values (200,1242 and 8616) m^3/s respectively ,(W1, W2, W3, W4 and W5) in these figures referred to the weir number as according to arrangement within river reach). The simulated hydraulic parameters or simulated values for the water depth over the crest of weirs along the river reach will be used for calculation the power and using the type of small hydro-power (turbines).

- After installing the five weirs, an improvement in the river properties was found. Inspected properties show decrease in the effect of low discharge values, with correspondingly less effect on the river behavior in case of flood discharge. These

changes are: the seasonal water depth variation decreased by (27%) and the average depth increased by (16%); the average flow area increased by (36%) against decrease in mean velocity average by (29%); the flow efficiency increased by (20%) because of the increase in average hydraulic radius.

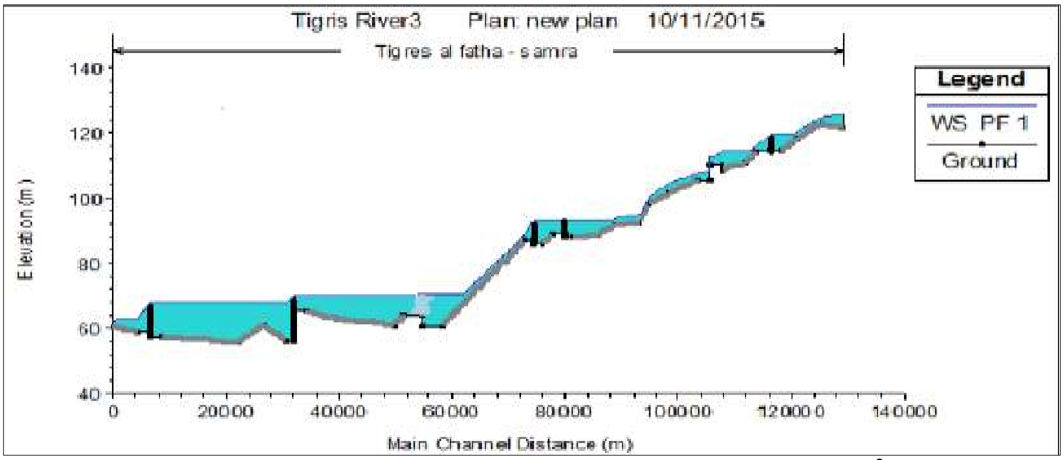


Figure (17): Water surface profile with weirs for Q=200m^3/s.

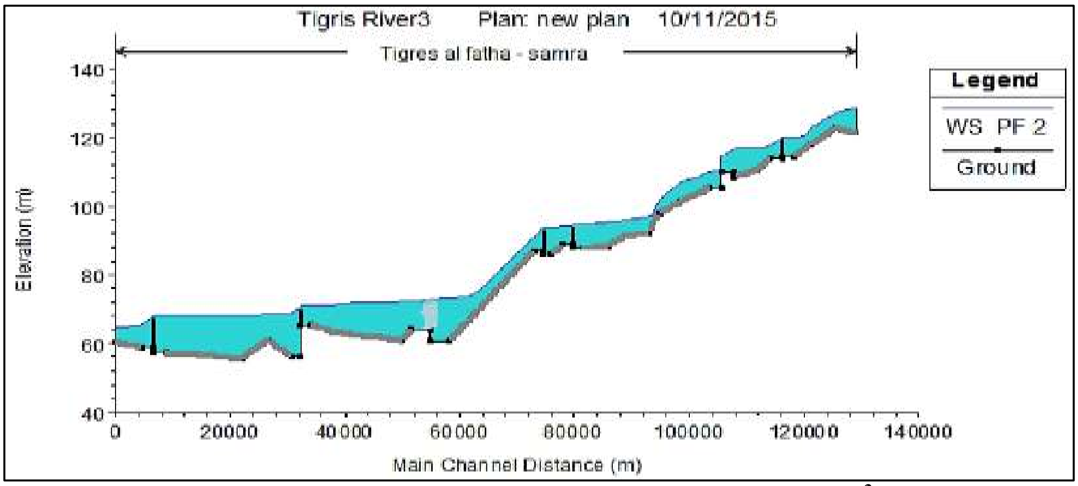


Figure (18): Water surface profile with weirs for Q=1242m^3/s .

