Hydrological Characteristics and Water Balance of Bosten lake, Xinjiang, China

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Abstract

The hydrological characteristics of the lake Bosten are studied based on the analysis of available data obtained from 1976 to 1989 at the hydrological stations around the lake. The results are as follows: (1) The annual average of volume transport of main inflow river, named Kaidu river, varies from 80 to 120m^3/s. The maximum and minimum values are found in 1980 and 1986, respectively. (2) The other inflow rivers and the outflow river show almost steady volume transports during this period. (3) The water level of the lake Bosten decreases and has the minimum value at 1987, then increases slightly. (4) The seasonal water balance of the lake is investigated from March 1983 to February 1984 in detail. The result shows that only evaporation, precipitation, discharges of the main rivers, and the change of water level can not explain the water balance.

1.Introduction

The lake Bosten is the biggest freshwater lake in the inland of China nowadays. It plays a very important role in the development of agriculture, industries, and fisheries as well as the aspect of natural environment. However, the water area recently becomes smaller and smaller, and the water becomes salty and salty especially during 1980' decade. To avoid the similar old disastrous story of the lake Lop, which was the former biggest lake in China and had dried up since 1930's, it is very necessary to clarify the hydrological characteristics and water balance mechanism of the lake Bosten as early as possible. In the present study, by using the available data of the hydrological stations around the lake, we investigate the hydrological characteristics of the lake and water balance in the main lake and its surroundings. In the Section 2, Geographical characteristics and land utilization around the lake are introduced; the Section 3 demonstrates the hydrological characteristics; we give the water balance model of the Bosten lake and the each water budgets in the Section 4 ; as an analyzing results, we describe the conclusion in the Section 5.

2. Geographical characteristics of Bosten region

The lake Bosten, located in the Yanji Basin as shown in Fig.1, had been the third biggest lake following the Lop and Aibi lakes in Xinjiang Uygur Autonomous Region in northern part of China. Nowadays, however, the lake Bosten becomes the biggest one as the other two lakes had dried up or diminished their water area. The Yanji Basin is surrounded by the Tianshan Ranges and the lowest place in the basin is the lake Bosten. Most of the inflows are from the northwestern and northern mountain areas. The river Kongque is the unique outflow originated from the southern lake. The area of the lake is about 930km^2 and the depth is 7.7m in average with the maximum depth of 16m in the southern part. In addition, the lake Bosten is surrounded by a number of small water areas, duckweed areas, cattail and reed marshes and irrigation lands. The main agricultural areas are located to the western and northern sides of the lake where the irrigation water is easily got from upper reaches of the inflow rivers.

