Figure 3, were obtained by collecting the meshes in which their flow directions reach to same site together. In the database, one land utilization type was allotted in each mesh.

Population density of each mesh was not available from an original source, which had populations in their administrative divisions; 31 towns and 49 districts. Then, a multiple linear regression analysis was applied to 49 districts, using population density as the target variable, and land utilization percentages of land use types as explanatory variables. The population of each mesh was estimated with this multiple linear regression equation. **Table 2** summarizes the region properties of the 39 catchments, which were constructed from the database by integrating or averaging the values in the meshes that each catchment contains. The information includes altitude, land utilization and population density of each site.

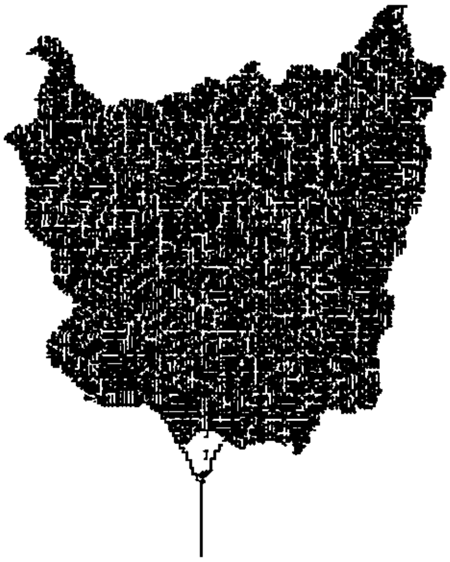

Fig. 2 Flow direction

Water quality and quantity surveys

A simultaneous water survey was conducted at 39 sites in one day from 6 am to 1 pm. The survey was repeated three times on 24 November 2000, 24 October 2001 and 2 December 2002. To avoid the influences of storm events, the survey dates were selected when the basin had not received any rainfall during the sampling and their preceding 48 hours. At each site, a flow rate was measured and a water sample was collected to analyze more than 20 water quality items related with organic matter, nutrients, ionic and elements. Environmental conditions such as DO, pH and temperature were measured at the site. Average of three times observations in each sampling site is summarized in Table 2. In addition, a continuous observation survey was conducted at sites, No. 37 and 38, every 2 days during 23 September to 12 December 2002 to observe variation of water quality. The items measured in the continuous survey were the same as those in the simultaneous water survey.

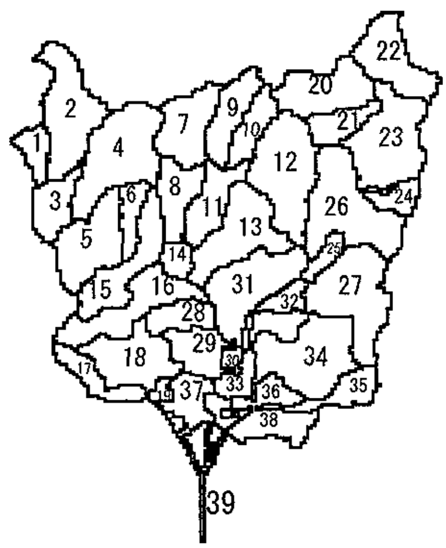

Fig. 3 Catchment area

Water data analysis

Analysis of variance (ANOVA) is technique to statistically evaluate the influences of each factor on variation, and can give these effects by contribution percentages on the whole variation. In this research, two-way ANOVA was used to examine the effects of date and site, simultaneously and quantitatively. The data used for this analysis are three sets of thirty-nine observations for each water quality item and the equation of "$y_{ij} = x_0 + A_i + B_j + e_{ij}$" is used as the model. In this equation, x_0 is average level of y_{ij}, A_i and B_j are main effects concerning i^{th} date and j^{th} site, and e_{ij}: residual part of variation that these parameter value cannot explain. Table 3 presents the ANOVA

