Methodology for Water Balance in Hemren Reservoir

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Abstract:

The water balance is considered as an important subject in the present time which has a great role in estimation of the quantity of water entering a dam. In this paper approach to estimate the water balance in Hemren dam, an equation has been found to calculate the discharge entering to Hemren dam through relate the variables (Qout from Derbendi-Khan, Qin to Hemren reservoir and rainfall intensity falling on the intermediate catchment area between Hemren-Derbendi-Khan dams) by using the regression analysis. The data were collected for the interval from 1980 to 2004. The equation gives a correlation coefficient 0.956 for the relation between the observed and calculated discharges.

Keywords: water balance, Hemren reservoir, rainfall intensity, regression analysis

طريقة حساب الموازنة المائية في خزان حمرين

الخلاصة

يعتبر موضوع الموازنة المائية من المواضيع المهمة في الوقت الحالي لما له من دور كبير في التنبا بحساب كمية المياه الداخلة الى سد ما. تم التطرق في هذا البحث الى الموازنة المائية في سد حمرين حيث تم ايجاد معادلة لحساب التصريف الداخل الى سد حمرين من خلال ربط المتغيرات (التصريف المطلق من سد دربندخان ،الشدة المطرية الساقطة على المساحة الوسطية بين سدي دربندخان وحمرين، و التصارف المقاسة الداخلة الى سد حمرين) بواسطة تحليل الانحدار، حيث جمعت البيانات اعلاه للفترة من 1980 الى 2004. اعطت المعادلة معامل ارتباط مقداره 0.956 للعلاقة مابين التصاريف المحسوبة من خلال المعادلة والتصاريف المقاسة الداخلة الى خزان حمرين.

1-Introduction:

The Hemren reservoir is a second reservoir on the Diyala river and its utilization synchronized with upstream Derbendi-Khan reservoir operation. Such synchronized operation of two reservoirs on the same river requires rather good knowledge of water regime both in the Derbendi-Khan catchment's area and in the Derbendi-Khan –Hemren intermediate catchment's area. In addition, this knowledge is essential not only for the reservoir operations studies but also for the sake of knowing all the elements required in the process of designing the Hemren dam. The first hydrological data on the Diyala river are dating from 1924 when the discharge site gauging station its operation (State Organization of Dams, 1978). The discharge site gauging station is located in a narrowed section of the Diyala river flow, in the Jebel Hemren zone, 150 km downstream of the Derbendi-Khan. The Diyala river water balance for the Derbendi-Khan –Hemren intermediate catchment's area has been studied for the first time

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by Harza Engineering Company in 1954 within the Derbendi-Khan dam and reservoir project. As the hydrological data had been generally reduced to those recorded at the Hemren dam, water balances for the Derbendi-Khan-Hemren intermediate catchment's area has been derived synthetically by the analogy with the adjacent Adhaim river catchment area. They found the following relation (State Organization of Dams, 1981):

$$Q_{D.S} = 1.25 * Q_{D.K} - 10$$

Where:
$Q_{D.S}$=discharge at the Hemren site
$Q_{D.K}$=discharge at the Derbendi-Khan site al (2002), drawing on Booker and Young (1994), develop a nonlinear net benefit maximization model applied to Southern Alberta. The demand sector includes urban, irrigation, industrial, and hydropower nodes. A novel environmental feature is the explicit account of the conversion of untreated water to treated potable water.

2-Description of The Catchment area:

The Diyala river catchment area is situated in the east boundary region of Iraq towards Iran, at approximate latitude 35. The north major part of the catchment a

In the above equation the number (10) refers to the average water intake for the irrigation requirements by Pelago channel, about 5 km upstream Hemren dam.