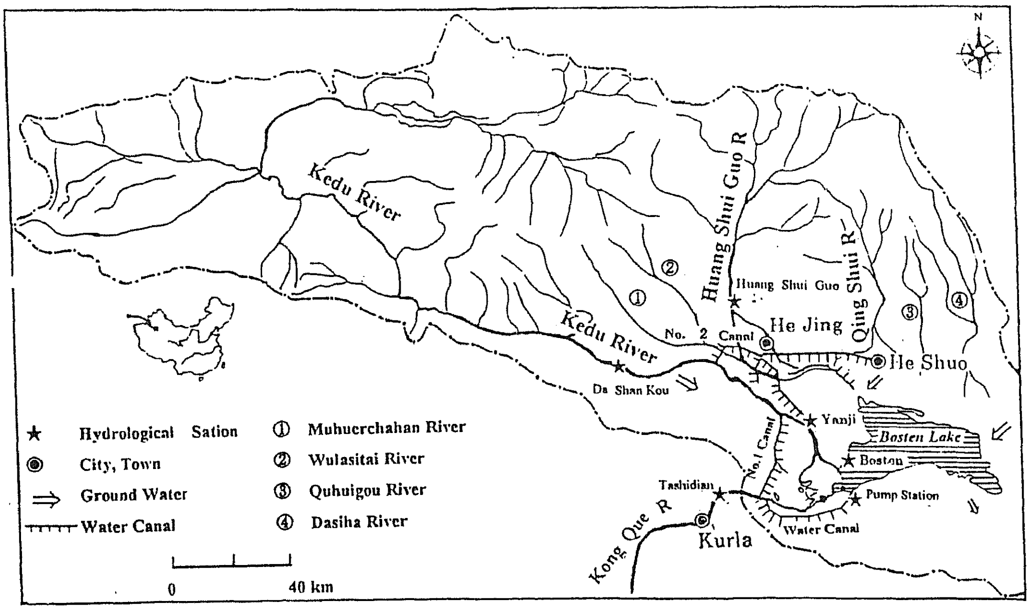

Figure 1. Locations of Bosten Lake and Hydrological Stations in Yanji Basin, Xinjiang, China

From the contour map of the lake, the area and capacity of the lake are estimated as a function of water level H referred to the altitude of 1040m. The results are as follows:

$$Sm_i = a_i \cdot H_i + b_i \quad (1)$$

$$V_i = c_i \cdot H_i + d_i \quad (2)$$

where Sm_i is the area of the main lake with the unit of square kilometer, Vi is the capacity with the unit of 10^8 m^3, and a_i, b_i, c_i, d_i are the coefficients in the formula (1) and (2). Their values are listed in Table 1.

Table 1. The Parameters for Calculating the areas (Sm_i) and the Capacity (V_i) from the Water Levels of Bosten Lake.

$H_i - 1040$ (m)	a_i	b_i	c_i	d_i
$3 \leq H_1 < 4$	75.0	520.0	8.0	11.0
$4 \leq H_2 < 5$	60.0	580.0	9.4	5.4
$5 \leq H_3 < 6$	50.0	630.0	9.6	4.4
$6 \leq H_4 < 7$	38.0	702.0	9.5	5.0
$7 \leq H_5 < 8$	24.0	800.0	8.7	10.6
$8 \leq H_6$	13.0	888.0	9.8	1.8

In the Bosten region, the land types are generally classified into four groups such as reed lands, irrigation lands, cattail lands and uncultured lands with alkalized characteristics. The area of first two groups are much larger the others. The area of reed lands around the lake and its surroundings is estimated by aerial photograph as 495.87 km^2 in 1981. The value is 62.53km^2 smaller than the value 558.40km^2 in 1959. This means the area of reed land decreases with the degression rate of

$2.84 km^2$/year during the past 22 years. In 1965, the reed resources were investigated by the local government at the southwestern side of the lake. The reed lands are classified into the four types by the criteria listed in Table 2. The areas of these for types are estimated respectively from the data taken in 1965 and 1981 and derive the following empirical relation of the area of reed lands:

$$SR_i = SR_i^* + (1981 - Y_k) \cdot \gamma_i \qquad (3)$$

where SR_i is the area of reed land of the i-th grade of reed type, Y_k is the year from 1965 up to now, SR_i^* is the area of reed land in 1981, and γ_i is the degrading rate per year. The estimated values of γ_i are listed in Table 3. Note that negative sign of γ_i in 4-th grade is due to an increase of the reed land area.

Table 2. The Criteria of Reed Land Types in Bosten Region

Grade	Height (m)	Diameter of Stem (cm)	Coverage (%)	Dried Biomass (kg/m^2)
1	>7.5	>1.2	>80	>1.5
2	2.5 ~3.5	0.8 ~1.2	60~ 80	0.8~ 1.5
3	1.5~ 2.5	0.5~ 0.8	40~ 60	0.4~ 0.8
4	<1.5	<0.5	5~ 40	<0.1

Table 3. The Grades of Reed Land with Areas(Km^2) and the Average Degrading Rate of Reed during 1965~1981.

Grade	SR* (1981)	SR' (1981)	SR' (1965)	Rate of Digression (γ) (km^2/year)
1	57.60	29.89	46.91	1.06
2	37.96	26.29	47.11	1.30
3	99.36	75.23	83.46	0.51
4	193.02	122.49	120.55	-0.12
Total	387.94	253.9	298.03	2.76

SR*: The areas of all reed lands in the Bosten region.