Table 2 Summary of catchment properties and water quality

Sampling point	Distance from No. 39 (km)	Average altitude (m)	Land utilization area (km^2)			Population*			Water items** (mg/L)																										
			Mountains and forests	Paddy field	Residential	Without	Separate	Combined	Water temparature (°C)	Flow (m^3/s)	pH (-)	DO	COD_{Mn}	$D\text{-}COD_{Mn}$	TOC	DOC	IC	SS	VSS	TN	DN	TP	DP	Cl^-	NO_2^-	NO_3^-	NH_4^+	SO_4^{2-}	SiO_2^-	Na	Mg	K	Ca
1	23.6	343	1.54	0.00	0.00	0	0	0	10	0.03	7.1	10.9	0.6	0.5	0.6	0.3	5.0	0.5	0.5	0.448	0.263	0.021	0.017	3.3	0.00	0.21	0.00	1.6	7.0	4.1	1.2	0.9	5.9
2	23.6	327	6.21	0.00	0.00	0	0	0	9	0.16	8.0	11.8	0.9	0.4	0.6	0.4	5.1	1.6	0.7	0.214	0.243	0.015	0.014	3.0	0.00	0.17	0.00	1.4	7.5	3.8	1.2	0.7	5.3
3	19.8	275	2.44	0.03	0.14	185	0	0	10	0.19	8.0	11.2	0.6	0.4	0.5	0.4	5.2	0.5	0.5	0.244	0.269	0.016	0.017	3.1	0.00	0.19	0.01	1.6	7.2	4.3	1.2	0.6	5.7
4	19.8	269	7.32	0.00	0.03	52	0	0	10	0.16	8.2	11.3	0.6	0.3	0.5	0.5	7.4	0.5	0.5	0.427	0.376	0.018	0.019	3.0	0.00	0.32	0.03	1.6	6.8	3.8	1.6	0.8	7.6
5	13.5	177	5.18	0.01	0.05	89	0	0	10	0.46	7.8	11.2	0.6	0.5	0.5	0.5	6.3	0.5	0.4	0.355	0.340	0.015	0.019	3.4	0.00	0.26	0.00	2.1	7.2	4.6	1.5	0.8	8.4
6	13.5	189	1.75	0.00	0.00	0	0	0	10	0.03	7.8	10.9	0.3	0.2	0.4	0.4	7.6	0.3	0.4	0.463	0.397	0.020	0.018	3.0	0.00	0.37	0.00	2.8	8.5	4.8	1.8	0.6	10.2
7	17	348	4.24	0.00	0.00	0	0	0	10	0.11	8.2	10.5	0.5	0.2	0.5	0.3	8.2	0.9	0.5	0.406	0.433	0.020	0.021	3.0	0.00	0.28	0.01	1.2	6.5	3.1	1.7	0.5	9.7
8	14.3	213	2.96	0.00	0.05	106	0	0	11	0.23	7.8	10.5	0.7	0.5	0.6	0.5	11.1	0.8	0.6	0.466	0.488	0.035	0.026	3.3	0.00	0.40	0.00	1.7	7.1	5.3	2.2	0.8	10.3
9	17.6	322	3.23	0.00	0.00	0	0	0	10	0.09	7.5	10.7	0.4	0.3	0.4	0.3	3.1	0.8	0.6	0.306	0.333	0.023	0.023	3.5	0.00	0.26	0.01	1.2	5.6	3.1	1.2	0.7	3.3
10	17.8	330	2.31	0.00	0.00	0	0	0	11	0.07	7.4	10.8	0.5	0.4	0.4	0.3	2.8	2.0	0.8	0.266	0.273	0.023	0.024	3.0	0.00	0.23	0.00	1.3	5.7	2.9	1.1	0.6	2.8
11	14.3	213	3.10	0.01	0.17	565	0	0	11	0.25	7.7	10.6	0.7	0.5	0.3	0.3	6.2	0.8	0.5	0.448	0.506	0.035	0.039	3.9	0.01	0.41	0.01	1.8	5.3	4.1	2.3	0.6	10.5
12	16.8	218	6.94	0.06	0.03	155	0	0	11	0.14	7.3	9.5	0.4	0.3	0.7	0.4	4.2	0.8	0.6	0.429	0.431	0.023	0.025	3.3	0.00	0.36	0.00	2.0	6.8	3.7	1.3	0.9	4.9
13	12.4	160	5.11	0.52	0.23	688	0	0	10	0.04	7.6	9.7	0.6	0.4	0.7	0.6	8.9	0.9	0.5	0.712	0.748	0.024	0.025	5.3	0.00	0.61	0.00	11.3	6.4	5.0	2.6	1.2	15.0
14	12.4	157	1.08	0.00	0.12	226	0	0	10	0.06	7.8	10.2	0.6	0.4	0.7	0.5	8.1	0.8	0.5	0.528	0.555	0.041	0.040	3.9	0.01	0.47	0.02	2.0	6.4	4.1	1.9	0.9	10.0
15	9.7	121	4.67	0.02	0.03	201	0	0	11	0.15	7.7	11.5	0.5	0.4	0.5	0.5	7.6	0.3	0.4	0.434	0.508	0.019	0.023	3.4	0.00	0.32	0.00	3.0	7.2	5.1	1.5	0.8	9.9
16	8	109	4.38	0.21	0.62	331	3057	0	11	0.94	8.5	11.4	0.5	0.4	0.5	0.4	7.3	0.6	0.4	0.453	0.495	0.025	0.026	3.6	0.00	0.36	0.00	2.6	6.5	4.6	1.7	0.9	10.0
17	5.7	85.5	1.35	0.00	0.80	89	5768	1192	13	0.03	7.8	10.1	2.0	1.6	1.3	1.1	7.6	4.3	1.2	0.840	0.796	0.051	0.035	7.1	0.01	0.67	0.01	3.2	5.6	13.6	1.9	1.8	10.6
18	5.9	85.5	2.78	0.58	1.49	505	13057	0	13	1.09	8.0	10.9	0.8	0.6	0.6	0.5	7.8	1.0	0.5	0.541	0.539	0.029	0.030	4.0	0.00	0.45	0.01	2.9	6.6	5.0	1.8	1.0	10.6
19	4	68.5	0.08	0.00	0.67	75	3703	951	14	1.06	8.6	11.3	1.1	1.0	0.7	0.7	8.0	1.8	0.7	0.535	0.484	0.031	0.032	6.9	0.01	0.39	0.01	2.8	6.0	10.9	2.0	1.4	9.9
20	21.5	308	4.69	0.00	0.00	0	0	0	9	0.15	7.1	10.2	0.4	0.3	0.4	0.4	2.2	1.0	0.4	0.259	0.250	0.016	0.014	3.1	0.00	0.21	0.01	1.6	4.2	2.5	1.1	0.5	2.8
21	21.5	316	2.16	0.00	0.00	0	0	0	9	0.07	7.1	9.9	0.6	0.4	0.5	0.4	1.8	0.3	0.4	0.218	0.214	0.005	0.005	2.8	0.00	0.13	0.00	1.6	3.7	2.2	1.1	0.5	2.0
22	21.2	298	4.50	0.01	0.00	2	0	0	10	0.11	7.3	9.7	0.4	0.4	0.4	0.4	3.4	0.7	0.4	0.370	0.334	0.010	0.011	2.7	0.00	0.31	0.01	1.8	5.9	3.5	1.5	0.4	3.6
23	16.6	240	5.75	0.28	0.70	330	0	0	10	0.57	7.2	10.5	0.5	0.5	0.5	0.4	3.6	0.6	0.5	0.596	0.445	0.029	0.014	3.2	0.00	0.38	0.01	2.1	5.3	3.3	1.3	0.6	4.9
24	16.6	232	1.20	0.05	0.12	258	0	0	10	0.05	7.1	9.6	2.5	1.9	1.6	1.5	6.4	4.0	2.3	1.826	1.184	0.124	0.058	6.8	0.02	1.42	0.12	2.1	8.4	8.2	1.1	1.3	7.0
25	14.1	233	0.96	0.06	0.05	178	0	0	13	0.04	6.7	6.9	1.3	0.9	0.9	0.8	6.0	2.5	0.9	2.853	2.566	0.121	0.073	6.7	0.05	2.61	0.03	3.1	6.6	8.0	2.3	1.9	10.9
26	14.1	201	6.39	0.94	0.58	1618	0	0	10	0.70	7.1	9.8	0.7	0.5	0.7	0.5	4.3	1.0	0.7	0.938	0.813	0.028	0.025	4.0	0.01	0.85	0.01	2.2	5.9	4.5	1.4	0.9	6.3
27	10.7	153	6.68	0.16	0.17	236	510	0	10	0.97	7.3	9.7	0.7	0.5	0.8	0.6	4.8	1.4	0.8	1.074	0.969	0.033	0.031	6.8	0.00	0.98	0.01	2.4	6.4	7.9	1.6	0.9	7.5
28	10	119	1.81	0.13	0.26	150	1703	0	11	0.03	7.6	10.0	1.9	1.6	1.4	1.3	13.9	2.5	0.9	1.172	0.699	0.068	0.043	5.1	0.04	0.61	0.09	4.0	10.3	9.1	1.9	2.3	19.4
29	7.1	103	1.67	0.31	0.87	812	4930	0	13	0.13	7.8	10.8	2.1	1.8	1.3	1.5	14.3	1.9	0.7	1.303	1.231	0.062	0.037	8.0	0.02	1.02	0.03	4.7	7.9	9.4	2.9	2.6	17.6
30	7.1	94.5	0.00	0.19	0.31	0	2187	0	11	0.07	7.6	11.7	1.1	1.0	0.9	0.8	10.9	0.9	0.6	1.140	0.979	0.064	0.062	6.0	0.01	0.97	0.01	3.1	7.1	7.3	3.3	1.9	14.8
31	8.1	106	5.08	0.33	0.70	265	5175	0	13	0.05	7.5	9.1	1.0	0.9	1.0	0.8	9.0	1.1	0.6	1.193	1.100	0.081	0.057	6.6	0.01	0.92	0.04	2.4	7.0	6.8	2.7	1.7	10.9
32	8.1	106	1.16	0.03	0.32	0	2136	0	13	0.01	7.5	9.1	1.6	1.2	1.3	1.3	14.7	1.6	1.0	1.358	1.352	0.053	0.053	5.8	0.03	1.17	0.03	4.1	6.9	8.1	3.9	1.9	17.7
33	6.2	93	1.77	0.14	1.00	72	6731	0	13	0.17	8.1	11.4	1.6	1.0	1.1	0.9	12.6	1.4	0.7	1.098	1.025	0.060	0.049	6.9	0.01	0.80	0.01	4.0	7.1	7.9	2.6	2.1	14.3
34	6.2	89.8	5.42	0.14	1.45	672	7876	0	13	1.02	7.9	10.4	0.7	0.6	0.8	0.6	6.1	0.8	0.5	0.965	0.927	0.031	0.029	7.1	0.01	0.93	0.01	2.8	6.3	7.6	1.9	1.0	9.0
35	5.3	83.3	2.12	0.02	0.17	303	1224	0	11	0.14	8.2	10.3	1.1	0.8	0.7	0.7	7.4	1.8	0.9	1.113	1.064	0.038	0.037	6.1	0.01	0.97	0.00	2.6	6.7	7.7	1.7	1.2	9.5
36	3.9	68	1.65	0.23	2.43	452	19951	110	14	1.11	8.6	11.1	1.4	1.2	0.8	1.0	8.1	3.9	0.8	0.817	0.960	0.032	0.034	7.0	0.01	0.70	0.00	3.1	6.7	7.4	1.9	1.6	11.0
37	2.4	54.5	0.57	0.11	1.71	0	12441	1350	15	1.48	7.4	10.7	1.1	1.0	0.8	0.8	8.2	2.8	0.7	0.831	0.884	0.031	0.036	6.8	0.01	0.68	0.01	3.4	6.1	8.0	2.1	1.7	11.6
38	2.4	54.3	0.21	0.02	1.04	0	4961	2442	15	1.30	7.4	10.6	0.8	0.7	0.7	0.7	8.3	1.2	0.6	1.436	1.430	0.039	0.042	8.7	0.01	1.34	0.01	3.9	5.8	9.0	2.5	1.7	12.0
39	0	39	0.00	0.00	0.01	0	0	0	11	2.91	7.4	9.3	1.0	0.8	0.7	0.6	8.0	1.4	0.5	1.321	1.120	0.023	0.030	6.9	0.01	1.15	0.01	3.3	5.6	8.5	2.1	1.6	12.0

*Population classified by sewerage system (capita)

**Water items are average of three years data

Table 3 Equations of *SOS, df, MS, SOS"* and contribution ratio

Source	SOS	df	MS	SOS"	Contribution (%)
Date	$b\sum_{i=1}^{a}\left(x_{i.}-x\right)^2$	a-1	SOS_a/df_a	SOS_a-$df_a(MS_e)$	$100(SOS_a")/SOS_t$
Sampling point	$a\sum_{j=1}^{b}\left(x_{.j}-x\right)^2$	b-1	SOS_b/df_b	SOS_b-$df_b(MS_e)$	$100(SOS_b")/SOS_t$
Residues	$\sum_{i=1}^{a}\sum_{j=1}^{b}\left(x_{ij}-x_{i.}-x_{.j}-x\right)^2$	$(a$-1$)(b$-1$)$	SOS_e/df_e	SOS_e-$df_e(MS_e)$	$100(SOS_e")/SOS_t$
Total	$SOS_a+SOS_b+SOS_e$	$(n$-1$)$	SOS_t/df_t	SOS_t	100

a, b, e, t as subscriptions are representatives of date, sampling point, error and Total, respectively.

table, which explains how to calculate sum of square *(SOS)*, degree of freedom *(df)*, mean square error (*MS*), adjusted sum of square (*SOS"*) and contribution ratio.