The water balance has a great importance in the hydraulic engineering. Many researchers have studied it. Chang and Richards (1971) solved the equation of continuity and motion by the method of characteristics and the sediment continuity equation by finite difference scheme. Vaux and Howitt (1984) apply a model to California, using nonlinear demand functions, and price-sensitive linear supply functions. The results show that market-based water transfers reduce the need for supply-augmenting facilities, and generate welfare gains. Booker and Young (1994) model intrastate and interstate water transfers within the Colorado basin, accounting for both water quantity and quality (salinity) balances. They use an explicit representation of the river twenty-node network, with its tributary inflows, diversion points, reservoirs, and hydropower plants. The model (CRIM Colorado River Institutional Model) is a nonlinear program that maximizes total net benefits, subject to linear water balance and nonlinear salinity balance constraints. Flows and salinity concentrations are functions of withdrawals, exports, and salt discharges, which are all decision variables. The CRIM is treated as a closed system, with a constant water supply. Model results suggest that efficiency gains are derived primarily from intrastate (not interstate) trade. Mahan et rea occupying the territory of Iran is predominantly of mountainous character, the altitudes exceeding sporadically 3000 m. Considerable part of runoff in this area results from snow melting. Such features are characteristical only of the catchment area spreading as far as to the Derbendi-Khan, covering the surface of about 16972 sq.km. Downstream part of the catchment area from the Derbendi-khan to Hemren (study area) is characterized by somewhat lower altitudes and gradients. Mountainous character is typical only of the east reaches of the intermediate catchment area but the altitudes very rarely exceed 2000 m so that the influence of snow is negligible. The Diyala river flow on this stretch is about 150km long. The average gradient being about 1m per one kilometer. The main left tributary Alwand has somewhat greater gradient of about 2m/km and it drains the area of 3974 sq.km. The largest right tributary is Narin characterized by small gradient having the catchment area of 2344 sq.km. The Narin river empties into the Diyala river close to the Jebel Hemren.

The total intermediate catchment area from Derbendi-Khan to Hemren was estimated to cover the surface of 12760 sq.km. The total Diyala river catchment area to Hemren is covering the surface of 29772 sq.km.

The upper Diyala river catchment area to Derbendi-Khan and the east part of intermediate catchment area (Alwand) substantially differ from the downstream areas, both in respect of topography and physical features of soil, climate and other.

The rainy season lasts from October to May. Mean annual precipitation ranges to about 1000 mm in the upstream reaches of the catchment area. In the south west direction the depth of precipitation suddenly decreases to about 200 mm at Hemren. Figure (1) shows the mean annual precipitation for Diyala catchment area.

3-General Description of Hemren Dam: The Hemren dam project is designed as a multi-purpose project providing the following requirements;

- control of Diyala river floods
- regulation of Diyala river flows
- power generation
- re-regulation of the Derbendi-Khan power plant discharges.

The Hemren dam and the associated facilities are located in the gorge, cut by Diyala river flow through Jebel Hemren, upstream of Diyala weir in Sadoor.

The project is composed of the dam, the reservoir, spillway, power plant, power tunnels and irrigation tunnels. The main characteristics of the structure are described below:

1. Main dam

The main dam is an earth fill type with central clay core followed by two layers of filters on both sides and supported by a gravel shell.

2. Spillway structure

The spillway structure is composed of the following parts

A. Approach channel
B. Headworks
C. Chute and transition zone
D. Stilling basin
E. Discharge channel

3. Irrigation tunnels
4. Power plant

4-Water Balance Methodology:

The water balance calculation is based on the circulation of water. It assesses the quantities of water in a certain area and over a certain time period. It must be considered all the inflows and outflows as well as changes in storage. For simple systems, such as a container or a water reservoir with measurable inflow and outflow (Frantar, P. et.al., 2005) the balance is straightforward and easily understood. The small water cycle schematic, where the main “inflow” is precipitation and the main “outflow” is evaporation, is also straightforward (Ritter, 2006). The water balance of a selected area, such as a country, region, etc, is much more complicated. Such a balance is invariably a simplified depiction of the actual conditions that covers the essential water balance elements and accurately portrays the relations between them. This research presents a water balance for the intermediate catchment area between Derbendi-Khan and Hemren dams, that's balance depends on using the regression analysis for the following constraints:

1) The rainfall intensity (I) falling on the intermediate catchment area between Debendi-Khan-Hemren dams, The released discharge from Derbendi-Khan dam about 150 km upstream the Hemren dam (Qd) The inflow discharge for Hemren dam (Qin) All the above data have been collected from the date October 1980 to September 2004 from General Directorate for the dams and reservoirs as shown in Tables (1), (2) and (3). These monthly data also have been plotted versus months, which represent time series. Figures (2,3,4) show the time series of (rainfall intensity mm/hr, the discharge released from Derbendi-khan dam m^3/sec and the discharge entering to Hemren reservoir m^3/sec) respectively for the entire period.

5-Results and Discussion:

The Hemren reservoir was put in operation in 1980. The data which have been collected extend from 1980 to 2004 that gives sufficient information and good confidence level to find the water balance equation for the intermediate catchment area between Derbendi-Khan and Hemren dams. The following equation has been found by using regression analysis for the 24 years for the data (intensity, Q.out Derbendi-Khan and Q. in to Hemren):

$$Qin = 0.0002 * I * A + 1.1Qout - 10$$

Where:

Qin = the discharge in m^3/sec to Hemren

I = the rainfall intensity mm/hr falling on the intermediate catchment area

A = the area of the intermediate catchment area which equal to 12760 km^2

Qout= the discharge released from Derbendi-Khan dam m^3/sec.

(10) Refers to the average water intake for the irrigation requirements by Pelago channel about 5 km down stream Derbendi-Khan dam

From the above equation it can be noticed that the first term represents the rational equation $Q = K * I * A$ and the losses factor 0.0002 represents the losses from the following:

- The type of the soil and the soil permeability in the study area
- The evaporation from the flowing water between Derbendi-Khan and Hemren dams

Figure (5) below shows the relationship between the discharges to Hemren (Q.in) observed from October 1980 to September 2004 and the discharge to Hemren calculated by the regression analysis equation.

From Figure (5) the correlation coefficient R is equal to 0.956 and this means the regression equation above gives a good result in comparison With the Observed data.

6-Conclusions:

The discharge entering to Hemren reservoir is related to the discharge released from Derbendi-khan reservoir and intensity of rainfall on the catchment's area, and the relationship among these variables is linear.

1. The balance equation covered wide range of variation of the annual and monthly discharges values for Derbendi-Khan dam, inflow discharge of Hemren reservoir and the rainfall intensity of the intermediate catchment's

area with correlation coefficient R equal to 0.956.

2. The water balance equation can be used to operate Hemren dam depending upon rainfall intensity and the discharge released from Derbendi-Khan dam.

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Table (1) The Monthly Rainfall Intensity (mm/hr) of The Intermediate Catchment Area

month / Year	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun	July	Aug.	Sep.
1980	2	20.1	17.1	24	32.5	24.7	9	5.4	0	0	0	0
1981	21.2	12.1	29.2	13	9.7	6.6	25.4	4.3	0	0	0	0
1982	9.3	26.8	14.2	17.5	12	9.5	14.9	4.5	0	0	0	0
1983	0	5.2	29.7	5.8	11.6	18.3	15.6	5.8	0	0	0	0
1984	7.5	23.3	4.5	26	9.5	11.7	18.1	0	0	0	0	0
1985	0	12.7	10.4	8.4	12.5	5.3	17.1	6	0	0	0	0
1986	3.8	10.6	5.7	14.1	13.8	14.5	3.8	0	0	0	0	0
1987	22.5	4.2	3.8	7.6	5	22.5	11	3.5	0	0	0	0
1988	0.6	4.8	15.8	3.3	15.5	13.5	0	0.9	0	0	0	0
1989	0.4	45.9	11.5	13.1	18	17.2	24.4	0.9	0	0	0	0
1990	7.3	25.4	4.3	0	40.7	41.8	6.2	0.3	7.9	0	0	0
1991	2.1	16.7	27.6	11	6.9	6	2.7	44.9	0	0	0	0
1992	2	10.6	18.5	15.8	21.2	17.7	33	14.3	0	0	0	0
1993	8.5	29.3	16.8	23.3	4.6	14.8	7.1	2.7	0	0	0	0
1994	18.2	44.3	17.4	2.5	2.7	22.1	26.3	4.4	0.1	0	0	0
1995	0	8.1	11.5	33.8	4.1	30.1	11.4	2.8	0	0	0	0
1996	0.7	0.3	13.7	20.1	5.4	31.7	12.2	2.1	0	0	0	0
1997	5.1	36.5	23.3	40.1	3.7	35.2	3.1	0	0	0	0	0
1998	0	11.4	0	31.3	14.8	0.2	2.1	0	0	0.3	0	0