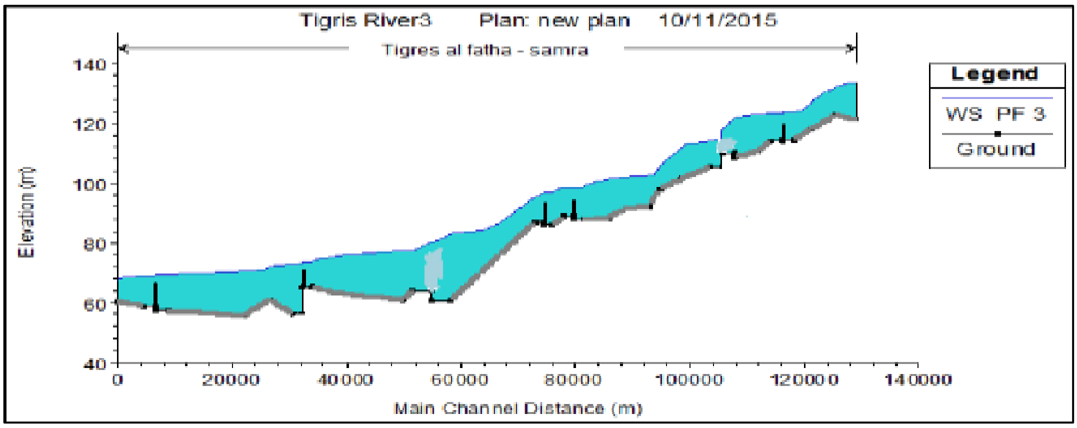


Figure (19): Water surface profile with weirs for Q=8616m^3/s.

- According to the available data in the study area which includes the hydraulic, environmental properties for the area and its distance from the city, the aim of the study is to serve the remote villages and rural areas with energy. The design number of weirs was divided into five weirs which its locations were adjacent to the Tigris River from the right and left sides of the river parameters. Table (3) shows the initial design parameters for these five weirs within the flow section as an input and output data for the model when HEC-RAS model was run with the three values of discharges. The selection of heights of weirs was depending on the geographic survey of the site, on hydraulic considerations and trial and error by the model. The ranges of the heights were 3.75 to 6 m. Table (3) shows the variation of design head values at every weir according to the change in discharges. The ranges of heads are (0.20 – 1.07) for $Q_{min.}$,(0.5 – 2.50) for $Q_{avg.}$ and (1.85 – 6.65) for $Q_{max.}$. The hydropower is based on net head of water between upstream and downstream of the weir after extracting the head losses. Table (3) is important to be sure that the ratio of (P_1/H_d) of weirs is acceptable or not. From this Table, it is clear that all of the weirs are suitable for minimum and average discharges of this case study according to the range of ratio (P_1/H_d> 1.33).

Table(3) : Initial design of weirs at different location within river reach.

Weir No.	River station	Elev. of weir Crest (m)	P_1^*	$(H_d)^{**}_{min.}$	$(H_d)_{avg.}$	$(H_d)_{max.}$
1	2650	120.00	4.85	0.40	1.15	4.95
2	1450	93.00	4	1.07	2.50	6.65
3	1250	92.50	3.75	0.50	1.42	4.35
4	650	69.50	6	0.45	1.30	4.25
5	250	67.50	4.50	0.20	0.50	1.85

*P_1 : Upstream height of the crested(ogee) weir
**$(H_d)_{min.}$: Design head at min discharge

-Table (4) presents the gross head for the turbine that can be obtained by calculating the differences between water surface elevation upstream and downstream of the weirs. According to the classification of head, these values represent low head.

The heights of weirs were chosen according to the geometry of the cross sections and the ratio of P_1/H_d. When P_1/H_d greater than 1.33 and the approach velocity head is negligible, the coefficient of discharge (C_d) has been found to be 4.03.

- There are many considerations to design micro-hydro power plant which must be taken into account in the design procedure. These considerations are:

1-Selection of an appropriate turbine to a large extent is depending on the net water head and the available flow rate. The net head is calculated by subtracting the losses due to (open channel, trash rack, entrance, valve gate and penstock losses) from the gross head. These losses represent 10% of the

Table(4):Gross head, water surface elevation in u/s and d/s for each weir station.

Weir No.	River St.	Height of weirs, m	Water surface Elev. Upstream of the weirsm.a.s.l.			Water surface Elev. Downstream of the weirsm.a.s.l.			Gross head m		
			$Q_{min.}$	$Q_{avg.}$	$Q_{max.}$	Q_{min}	Q_{avg}	Q_{max}	Q_{min}	Q_{avg}	Q_{max}
1	2650	4.85	119.41	120.82	**123.96**	**115.41**	117.17	122.80	4	3.65	1.16
2	1450	4	93.12	94.10	98.63	88.92	90.25	96.76	4.20	3.85	1.87
3	1250	3.75	92.98	93.92	96.84	88.48	89.97	94.71	4.50	3.95	2.13
4	650	6	69.92	70.75	73.80	63.17	65.75	71.00	6.75	5.0	2.80
5	250	4.50	67.66	68.01	69.34	62.07	64.02	67.37	5.59	3.99	1.97