Loading analysis

The results of the ANOVA analysis showed water quality items that had high contribution percentages on sites. These items were chosen for investigation of land utilization effects to pollutant loading. Forest area was first investigated to find out relationship to pollutant loading because it occupied 80% of total area. Eight catchments (sampling Nos. 1, 2, 6, 7, 9, 10, 20 and 21), which only consist of forest area located in upstream, were used to extract the effect of forest because of no effect from other land utilization types nor human activities (no resident). The linear relationship between the area and loading was investigated with coefficient of determination (R^2).

The effects of paddy field (including other agricultural areas) and residential area were examined with the remaining loading, which was obtained with subtraction of forest loading from the whole loading. The forest loading was calculated with the product of forest area (km^2) and the forest unit loading ($kg/km^2/d$) that was estimated with the above analysis. The equation of "$L = a_1x_1 + a_2x_2$" was applied to the remaining loading to evaluate the effects of paddy field and residential areas by a multiple linear regression. In the equation, L is the pollution loading (kg/d) excluding forest loading. x_1 is paddy field and x_2 is residential area. a_1 and a_2 are coefficient values.

Relationship between population density and pollution loading excluding loading from forest area was also investigated at both areas of without sewerage and separated sewerage. The area of combined sewerage system was not contributed in this calculation because this area was not contaminated from domestic wastewater in fine weather day.

RESULTS AND DISCUSSION

River water characteristics

At first, the river states at the simultaneous survey dates were evaluated with the comparison of two kinds of time-series investigations. One was our project from 23 September to 12 December 2002 with two days interval, while the other was regular observation conducted by Kyoto local government during 1994 to 1999. Figure 4 shows flow rates at No. 37 and 38, which are located just upstream from the juncture of two main streams (Kamo River and Takano River) in the basin. As seen in Figure 4a), flow rates at both sites were highly fluctuated from 0.4 to 6m^3/s, but had similar variation patterns. Precipitation in the basin caused the peaks in flow rates more than 2 m^3/s only in rainy days or their next days. The flow rates of the simultaneous survey were 1.48 and 1.30

m^3/s, respectively for No. 37 and 38. Therefore, it might be concluded that the dates of the simultaneous surveys could represent fine weather days that have no direct influence of storm events. Since catchment area is $66.8km^2$ for No. 37 and 75.7 km^2 for No. 38, the specific flow rate was estimated to be 700 mm/y for No.37, and 540 mm/y for No.37. These values correspond to one third of the annual precipitation (about 1700 mm/y) in this region.

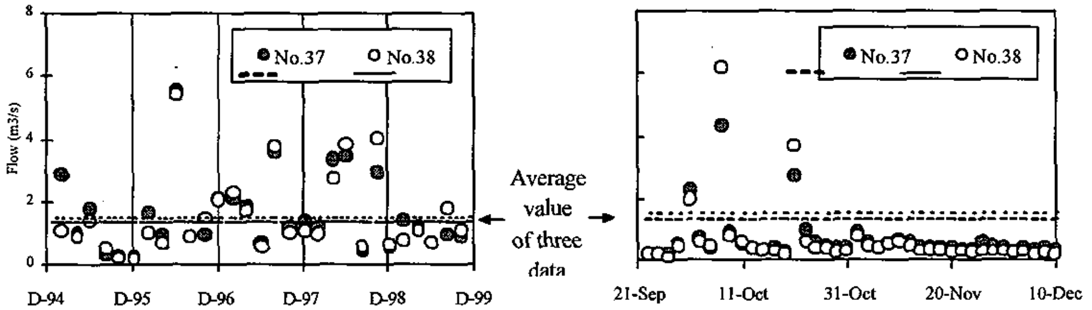

Fig. 4 Flow rate at No. 37 and 38 a) during 1994 to 1999
b) during 29 September to 12 November 2002

The flow rate was highly fluctuated daily, but some of water quality indices have relatively small variations. For example, *CV* value (coefficient of variation = standard deviation / average) at No. 37 in 2002 investigation was 1.22 for flow rate, but was 0.335, 0.332 and 0.583, respectively, for TN, DOC and COD_{Mn}, although some indices such as SS and TP had relatively high *CV* values. Table 4 shows concentration differences between the simultaneous survey and continuous observation with their ratios. Flow rate had ratios more than 2, but most of water quality indices had ratios ranging of 0.9 to 1.1. These results mean the simultaneous survey results can represent average concentration of the basin.

Table 4 Comparison of two investigations

Point	No.37	No.38
Flow rate	2.38	2.16
pH	1.00	1.01
DO	1.04	1.07
COD_{Mn}	0.69	0.59
D-COD_{Mn}	0.87	0.72
DOC	0.96	0.82
IC	0.85	1.01
SS	0.71	0.43
VSS	0.76	0.80
TN	0.94	1.09
DN	1.14	1.32
TP	1.05	1.03
DP	1.97	1.40
Cl^-	0.72	0.81
Si	0.96	0.72
Na	0.97	0.97
Mg	0.89	1.00
Ca	0.88	0.95

$$\text{Value} = \frac{\text{Simultaneous Survey}}{\text{Continuous Observation in 2002}}$$

Horizontal distribution of river water quality and quantity can be seen in Table 2. Observed flow rate was 0.1 m^3/s at the upstream sites, but it increased with the juncture of tributaries, resulting in 2.9 m^3/s at No.39. The water quality was quite good at the upstream, and had almost the same level as rain water. For example, DN and DP concentrations in rain were reported to be 0.53 and 0.007 mg/L, respectively, and those at upstream forest (No. 1, 2, 6, 7, 9, 10, 20 and 21) were ranging 0.21-0.43, and 0.005-0.026 mg/L, respectively. However, ionic species such as Cl, Ca and Na had higher concentrations (2.8-3.3, 2.0-10.2, 2.2-4.8 mg/L) than those in rain water (0.9, 0.1, 0.28mg/L, respectively) due to contamination of corrosive soil. These concentrations basically increased with the journey to downstream. The concentration at No.39, the exit site of the basin were 6.9 mg/L, 12.0, and 8.5 mg/L for Cl^-, Ca and Na, respectively, showing 2-4 times increase from upstream forest discharge. The river quality became worse in passage in the basin, but the quality did not reach to the level of the effluents of sewerage treatment plants. The concentration ratio of water quality at No.39 to that of secondary treated effluent were roughly calculated to be one tenth by using the effluent quality of 7.5-12, 8.5-17 and 0.6-1.6 mg/L for COD_{Mn}, TN and TP, respectively. The percentage of sewerage in the river water at site No. 39 were estimated to 0.5-5 % (assumption; residents: 8616 (no sewer service) - 110,070 (total), daily water discharge: 0.25 m^3/ca/d, precipitation: 1700 mm/y), so that this river water may receive pollutants from others such as non-point sources as well as human activities.

ANOVA analysis

Figure 5 shows contribution percentages of dates, sites and residuals in the two-way ANOVA. The figure depicted differences of variation patterns among water indices. The results showed that SS, pH and DO scarcely received effect from site variation while most of organic matter, nutrient and some ionic items such as Mg, Ca and K had strong effects of site, exceeding 50%. Variation of date had major effect of date on water temperature, sulfate, SiO_2. These results suggested that many of water quality concentrations depend on sites in this basin.