SR': The areas' changes of the reed lands in the sampling region in southwestern Bosten lake.

3. Hydrological Characteristics

The Fig. 2 shows the yearly variation of the Bosten Lake's water level from 1955 to 1993, and the annual variation between 1955-1993 is more than 3 meters. On the other hand, as the monthly data recorded after 1976, the seasonal changes of the water level fluctuate within 1 meter. Hydrological data are available at the several observation stations listed in Table 4, and the data up to 1989 are used in this study. In Fig. 3, the annual averaged values of river discharge are shown at the Dashankou, Huangshiugou and Qinshuihe for the Kaidu, Huanshugou and Qishui rivers, respectively. The Kaidu river is the biggest inflow in the Yanji basin with a wide catchment area and has the immense water discharge, which is about 80% of the total discharge. However, the annual variation of the discharge in Kaidu River is very large as shown in Fig. 4. The maximum discharge of $115 m^3$/sec was recorded in 1980 and is 1.47 times larger than the value $78.2 m^3$/sec in 1986. In contrast, the discharges of other rivers are rather stable. The Kongque River is the unique outflow that mostly flow out from the pump station at the northwestern Bosten Lake. The annual variation of the flows is very small as shown in Fig. 4.

Evaporation has been measured near the lake by using an evaporation pan whose diameter is 20cm. However, the measured values can't be used directly, because the evaporation is usually influenced by the local weather and the temperature of small pan. In 1983 to 1984, the evaporation experiment was carried out in the lake Bosten, where a larger evaporation pan with the diameter of 60.1cm was used. Moreover, meteorological factors are observed in detail. We used these data and

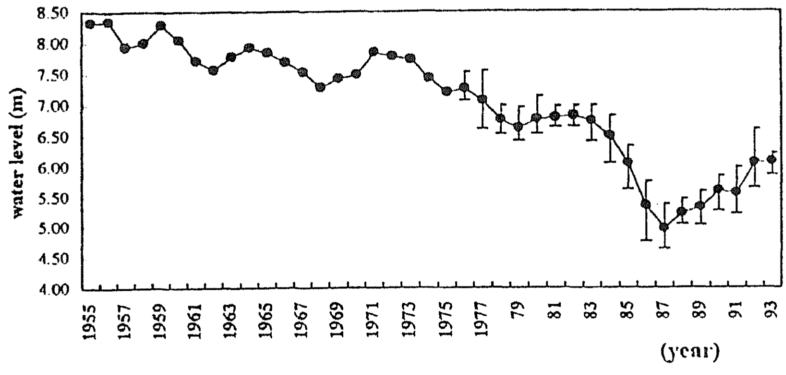

Figure 2. The Variation of the Bosten Lake's Water Levels from 1955 to 1993.

Table 4. The List of Hydrological Stations and the Observed Items

Station	Name of river	Catchment area (km^2)	Elevation (m)	Observation Period	Observation items[1)]
Dashankou	Kaidu	19,022	1338.9~ 1339.7	1955~present	H, Q, Sd ect.
Yanji	Kaidu	20,705	1056.2~ 1058.9	1947~present	H, Q, Sd etc.
Huangshui	Huangshuigou	5,000	1319.4~ 1323.3	1955~present	H, Q, Sd etc.
Kerguti	Qingshui	465	------	1956~present	H, Q, Sd etc.
Tashidian	Kongque	------	1048.2 ~1052.3	1948~present	H, Q, Sd etc
Bosten	------	------	1047.7 ~1049.1	1955~present	H, E*, P, Tw, Ta etc.