gross head as maximum. The limitations of these variables for selection the turbine type were depending on the net head and specific speed which illustrated in the characteristics curves for each type of turbines. If the turbine is running below the design flow(Q_o) the efficiency for the Kaplan turbines is not reduce when the ratio of the real flow rate(Q) to the design flow rate (Q/Q_o) is reduced from 1.0 to 0.5, Figure(3). In general, impulse turbines are used for high head sites, and reaction turbines are used for low head sites. Kaplan turbines with adjustable blade pitch are suitable for wide ranges of flow or head conditions. The range of flow rates, heads and power were from 10-50 m^3/s, 3-7m and 250-2500 Kw respectively. The available turbine head is calculated at every structure (weirs) which represent the different between two water elevations in upstream and downstream as shown in Table (4). From this table, it can be observed that the range of turbine head at minimum discharge is (4 – 6.75) m, at average discharge the range is (3.65 – 5) m and at maximum discharge the range is (1.16 – 2.80)m. According to Figure (2) and the criteria of hydro power system classification (Kuhl, K. (2014)) , the type of hydro power in this study is small hydro power and the suitable turbine is Kaplan turbine. The runner diameters of the turbine vary between 0.63m to 2.80m.

2- A considerable factor in the comparison of different turbine types is their relative efficiencies both at their design point and at reduced flows. Referred to Figure (3) which shows the efficiency curves, an important point must be considered that a Kaplan turbine is running with very high efficiency below the design flow. The efficiency of turbine depends on discharge ratio (Q/Q_0).According to Fig.(2), it can be noted that the maximum discharge of Kaplan turbine is 30 m^3/s. Seven turbine as a minimum can be used at every weir site with a flow rate of 30m^3/s for the minimum discharge (200 m^3/s). The efficiency of turbine is about (88 – 90) % and decreases if there are decreases in the flow rates.

3-Because of micro-hydro-electric power plants are normally built as run of the river plants, the maximum water flow capacity of the turbine must be determined by mean of the flow duration curve for the river or stream. A way for organizing discharge data here is by using the records of flow rate which obtained from the Ministry of Water Resources of Iraq and through calculation we get three flow rate at this reach of case study that are (200, 1242 and 8616)m^3/s that represent minimum, average and maximum discharges. The number of hours in year for which the specified flow (minimum, average and maximum) occurs were 8322, 7626 and 175 respectively.

4-The turbine power in Gwh/year which generates from several turbines installed on the river reach can be estimated by multiplying the water power generated with the turbine efficiencies and the number of hour per a year, Table(5). These values were for the three discharges of the river reach. many turbines units were used at every station with a 30 m^3/s for one turbine according to available consideration at sites or stations. These values of power turbine represent as install capacity of turbine with out considering effeciencies of generation and transformation. This table showed the minimum and maximum limits of power generation at every station. Because of the big river of the study area which have more flowing water, more energy can produced. For flood flow rates of river reach, the gross heads between the upstreem and downstream of the weirs were less than 3m due submergence phenomena. The tail water in the downstreem of the weirs was higher than the crest of the weirs. The classification of small hydro power (turbines) was for a head of water larger than 3m. The annual power production in Iraq has increase from 29.13GW in 2000 to 48.83GW in 2010. The installed capacity of small hydro power projects is about 10% of the total hydropower capacity(UNIDO (2013)). The annual consumption per capita was 1000 to 2000 kwh.If it is assumed that the annual consumpsion for the electricity is 1500 kwh/capita, the total number of population who cover with this value of consumpsion are about 300,000 person.It was found by using the empirical Eq. (9),that the maximum cost of the electromechanical equipment for hydro project using one, seven and 41 turbines was 3.78, 14.77 and 42.91 million US$ respectively.

Table(5): Hydro power and cost for three flow rates .