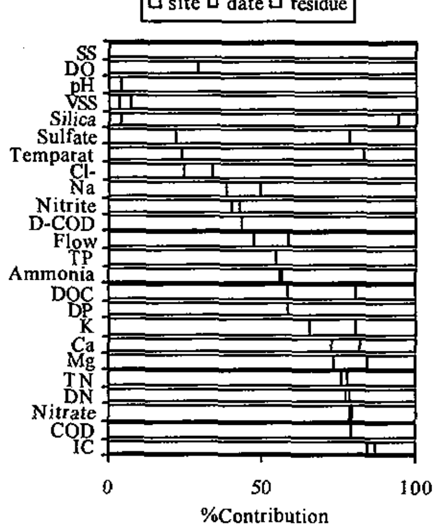

Fig. 5 Relationship between water items and ANOVA Contributions

Influence of land utilization to water quality loading

Table 5 summarizes relationship between forest area and loading of each water quality. The regression analysis was conducted with two linear equations with and without intercept. The reliability of regression analysis was shown as determination coefficient, R^2, which has the same meaning of contribution in ANOVA. Unit loading rate was give with the slope in the regression equation without intercept. As shown in the table, IC and Ca had small R^2 values, so that their loading rates were not much reliable. However, the others had values of more than 0.6, and their unit loading rates may be useful for estimation of forest loading. The higher values are seen in Na, Mg, CI, and SiO_2. Figure 6 is example of linear relationship of DOC loading and unit loading factor can be obtained from slope of relation.

Table 5 Linear relationship between forest area and loading

Water Items	Unit * loading	R^2 $1	$2
Na	7.69	0.951	0.982
K	1.45	0.928	0.968
Flow rate	2.43	0.926	0.968
Cl^-	7.39	0.917	0.963
SiO_2	14.68	0.901	0.966
TOC	1.24	0.868	0.955
Mg	3.04	0.862	0.938
DOC	0.92	0.860	0.942
VSS	1.43	0.847	0.942
DN	0.70	0.736	0.878
TP	40.85	0.711	0.865
COD_{Mn}	1.44	0.684	0.892
D-COD_{Mn}	0.79	0.676	0.847
SS	2.80	0.637	0.870
DP	38.68	0.634	0.826
TN	0.67	0.617	0.846
IC	10.76	0.543	0.787
Ca	12.14	0.490	0.750

*Unit: 103m^3/km^2/d (Flow rate), g/km^2/d (TP, DP), kg/km^2/d (Others)

$1: R^2 for the regression without intercept, $2: R^2 for that with intercept

(R^2 : determination coefficient, = contribution)

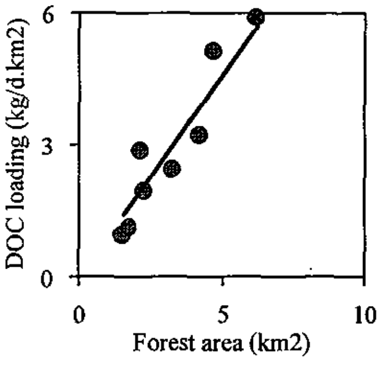

Fig. 6 Relationship of forest area with DOC loading rate

Table 6 Unit loading rates from land utilization

Water items	Unit loading ($kg/d/km^2$)	
	Paddy field	Residential area
DOC	-	3.21
DN	2.53	10.51

Then, the effects of paddy field and residential area to pollutant loadings, subtracting pollutant loading from forest area, were examined by a multiple linear regression. Statistically meaningful results were obtained in case of DOC and DN loading. These results are shown in Table 6. Compared with forest area, the unit loading of residential area was 3.5 times for DOC and 15 times for DN. In case of paddy field, it was 4 time for DN. DN is the index which has high influence from human activities.

Influence of population density to water quality loading

Table 6 showed unit loading in residential area was higher than area of forest and paddy field. Therefore, population itself may affect to water pollutant loading such as discharge of wastewater to basin. From this idea, the effects of population density were considered by using pollutant loading subtracting pollutant loading from forest area. As shown in Figure 7 , population density was good linear relationship with DN loading in both areas of sewerage systems. Slope in the regression line for population without sewerage was steeper about 10 times than that population with separated sewerage. This means the control of discharge from non-sewer service area is one of the most effective measures.

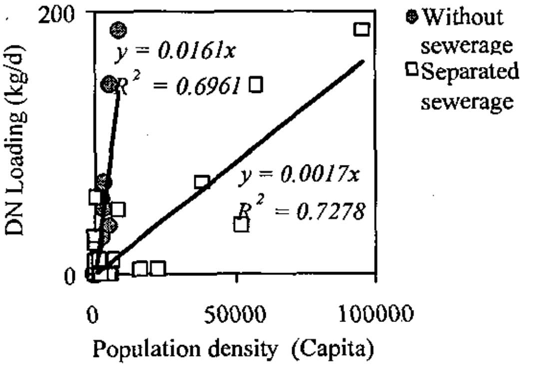

Fig. 7 Relationship between DN loading and population density

CONCLUSIONS

In this research, the objectives are set to extract main influential factors to pollutant loading in fine weather days and to evaluate their effects quantitatively. For these purposes, simultaneous surveys of 39 sites were conducted three times during 2000-2002 to understand horizontal distribution of water quality in the basin. ANOVA was introduced, and some of water quality indices were identified to be receive significant effects from sites. Positive linear relationship between loading and its area was obtained in the indices suchas DOC, DN and Mg (R^2>0.7). The effects of paddy field and residential areas were analyzed with a multiple linear regression method, and were quantitatively evaluated in DOC and DN. Population density also showed important effect to DN loading. Finally, 0.76 and 3.21 $kg/d/km^2$ of DOC and 0.65, 10.51 $kg/d/km^2$ of DN were successfully obtained as pollutant discharge rates from forest area and residential area, respectively, while 2.53 $kg/d/km^2$ of DN was availed for paddy field. These values may be applicable for evaluation non-point source loading pollution from land utilization in the basin.

REFERENCES

Geographical survey institute (1997). Altitude data of 50 m unit, digitalmap.

Geographical survey institute (1998). Regional scale 1:25000.

Kyoto city (1999). Estimated population of Kyoto city and Public sewerage infrastructure map.

Ogaki S. and Yoshida H. (2002). Basin management by new strategies. GIHODO SHUPPAN Co., Ltd.

Seto S., Oohara M. and Ikeda Y. (2000). "Analysis of precipitation chemistry at a rural site in Hiroshima prefecture, Japan" *Atmospheric Env.* 34, 621-628.

DEVELOPMENT OF A COMPREHENSIVE WATER QUALITY DATABASE SYSTEM AND ITS APPLICATIONS IN LAKE BIWA

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ABSTRACT

Water quality survey is a fundamental work for water quality analysis and management in every lake, and is repeatedly conducted, especially in a large lake. However, it is not easy to analyze results of one survey project together with those of others, because each project usually has its own investigation method on sampling sites, depths, frequency and measurement. The objective of this research is to develop a data management system of water quality that can utilize most of past survey data in a lake. Then, Lake Biwa was chosen as a target lake, where more than 20 surveys projects have been conducted and a huge number of water quality data have been accumulated during the last century. Coherence of data structures is too poor among these survey projects to store these data in a single table, causing difficulty in results comparison of different survey projects. To overcome this problem, attributions of water quality data were analyzed systematically and a database system was established with the help of relational database application software, Access 2000 (Microsoft ®). This system can easily access any data and compare results of different projects in Lake Biwa. Fundamental analysis of these data skillfully drew the figures of past surveys characteristics in Lake Biwa. This system has high flexibility on the data management and application, so that further extension of the system can be easily achieved.

KEYWORDS

Database system; lake; monitoring; relational database; surveys; water quality.

INTRODUCTION

Lake Biwa, the largest lake in Japan is located near the Kansai Metropolitan consisting of Osaka, Kyoto and Kobe, and works as a reservoir for people more than 14 million. The lake water quality was quite good, and recorded the highest Secchi depth of 16.0 m in 1926 (Yoshimura, 1931). However, the water quality has been deteriorated in recent years due to population increase and industrial development around the lake (Nomura *et al.*, 1993). Presently water quality seems to rank the North Basin as a mesotrophic state and the South Basin as a eutrophic state.

Water quality survey is a fundamental work for water quality analysis and management in every lake, so that many kinds of survey have been conducted in Lake Biwa to tackle this pollution problem. As a result, a huge number of water quality data have been accumulated about Lake Biwa. However, it is not easy to analyze results of one survey project together with those of others, because each project usually has its own investigation method on sampling places, depths, frequency and measurement items. The objective of this research is to develop a data management system of water quality that can utilize most of past/ present surveys in a lake.