*: Evaporation with 20 cm evaporation pan

1) H: Water level Q: Discharge Sd: Suspension sandtransport E: evaporation P: precipitation Tw: Water temperature Ta: Air temperature

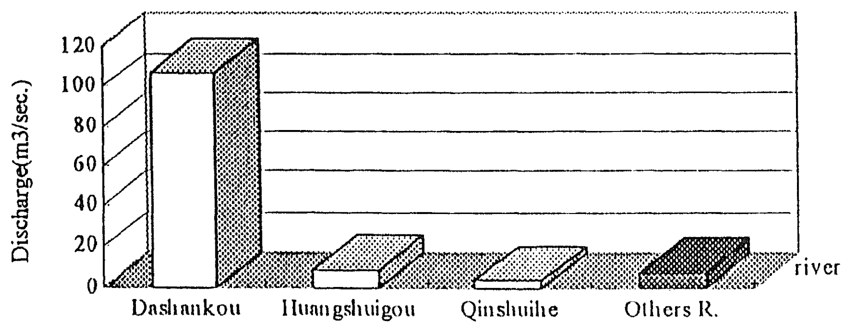

Figure 3. The Annual Discharges of the Inflows Rivers in Bosten Region.

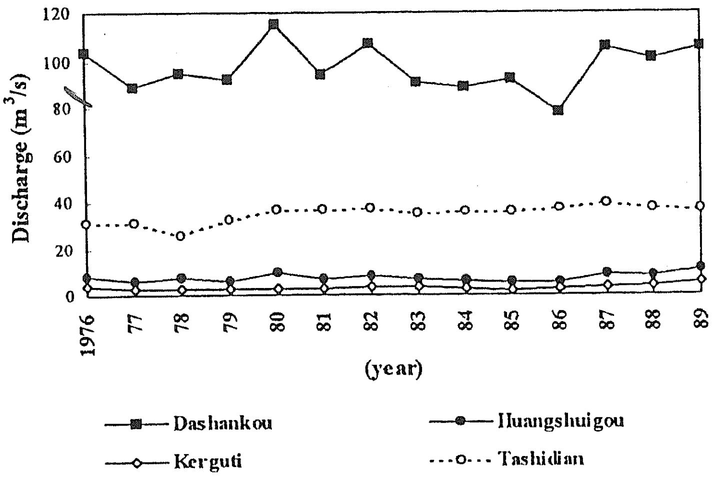

Figure 4. The Variations of Discharges of the Rivers in Bosten Lake. from 1976 to 1989.

calculated the evaporation from the water surface (E_w) by the bulk method. Comparing results of these three methods, we have the conversion constants $\lambda_w = E_w/E_{601}$ and $\lambda_{601} = E_{20}/E_{601}$, where E_{20} and E_{601} denote measured values by evaporation pans with diameters of 20cm and 60.1cm, respectively.

The annual precipitation in the Bosten region varies from 20mm in 1977 to 178.3mm in 1988 with the general ranges of 50-80mm.

4. Water balance of the lake from March 1983 to February 1984.

The water balance of the lake can be demonstrated as shown in Fig. 5. The equations of water balance is given by as follows:

$$QBI+QDI+P \cdot S_m+GI=QPO+Sm \cdot E_w+QH_m+GO+\delta \qquad (4).$$

The left-hand side of the equation (3) means inflows into the lake. QBI and QDI denote inflows of a river and irrigation drainage, respectively. P is the precipitation and Sm is area of the lake. GI is the unknown inflow of ground water. QPO in right hand side express the outflow from the lake. E_w is evaporation, QH_m is the increment of the lake water. GO is the unknown outflow of ground water. δ means the residual of water budget in the model. Annual values of these terms are listed in Table 5. By using monthly data, we calculate the monthly value of the term GI-GO- δ . As shown