Weir	Discharge (m3/s)	Net head m	Hydro-power and Cost								
			One Turbine			7 turbines			41 turbines		
			(MW)	(GWH/year)	Cost $*10^6$ $	(MW)	(GWH/year)	Cost $*10^6$ $	(MW)	(GWH/year)	Cost $*10^6$ $
1	200	3.6	1.03	8.57	2.54	7.21	60.0	9.91	-	-	-
	1242	3.29	0.82	0.51	2.22	5.74	-	8.68	33.67	20.91	29.94
	8616	1.04	-	-	-	-	-	-	-	-	-
2	200	3.78	1.15	9.57	2.70	8.05	66.99	10.55	-	-	-
	1242	3.47	0.95	0.60	2.42	6.65	-	9.47	38.95	24.60	32.63
	8616	1.68	-	-	-	-	-	-	-	-	-
3	200	4.05	1.31	10.90	2.90	9.17	76.30	11.32	-	-	-
	1242	3.56	1.01	0.63	2.51	7.07	-	9.81	41.41	25.83	33.80
	8616	1.92	-	-	-	-	-	-	-	-	-
4	200	6.08	2.28	18.97	3.78	15.96	132.80	14.77	-	-	-
	1242	4.50	1.57	0.98	3.19	10.99	-	12.45	64.37	40.18	42.91
	8616	2.52	-	-	-	-	-	-	-	-	-
5	200	5.03	1.83	15.23	3.43	12.81	106.61	13.40	-	-	-
	1242	3.59	1.03	0.65	2.54	7.21	-	9.92	42.23	26.65	34.18
	8616	1.77	-	-	-	-	-	-	-	-	-
Total	200	-	7.60	63.24	-	53.20	442.70	-	-	-	-
	1242	-	5.38	3.37	-	37.66	-	-	220.63	138.17	-
	8616	-	-	-	-		-	-	-	-	-
No.of Capita	-	-	-	35,466 2,247			295,133 - -		- 147,086 -	- 92,113 -	

CONCLUSIONS:

The collected information during this study, and the analyzed results obtained from the modeling and simulation processes, enable us to conclude the following:

-The geometry of the study reach, its length of 140,000m and 60m of total vertical elevation difference between the upstream and downstream of the river reach which make the slope of bed to be 0.0005. This is a suitable to establish a series of weirs for generation a small hydro-power.

-The flow regime for the steady reach by using HEC-RAS model was subcritical with average Froude number of (0.25). The average energy slope was 0.00049, which is close to be slope of 0.0005.

-For the calibration of the HEC-RAS model, the optimum value of the manning coefficient was 0.027 which was used for the generator of the water surface profile.

-For minimum steady flow rate for the river reach, the velocities values vary from 0.40 to 0.90m/s. But for flood flow, these values were 205 – 5.5m/s. The ranges of flow velocities for the minimum flow represent an optimum values for the alluvial rivers.

-The hydraulic properties (velocities, flow area and top width surface) of the river reach have been changed due to install the weirs. Improvement in the river properties in case of development with weirs, inspected properties show decrease in the effect of low discharge values, with correspondingly less effect on the river behavior in case of flood discharge. The seasonal water depth variation decreased by (27%) and the average depth increased by (16%). The average flow area increased by (36%) against decrease in mean velocity average by (29%). The flow efficiency increased by (20%) because of the increase in average hydraulic radius.

-The heights of weirs in the study reach were chosen by trial and error according to the geometry of the cross sections and the ratio of the height of the weirs to the design head. The heights of weirs were 3.75 to 6.0m.

-The installing of weirs in the river reach has many potential impacts. The positive impacts are measuring the flow rates accurately, power generation, aeration of water and improve the navigation. The negative impacts are increased the flood risk, raise the groundwater level, bank and bed erosion (downstream) and deposition of sediment upstream.

-A small hydro – power which can be constructed at the specified sites represents an efficient method for creating a renewable energy from small heads and flow rates over a weir which constructed on a river and without pollution to the air and water.

-According to the results of this study, the total estimated capacity of one turbine was 5.38 to 7.60MW, for the seven turbines it was 37.66 to 63.24MW these capacities will cover some of the growth in demand to the electricity in Iraq. The total number of population who cover with this value of consumpsion are about 300,000 person.It was found that the maximum cost of the electromechanical equipment for hydro project was 42.91 million US$.

-For flood flows, the net heads of water between the upstream and downstream of the weirs were less than 3.0m. These heads cannot generate a hydro power for the small turbines due to the submergence phenomena.

-According to the criteria of hydro – power system classification, the type of hydro – power in this study was small and the suitable turbine was Kaplan turbine with a flow rate of $30m^3/s$ and with ranges of net heads of (3.29 – 6.08m). 7 and 41 turbines were selected for the flow rates of $200m^3/s$ and $1242m^3/s$ respectively. The Kaplan turbine is running with very high efficiency below the design flow.

-Further studies on the weirs system must be done to cover the mechanical, electrical, economical, environmental, hydraulic and geological aspects, and establishing costing formulas suitable to Iraqi aspects which are essential in the policy of water resources management.

-Developing the Tigris River with weirs by installing small hydropower electricity systems since it is an ideal option for the rural areas and villages because of its low construction, operational, and maintenance costs.

-Hydrologic and hydraulic data must be available by the water resources management for the study area include accurate digital elevation models (DEM), updated cross-sections surveys, and flow records to improve the modeling and simulating results which lead to accurate in results generated by the HEC-RAS model.
-Selecting the reaches of river in Iraq which have suitable of hydraulic conditions for installing weirs to generate hydro - power using HEC-RAS model analysis process.

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