DATA ACCUMULATION OF WATER QUALITY IN LAKE BIWA AND THEIR CHARACTERISTICS

Lake Biwa Surveys

Table 1 summarizes periodic water quality survey projects in Lake Biwa. As shown in the table, the number of these surveys exceeds 20, and a huge number of data are being accumulated in each year. Consequently, Lake Biwa becomes one of the lakes that possess the most abundant data in the world. Water quality of the lake Biwa fluctuates vertically, horizontally, seasonally and daily, keeping regular patterns as well as receiving irregular changes. Therefore, each of survey projects listed in Table 1 focuses on some limited purposes in its investigation, and has its own procedure on sampling points, frequency, items for measurement and so on.

Table 1 Summary of Periodic water quality surveys in Lake Biwa

Project No	Organization	Period	Freq. (y^{-1})	The Number* of			Remarks
				Sites	Points	WQIs	
1	Min. of Const. & Shiga Pref.	1966 ~	12	50	50	55	horizontal distribution
2	Shiga Pref. (Prefecture)	1975 ~	24	4	24	31	vertical profile
3	Min. (Ministry) of Const. (Construction)	1973 ~	12	2	16	33	vertical profile
4		1976 ~	57	2	2	29	short-term fluctuation
5	Kyoto City WB (Waterworks Bureau)	1974 ~	12	10	10	28	
6		1961 ~	12	1	1	80	detailed analysis
7		1974 ~	24	1	1	12	
8		1963 ~ 1988	12	1	1	25	
9	Yodogawa Water Quality Council	1973 ~	2 ~ 6	16	32	36	surface/bottom
10		1987 ~	1	12	27	22	multi vertical profiles
11		1990 ~	12	6	6	80	detailed analysis
12	Kyoto City	1974 ~ 1992	12	5	5	10	
13	Moriyama City WB	1989 ~	4 ~ 10	1	1	30	
14	Moriguchi City	1974 ~ 1994	2	8	8	20	
15	Kusatsu City WB	1989 ~	12	2	2	22	
16	Osaka City WB	1916 ~ 1992	12	1	1	46	oldest chemical data
17	Fishery Inst., Shiga Pref.	1915 ~	12	6	17	26	oldest observation
18	Hanshin Water Supply Authority	1982 ~	12	3	9	38	
19		1966 ~	6 ~ 10	9	10	40	
20	Water Quality Control Lab., Kyoto University	1976 ~ 1981	12 ~ 24	22	22	12	South Basin
21		1985 ~ 1986	12	12	12	23	
22		1995 ~ 2000	4	19	75	42	3-D distribution
23	Ecology Research Center, Kyoto Uni	1965 ~	12	4	20	5	vertical profile

No. (shaded): Data are imported into the Database. * Numbers in the latest surveys WQIs: water quality indices

Sampling Sites

Each project in Table 1 has one to 50 sampling sites, and sum of the site numbers for 23 projects reaches almost 200. Although some sites are used in plural projects, 89 places shown in Figure 1 are identified as different sampling sites in these surveys. The South Basin that only occupies 9 % in the whole surface area has dense sampling sites of 35, because water quality is highly changed in the South Basin, and most of water usage depends on the basin.

Sampling Depths

Eight projects in Table 1 focus on the vertical profile, and collect water samples from plural (2 to more than 10) depths in sampling sites. These projects have poor coherence of sampling depths to each others, so that about 40 different depths were found in these projects up to now. One of the important things for sampling depths is that the depths are determined with vertical distances, not only from the lake water surface, but also from the lake bottom. In addition, some projects just described the sampling points with names of layers (upper, middle and lower). Details will be discussed later with the database data.

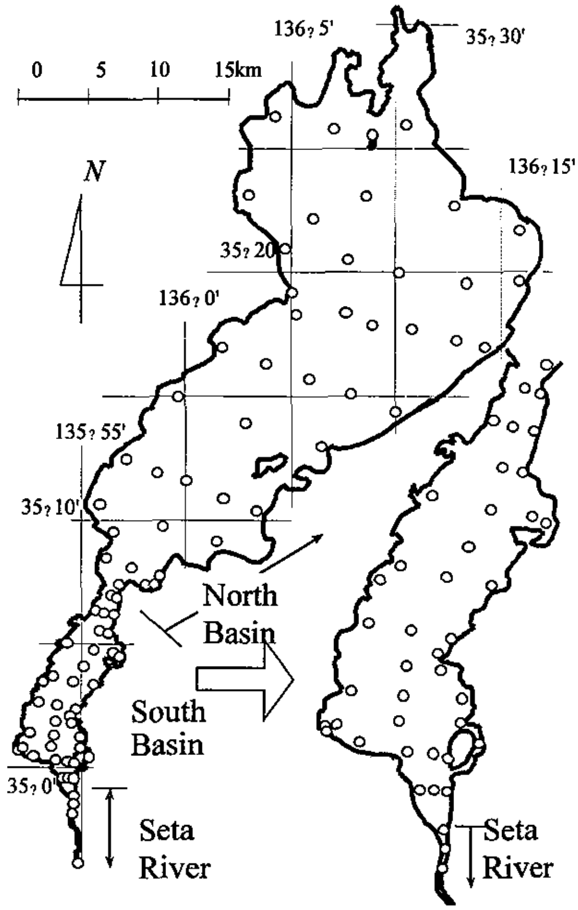

Figure 1 Lake Biwa and its sampling

Frequency

Table 1 also shows survey frequency in each project. The highest frequency is seen in project No.4, which collects two samples in both basins every week. No. 22 is one of the most comprehensive projects, collecting 75 water samples to obtain three-dimensional distribution, but have only four surveys in a year. Most of the others are conducted monthly.

Water Quality Items

Each project measures its own water quality items, but there are some common items measured in most of surveys. As a whole, more than one hundred items are measured in Lake Biwa, but some of items have only a few data compared with the whole number of water samples collected in all of the projects. Details will be again discussed later.

METHODOLOGY FOR DATABASE CONSTRUCTION

Relational Database

As shown in the previous section, each project has a different investigation scheme on sampling sites, depths, frequency, and measurement items. In addition, only a few projects keep their survey methods continuously, and most of projects had different methods in the past. As the results, it is quite difficult to summarize all of water quality data in a single table even if only one project is dealt with. Supposing we put all of the water quality data in a matrix table consisting of samples (rows) and water quality indices (columns), the table may have many vacant cells and the extraction of necessary information is not easy even if a Macro procedure is used.

Table 2 Tables composing the Lake Biwa Database System

Types	No.	Name of table	Number of fields	Number of records	Key code	Link to
Basic	1	TbData	3	673,623	-	-
Sub-main	2	TbSample	7	49,837	*CdSample*	1
	3	TbWQIndex	10	267*	*CdWQIndex*	1
Minar explanatory	4	TbSite	7	89	*CdPlace*	2
	5	TbDepth	3	45	*CdDepth*	2
	6	TbOrganization	3	15	*CdOrganization*	2
	7	TbForm	4	9	*CdForm*	3
	8	TbAManual	5	9	*CdAManual*	3
	9	TbElement	5	30	*CdElement*	3
	10	TbUnit	5	35	*CdUnit*	3

* includes codes for plankton species

For as of 2003.07.30

A relational database application software, **Access 2000** (*Microsoft* ®) was introduced to overcome this difficulty. In this database, all pieces of the information related to water quality data are stored in several tables, and these are linked to each other with several key codes. This application software also provides many kinds of support tools that facilitate utilization (various analyses) of the database data.

Design of the Database Structure

A database system was designed to systematically store all of the water quality data and their attribution information in suitable places (files). This database system consists of one main table, two sub-main tables and seven minor explanatory tables. These tables are listed in **Table 2**, and their relationships are shown in Figure 2.