Contiuue Table (1)

month / Year	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun	July	Aug.	Sep.
1999	4.2	0	6.6	13.3	0.8	9.8	1.3	0	0	0	0	0
2000	0.6	18.1	51.9	11.2	14.4	19.1	2.3	0.5	0	0	0	0
2001	0.5	4.7	20	35.3	14.1	18.2	20.9	0	0	0	0	0
2002	2.6	13.1	22.7	0	0	8.3	8.7	0	0	0	0	0
2003	0	19.9	26.6	29.9	7.1	1.2	3.1	7.1	0	0	0	0

Table (2) The Monthly Discharges Released from Derbendi-Khan Dam (m^3/sec)

month / Year	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun	July	Aug.	Sep.
1980	150	145	150	147	154	342	420	260	129	113	200	200
1981	116	105	109	102	118	212	346	206	99	99	132	114
1982	130	124	105	158	259	328	285	254	136	134	157	190
1983	172	101	100	90	90	85	85	85	94	107	120	80
1984	94	104	238	260	472	482	400	202	150	153	176	112
1985	170	155	126	143	87	105	170	191	129	120	120	112
1986	153	168	102	150	107	289	367	195	103	119	148	199
1987	180	177	150	281	312	1139	727	436	82	164	127	116
1988	110	110	110	110	110	277	243	114	110	110	110	128
1989	150	149	118	119	81	187	161	137	105	129	164	169
1990	142	102	100	90	79	163	157	122	150	147	143	239
1991	160	120	123	182	211	263	778	493	234	215	171	172
1992	137	118	119	106	105	90	124	231	115	97	87	94
1993	95	88	202	362	261	421	301	264	135	141	122	110
1994	127	155	249	273	357	155	440	281	184	145	132	149
1995	170	120	183	122	130	135	141	167	159	170	162	151
1996	135	107	105	117	106	40	74	101	134	154	144	94
1997	60	57	100	140	215	535	660	240	170	155	140	138
1998	132	120	130	35	37	44	38	44	47	46	47	42
1999	42	45	30	33	35	37	48	47	57	94	75	48
2000	35	14	44	28	30	27	24	27	48	66	71	50
2001	37	35	32	28	34	34	163	135	81	88	96	99
2002	108	93	126	127	158	156	173	130	114	135	142	163
2003	160	115	140	118	135	132	96	105	146	160	170	100

Table (3) The Monthly Inflow Discharges for Hemren Reservoir (m^3/sec)