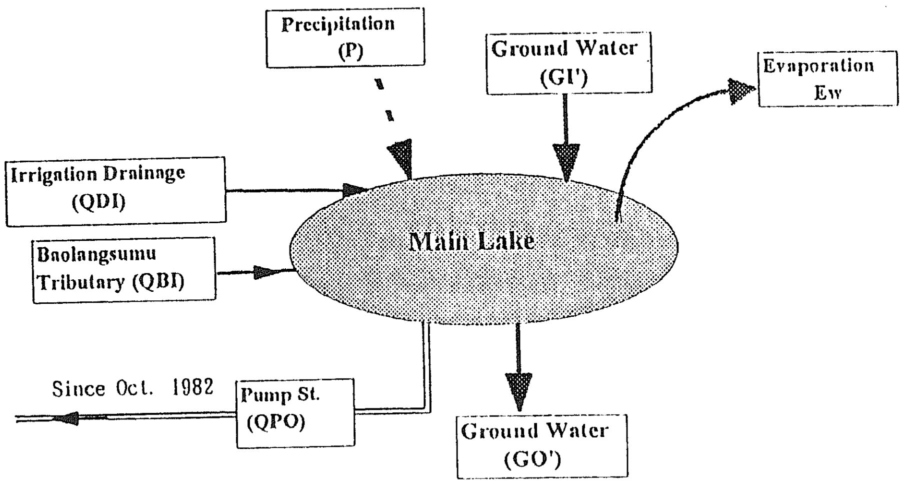

Figure 5. The Sketch Map of the Water Balance's Budget in Bosten Lake.

in Fig. 6, the term GI-GO- δ is not negligible and has positive value in winter season and negative value in summer season.

Table 5. The Annual Values of Water Budgets from March 1983 to February 1984.

10^8 m^3	inflows/outflows		Precipitation &. Evaporation	ground water	Water Level	Sum
input	9.64 (QBI)	2.00 (QDI)	0.72 ($P \cdot S_m$)	GI'		Σ QI'
output	5.94 (QPO)			037* (GO')		6.31 (Σ QO')
consume			9.31 ($S_m \cdot E_w$)			9.31 (Σ QC')
capacity increment					2.56 (QH_m)	2.56 (Σ QH')

*: 0.37 is quoted from the investigation carried out in 1983 **)

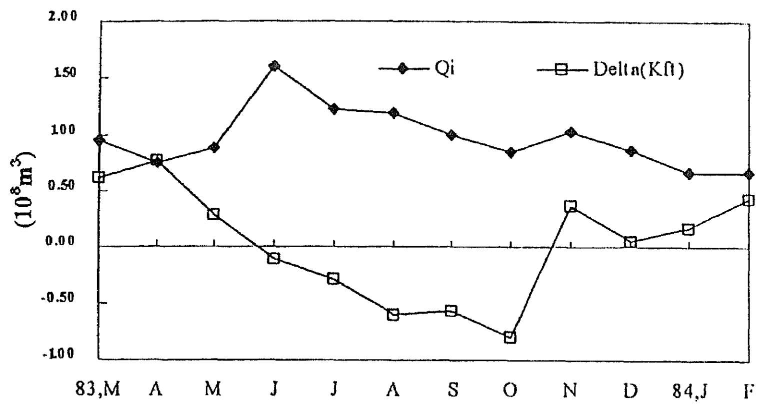

Figure 6. The Monthly Inflows(Q_I) at Bosten Lake's Inlets, and the Residual(GI-GO- δ) of Water Budget of the Model.

5. Conclusion

We analyzed available data of the lake Bosten from 1976 to 1989 at the hydrological stations around the lake. The results are as follows: (1) The annual average discharge of the main inflow river, called Kaidu river, varies from 78.0 to 115.4 m^3/s; and the maximum and minimum values occurred in 1980 and 1986, respectively. (2) The other inflow rivers and the outflow river show almost steady volume transports during this period. (3) The water level of the lake Bosten decreases and has the minimum value of 1044.73 meter at 1987, then increases slightly. (4) The seasonal water balance of the lake is investigated from March 1983 to February 1984 in detail. The result shows that the water balance can not be explained only by the evaporation, the precipitation and the water levels of the lake, as well as the discharges of the main rivers. It is known that the irrigation system play an impotent role in the water blalance model of the lake Bosten, thus, we should develop the model for a wide catchment area in future.

6. References

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