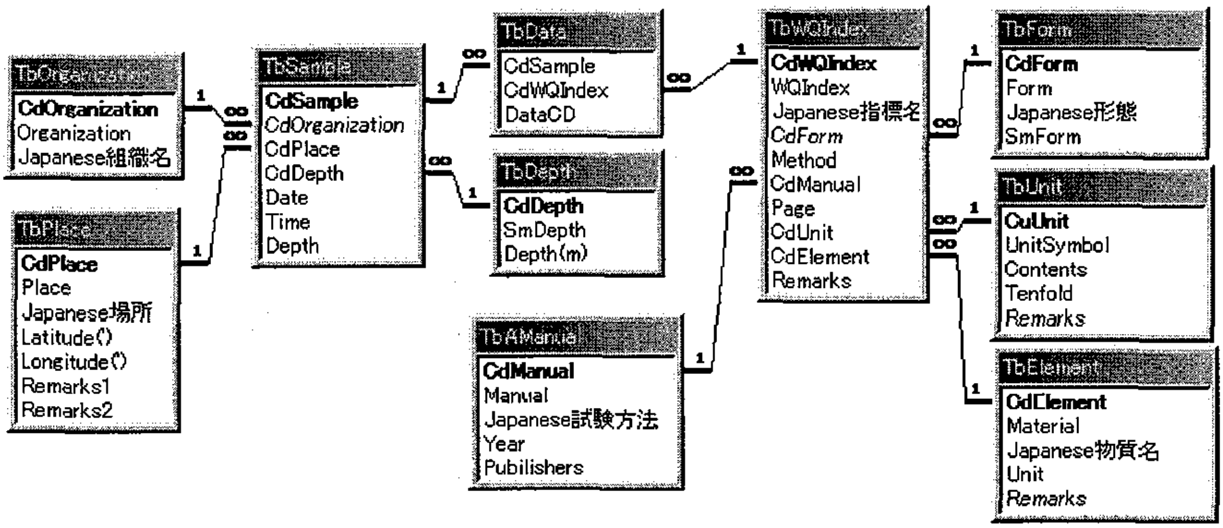

Figure 2 Relationships among data tables in Lake Biwa Database

The main table, named TbData, is placed in the center of this database system, and is used as the basic container where water quality conditions such as concentrations are stored. This table has only three fields (columns) for measured values, samples and WQIs (water quality indices). Each record, which corresponds to the row, only stores a single datum that is identified with its sample code (*CdSample*) and its WQI (water quality index) code (*CdWQIndex*).

CdSample is used to distinguish each sample from the others, being defined in one of sub-main tables, named TbSample, while *CdWQIndex* is to classify each water quality index used for measurement, being explained in the other sub-main table, TbWQIndex. Figure 3 gives the contents of TbData and its relationships to two sub-main tables.

Contents of Tables

TbSample is a table consisting of seven fields (= columns) and a tremendous number of records (=rows). One of seven fields is used for a key code of TbSample, and the code numbers of *CdSample* are stored. The other fields are used for sample attributions such as organization code, site code, sampling depth code, date, time and site-depth of each sample. Since information on organization, site and sampling depth is given with their code numbers, this table is also linked to three minor explanatory tables (TbOrganization, TbSite and TbDepth) through key codes. Each of the records in this table corresponds to each water sample.

TbWQIndex contains 10 fields. These are one key item, four attributions given in code numbers (*CdForm, CdManual, CdUnit* and *CdElement*) and other explanations. *CdForm* is a code that indicates which portion of sample (total, soluble, particle and so on) is measured. Its definition is given in TbForm. The preset standard unit for this database system (mg/L, µg/L, %, etc) is recorded with *CdUnit*, while the base material for the calculation of the unit (mg *etc.*) is given with *CdElement*. TbElement is a table that gives the definition of *CdElement*, and records elements such as C, N, P, $CaCO_3$ and Cl_2, which make the base values for units.

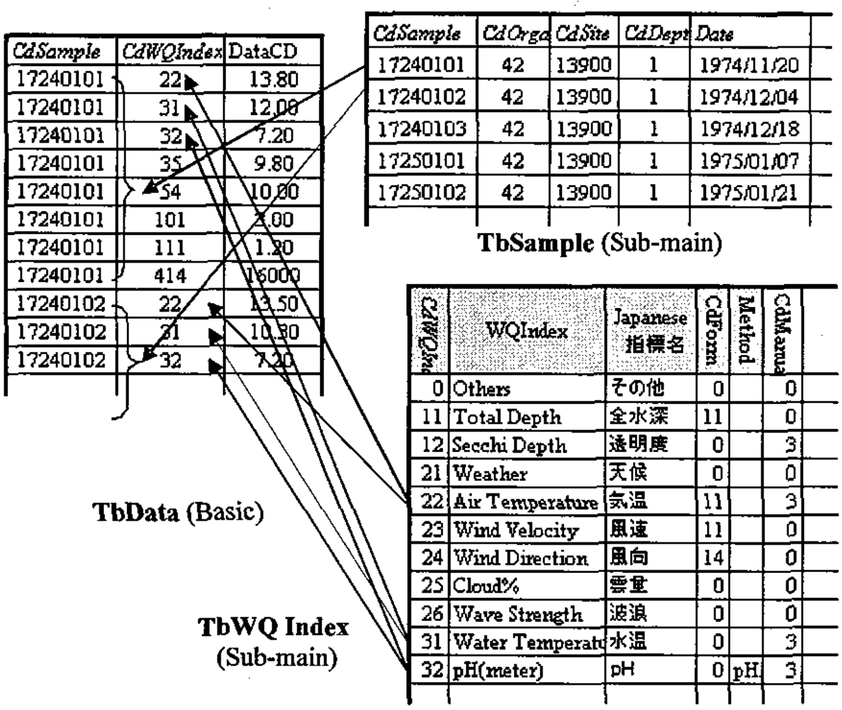

Figure 3 Contents of TbData and its relationships to sub-main tables

Data Input to the Database

Since the tables except TbSample and TbData have limited numbers of records basically, they can be completed manually during construction of this database system, although minor modifications are usually required. On the other hand, TbSample and TbData have a huge number of records, and will increase their records as long as some survey projects continue. Therefore, the procedure for survey data input is a key point in this system.

In the first step of the data input procedure, data for a certain project (*e.g.* project *X*) are stored in an **Excel** spreadsheet, consisting of WQI columns and sample rows, and the data are transferred to a table (the same style as that in **Excel**) in an **Access** file by using the **Import** function in **Access.** This table is prepared specially for the project (project *X*). Information on samples in this table is given as additional records in TbSample by means of an **Addition Query**, which is a function that **Access** provides. Duplicated data on samples are deleted with a **Deletion Query.** Contents of the Table (concentrations, *etc.*) are transferred to TbData with an **Addition Query.** Vacant data in TbData, which come from blank cells in the **Excel** file, are eliminated with a **Deletion Query.** This kind of procedures is repeatedly conducted for each project data.

Utilization of the Database

The primary goal of this database is efficient utilization and application of the existing data. As discussed in the previous section, this database system adopts a relational database software that is designed to store and arrange data so that the data are consistent and supporting quality assurance/ quality control data. The results of these analyses can be visually and instantly presented. The whole system may provide many kinds of water quality analyses such as (1) quick research on water quality conditions in any date, time, place and depth through 23 projects, (2) comparison of two different surveys, and its statistical analysis, (3) Graphical expression of water quality variation profiles for any given index, and (4) succession of horizontal distribution during the last two decades.

RESULTS AND DISCUSSIONS

Data Import to the Database

Up to now, 15 projects out of 23 are being included in this database system. The number of samples imported has reached almost fifty thousand, and that of their measured values has exceeded six hundred thousand, as shown in Table 2. The import work of Lake Biwa data is still ongoing, and will require some time for its completion. However, the database is estimated to involve more than half of the Lake Biwa data available, so that the data in this system can draw the figures of characteristics in past Lake Biwa surveys, and can show its water quality conditions.