month / Year	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun	July	Aug.	Sep.
1980	129	172	114	240	192	491	475	301	98	90	117	132
1981	89	110	135	188	208	244	493	277	100	86	91	132
1982	118	189	127	193	281	321	344	256	104	102	105	121
1983	132	88	103	90	91	112	102	75	65	63	67	55
1984	68	241	267	327	587	527	456	205	113	134	177	100
1985	134	162	148	150	191	116	151	206	107	73	63	65
1986	110	187	140	146	124	368	397	181	56	47	94	120
1987	152	193	322	369	550	1209	837	473	258	97	70	63
1988	10	80	152	118	109	306	220	69	46	52	54	71
1989	88	129	170	138	191	250	157	101	57	72	105	108
1990	107	90	78	111	151	230	148	90	89	64	61	143
1991	108	98	226	209	328	383	751	523	237	169	135	122
1992	116	115	186	184	190	119	171	233	96	54	53	58
1993	82	137	229	466	337	470	323	252	98	89	90	80
1994	118	295	305	345	441	218	468	318	157	100	101	113
1995	156	121	195	217	157	189	181	157	124	109	115	100
1996	102	108	125	161	133	135	117	95	108	97	100	73
1997	66	142	190	270	345	670	910	280	160	130	108	110
1998	113	126	130	120	95	49	23	23	12	5	5	6
1999	18	53	45	65	45	39	39	28	26	56	37	13
2000	20	24	142	77	74	59	23	0	0	15	26	12
2001	13	37	90	132	90	67	186	115	38	30	36	51
2002	83	108	226	185	215	222	204	124	82	80	83	112
2003	140	143	173	225	207	140	90	87	95	103	110	60

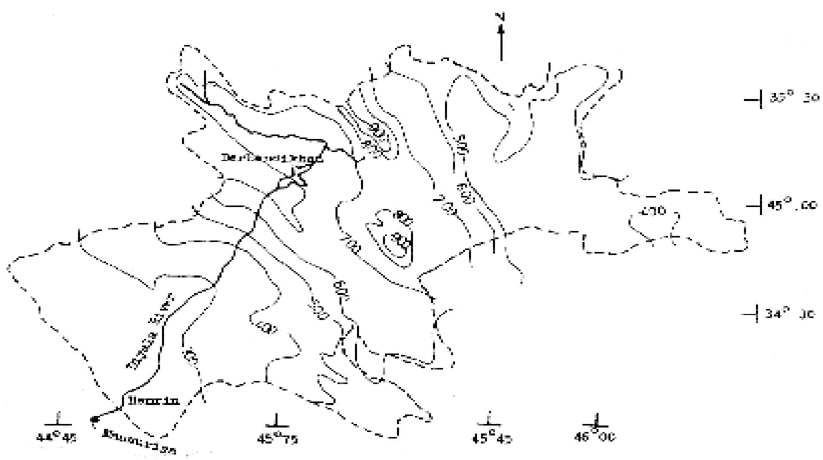

Figure (1) The Mean Annual Precipitation for Diyala Catchment Area

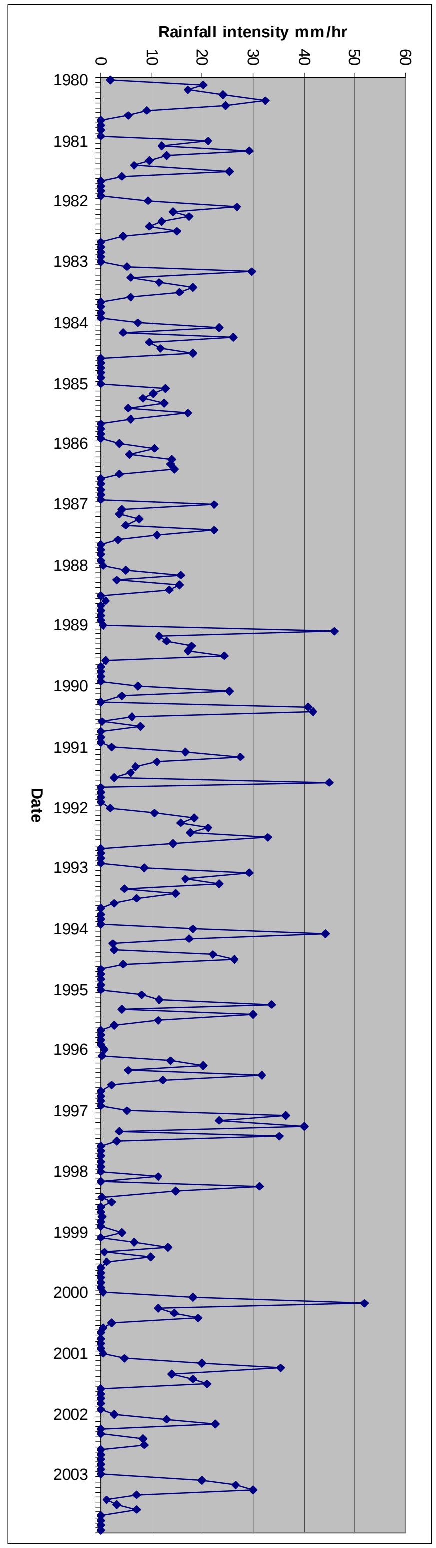

Fig. (2) The Time Series of Rainfall Intensity at The Intermediate Catchment Area (0ct.1980-Sep.2004)

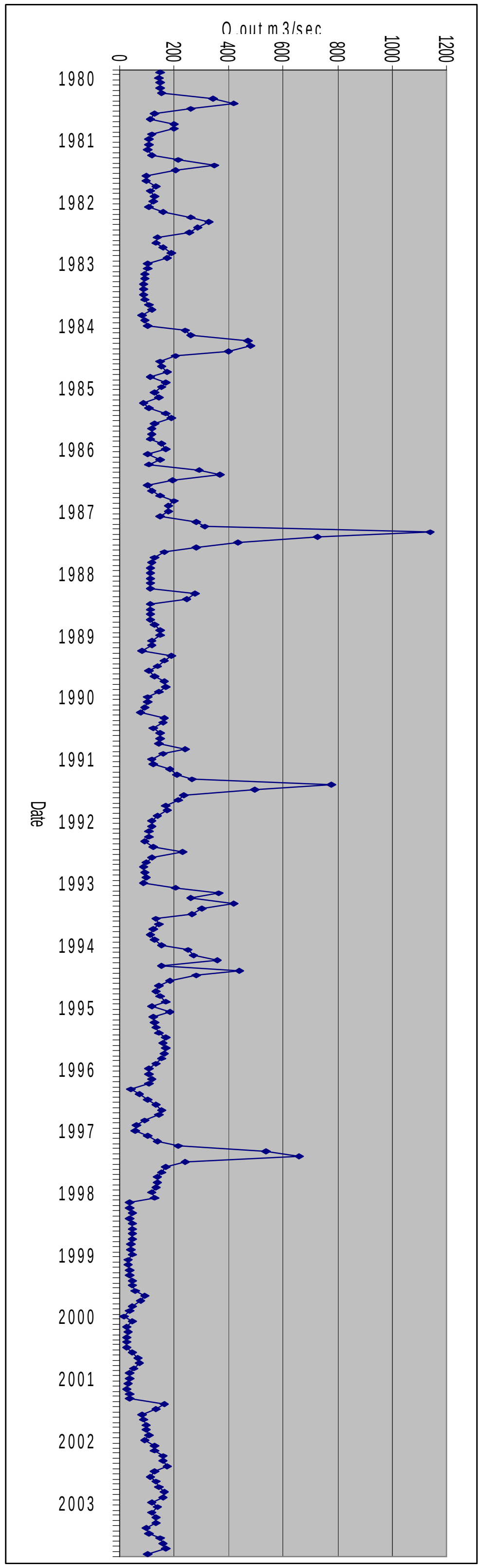

Fig. (3)The Time Series of The Released Discharge From Derbendi-Khan Dam (Oct.1980-Sep.2004)