Table 3 Sampling Depths in Lake Biwa surveys

Distance (m)	North Basin	South Basin	Seta River
from surface*	0, 0.5, 1.0, 2.0, 2.5, 5, 7.5, 8.0, 10, 12, 13, 14, 15, 17, 17.5, 18, 19, 20, 22, 25, 30, 35, 40, 45, 50, 55, 60, 65, 70, 75, 80	0, 0.5, 1, 2, 2.5, 3.0, 3.5, 4.0, 8.0, 10, 12	0.5
from bottom*	0.5, 1, 1.5, 2.5, 3, 5	0.5, 1	-
not quantitative	Upper, Middle, Lower	Middle, Lower	-

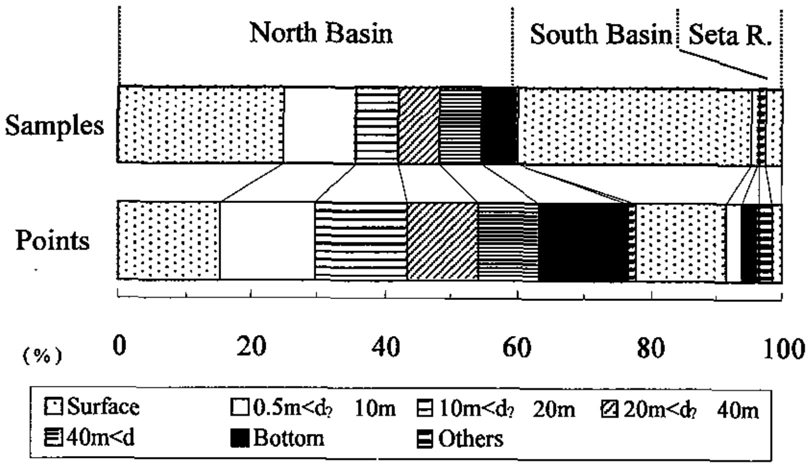

Figure 4 A variety of sampling depths and their data

The database covers 78 sampling sites out of the 89 different sites that the pre-investigation on Lake Biwa survey projects identified. 60 % of these samples were collected just from surface water only, while the residuals were from deeper depths. Table 3 shows all of the depths where samples of the database were collected. The North Basin has 37 vertically different sampling points while the South Basin has 13 points, and Seta River has only surface. The maximum number of sampling depths for one site in one survey is 18 for the North Basin, which is being conducted in its center. In case of the South Basin, the maximum is five. The database has obtained data from a various kinds of depths, but this is mainly due to the lack of coherence in survey methods.

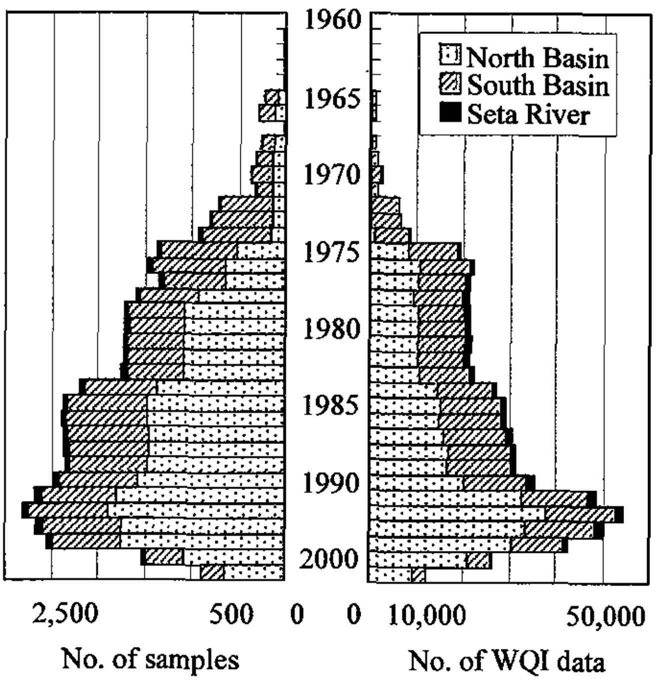

Figure 5 Yearly change of the datebase

Figure 4 shows distributions of sampling depths and their samples. As a whole, this database contains 352 sampling points, and many deep sampling points are seen in the North Basin. However, the number of water samples is rather concentrated in the surfaces points, and the surface samples occupy 25 and 35 % of the whole data, respectively for the North and South Basins. The average of sampling times stored in the database reached 180 and 360 times/point in surface, respectively for the North and the South.

Data Accumulation in the past surveys

Figure 5 shows yearly change of sample numbers and WQI data numbers. The present database has water quality data from 1961 to 2000. Both numbers of samples and their WQI data increased progressively from 1970, and reached to the similar levels of present surveys after 1975. The database has stored more than 1,000 samples and more than 20,000 WQI data for every year during 1975-1999. This figure classifies the Lake Biwa data into three areas of the North Basin, the South Basin and Seta River. Although the data accumulation patterns are a little different in three areas, similar percentages are seen after 1975 in both numbers. As a whole, percentages of the North, South and Seta are 60.0, 36.4, 2.6 %, respectively for the sample numbers, and 54.5, 42.0, 3.5 %, respectively for the WQI values.

Water Quality Indices

The database includes 90 WQIs, although the pre-investigation on Lake Biwa survey projects suggested 160 WQIs (+104 plankton species) have been measured. Figure 6 shows some of important WQIs and their observation percentages in water samples. Since the focused water quality seems to be different in depths, the percentages were shown differently for bottom and surface. Water temperature is the most fundamental items for field survey, and it was measured in more than 99 % of samples. DO and pH are also important information on environmental conditions and their measurement exceeded 90%. Ionic forms of nitrogen (NH_4^+-N, NO_3^--N) samples are also common items both for surface and bottom, while total indices of nutrients (TN and TP) are rather emphasized in surface samples. As a whole, surface samples seem to have more WQIs measured, but PO_4^{3-}-P, Mn, Fe and IC are investigated more often in bottom samples.

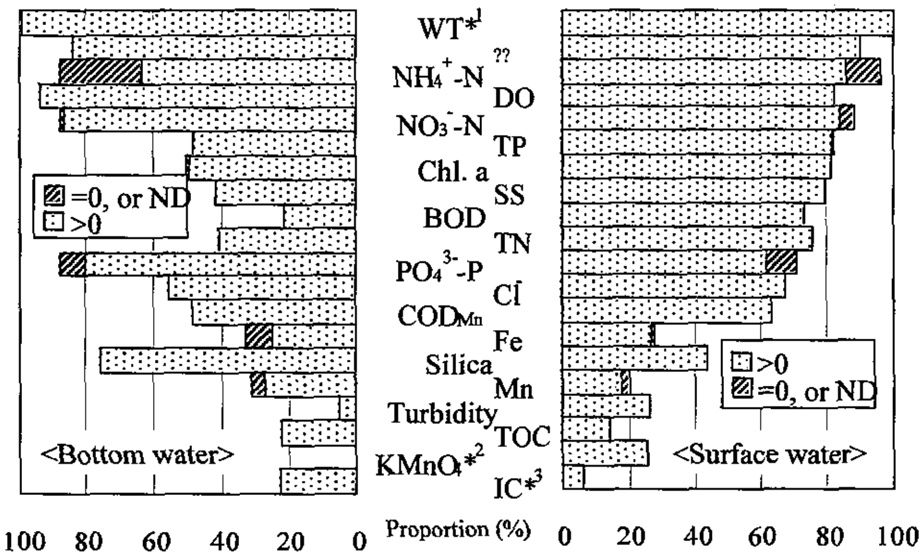

Figure 6 Percentage of measurement for main WQIs

(*1 Water Temperature, *2 $KMnO_4$ consumption, *3 Inorganic Carbon)

Many projects have many WQIs for measuring items, but some of their concentrations are too low to be quantitatively detected. In such case, the reports of projects record their concentrations as zero, ND (not detected) or other expressions (*e.g.* "<0.003" for PO_4^{3-}-P). These expressions are often seen in case of WQIs related to toxic materials. Table 4 lists typical indices related to human health, and show most of them are negligible. In case of phenol and cyanic ion, their measurements exceed 400 and 1800 times respectively, but their concentrations have never reached to their detection levels up to now.

Table 4 Detection of toxic substances

ND probability	Materials
$95\% \leqq P < 100\%$	Phenol, CN^-
$90\% \leqq P < 95\%$	Hg, Cr^{6+}
$80\% \leqq P < 90\%$	Se, Cr, Cd, Al, Pb, As

CONCLUSIONS

This study aims to develop a data management system of water quality that can utilize most of past survey data, choosing Lake Biwa as a target lake. As the first step, information on 23 present/past survey projects was collected, and their data characteristics were investigated in terms of sampling sites, depths, frequency and measurement items. These projects have various kinds of objectives, and cover 89 sites, 45 depths, 352 points and 160 items for sampling and measurement as a whole. Instead, coherence of data structures is quite poor among these survey projects to store these data in a single table.

To solve this problem, attributions of water quality data were analyzed systematically and a database system was established with the help of relational database application software, Access 2000 (Microsoft ®). This database consists of one main table, two sub-main tables and seven minor explanatory tables. The main table contained all data values in its records, each of which has only one datum on measurement values with two explanatory codes on sample and WQI. One of two sub-main Tables, a summary table for water sample information, gives the attributions of each sample such as its sampling date, time, site, depth and project, and is related to minor Tables on these sample attributions. The other sub-main Table is for water quality indices, followed by minor Tables on units, elements, manuals and forms.