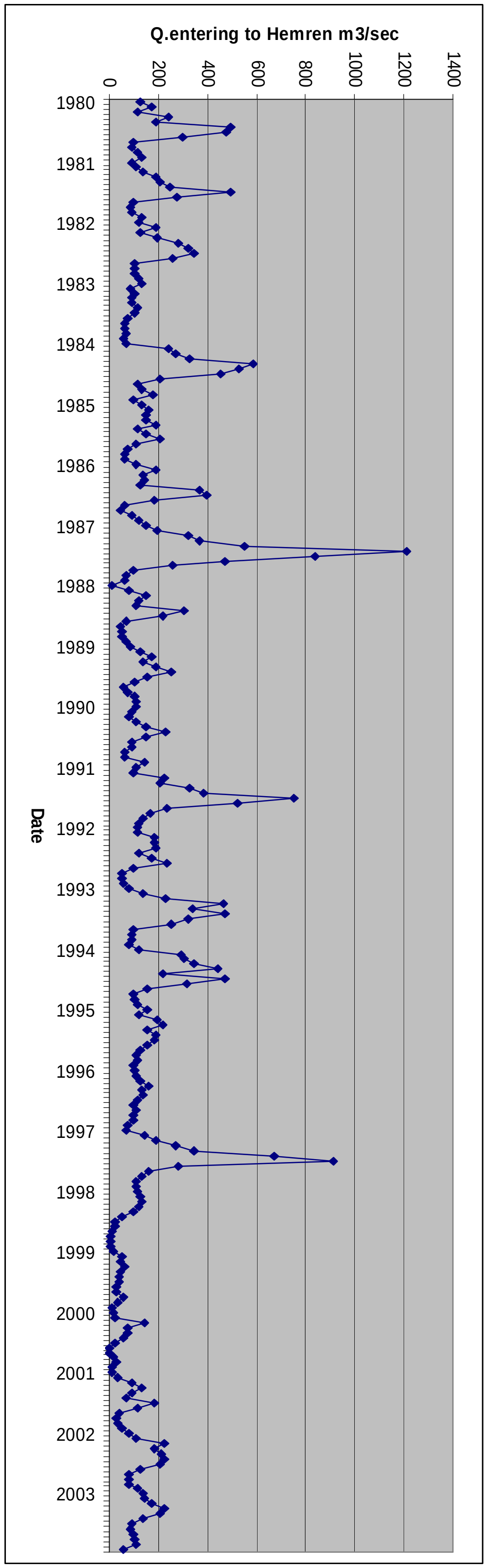

Fig.(4) The Time Series of The Inflow Discharges of Hemren Reservoir (Oct.1980-

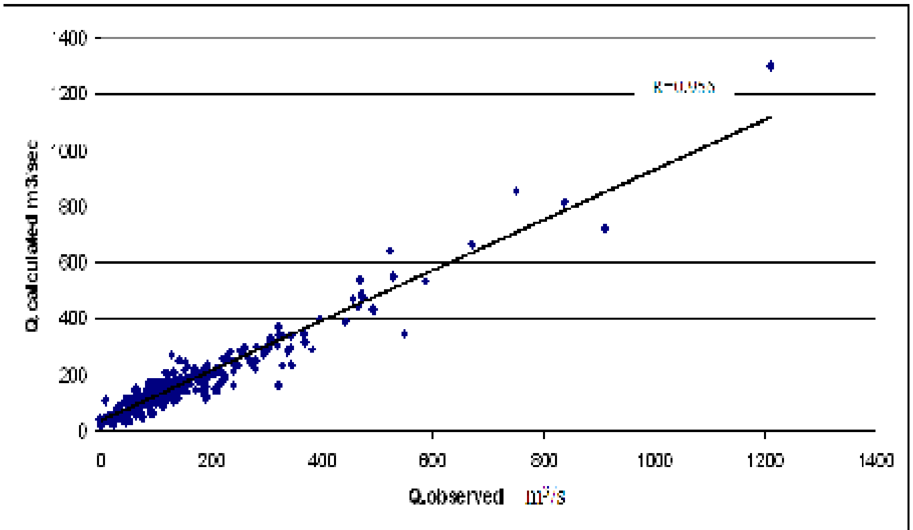

Figure (5) The relation between the calculated and observed discharge to Hemren dam