Since a huge amount of data have been accumulated in Lake Biwa, the database system have not covered all of the data, but included about 670,000 WQI data for 50,000 samples from 15 survey projects, which are estimated to be more than half of available data. Fundamental analysis of these data skillfully drew the figures of past surveys characteristics in Lake Biwa.

The lake data management system is still under progress, and more convenient and useful functions will be added in the future with the help of various functions supported **Access**.

REFERENCES

Fishery Institute of Shiga Prefecture (2000). Annual Research report of the Fishery Institute.

Hanshin Water Supply Authority (2000). Annual report on water quality.

ILEC&UNEP, "Data book of world enivironments1. (1993). Asia and Oceania, Kusatsu, Japan.

Kusatsu City Waterworks Bureau. (2000). Annual report on water quality.

Kyoto City Waterworks Bureau. (2000). Annual report on water quality.

Ministry of Construction. (2000). survey report on Lake Biwa.

Mitani, K. (1986). Study on water quality change and its monitoring in the Southern Basin of Lake Biwa, Master's theses of Kyoto University.

Moriyama City Waterworks Bureau. (2000). Annual report on water quality.

Moriyama City. (2000). Survey report on environment.

Nomura, K., Yoda, M. *et al.* (1993). The evaluation of water quality of Lake Biwa from vertical view, Rep. Shiga Pref. Inst. *Pub. Hlth. & Environ. Sci.*, 28, 105-110.

Osaka City Waterworks Bureau (1993). Annual report on waterworks.

Osaka Prefecture Waterworks Bureau. (2000). Report of water quality and surveys.

Shiga Prefecture. (2000). White paper on environment in Shiga -data book-.

Water Quality Control Laboratory. (1985). Comprehensive studies on the water quality in the Southern Basin of Lake Biwa.

Water Quality Control Laboratory. (2001). Comprehensive Studies on the Water Quality Formation Processes in the Northern Basin of Lake Biwa.

Water Resources Agency. (1993). Lake Biwa, forever!, Journal of Lake Biwa development work, 1/2, p.5.

Yoshimura, Shinkichi. (1931). Lakes with high transparency in Japan, *Japanese Journal of Limnology*, **1**, No.1, 47-48.

河川水質の年間変動に及ぼす流域特性の影響検討

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京大院・工　Piyaporn SONGPRASERT、永礼英明、清水芳久
Influence of basin properties on annual fluctuations of river pollutant loading by Masashi MORIYA, Shigeo FUJII (Kyoto University), Hirotaka IHARA (National Agricultural Research Center), Piyaporn SONGPRASERT, Hideaki NAGARE, Yoshihisa SHIMIZU (Kyoto University)

1．はじめに

本研究では2000年度より研究している京都市北部の鴨川流域（図1）において定期調査と雨天時調査を実施し、河川水質の年間変動を評価した。

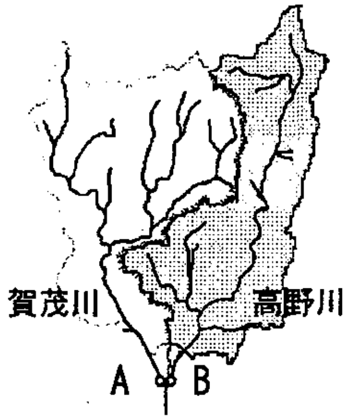

図1　対象流域

表1　集水域の概要

		A 加茂川	B 高野川
集水域面積	km^2	75.4	66.8
農地	km^2 (%)	1.5 (2.0)	3.0 (4.5)
市街地	km^2 (%)	5.7 (7.6)	9.5 (14.2)
森林	km^2 (%)	67.2 (89.1)	53.2 (79.6)
下水道整備面積	km^2 (%)	6.4 (8.5)	10.5 (15.7)
人口	人	41,300	62,700
下水道整備人口	人 (%)	38,000 (92.0)	57,000 (90.9)
平均勾配	m/km	364	320
平均流達距離	km	16.9	14.1

2．二地点水質・水量調査

主な流れである西部の賀茂川と東部の高野川の合流前の二地点（図中A・B）において2002/09/23から2002/12/12までは2日毎、それ以降から2003/12/10までは10日毎に水質・水量の定期調査を行なった。またこの期間の降雨のうち6度の降雨について雨天時調査を行なった。

2つの集水域の概要を表1に示す。高野川の方が比較的上流から市街化が進み下水整備区域の割合も大きい。

3．年間流出負荷量の算定[1]

6回の雨天時調査のデータから累加流出流量ΣQ_{net}、累加流出負荷量ΣL_{net}を集水域面積Aで除した比累加流出流量と比累加流出負荷量の関係をCODを例に図2に示す。ここで比累加流出流量・負荷量は、各雨天時の総流出流量・負荷量から基底流出分の流量・負荷量を差し引いたものとした。この図より以下の回帰式を得た。係数値を表2に示す。

$$\Sigma L_{net}/A = a \times (\Sigma Q_{net}/A)^n$$

累加降水量ΣRと比累加流出流量の関係を図2に示す。同じように以下の回帰式を得た。係数値を表2に示す。なお降水量は日単位のデータを用い、連続して降水のあるものを一降雨として計算した。

$$\Sigma Q_{net}/A = b \times (\Sigma R)^m$$

以上の回帰式を用いて2003年の降水時の累加流出負荷量をそれぞれの降水量から算出し、その和を降雨流出分の年間負荷量として求めた。一方、別途に基底流出分の年間負荷量を求め、降雨流出分と基底流出分の和を年間流出負荷量とした。また同じように季節ごとの流出負荷を算出した。結果を表3に示す。

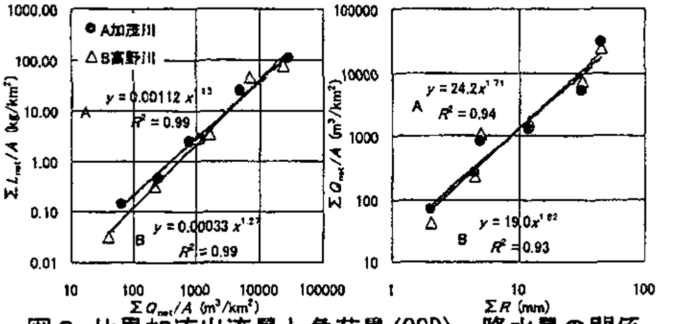

図2　比累加流出流量と負荷量(COD)、降水量の関係

2003/7〜9のCODの流出負荷量(t/km²)はA賀茂川で2.13、B高野川で3.72と多く、同年の少ない時期の5〜7倍にもなっている。また同じ時期でも2002/10〜12にはTNがAで7.2、Bで10.6であったのが、2003/10〜12にはAで14.1、Bで22.2と2倍程度増加しており、降水量によって大きく変動している。年間流出負荷量(t/y)をみると、CODはAで320、Bで485、TNはAで132、Bで208など、市街化が進み農地も多いB高野川の方が大きい値となった。SiO_2-Siをみると基底流出分はほぼ同じ値だが、降雨時にはAで300、Bで184と森林の割合が大きいA賀茂川の方が大きな値となった。

表2　回帰式の係数値

		COD	D-COD	TN	DN	TP	DP	SiO_2-Si		流量
A	a	0.001116	0.000972	0.000174	0.001562	0.00000927	0.00000515	0.00162	b	24.15
加茂川	n	1.13	1.10	1.21	0.92	1.24	1.23	1.10	m	1.71
B	a	0.000327	0.001070	0.000436	0.000205	0.00001101	0.00002087	0.00509	b	19.08
高野川	n	1.27	1.05	1.15	1.15	1.22	1.07	0.94	m	1.82

表3　年間流出負荷量

年間流出負荷(2003年)		降水量 (mm)	COD (t/y)	D-COD (t/y)	TN (t/y)	DN (t/y)	TP (t/y)	DP (t/y)	SiO_2-Si (t/y)
A 加茂川	基底流出分		43	32	32	28	1.04	0.79	160
	降雨流出分		278	171	100	41	7.49	3.86	300
	年間流出負荷	1814	320	202	132	68	8.54	4.65	460
B 高野川	基底流出分		40	30	54	52	1.24	1.09	160
	降雨流出分		446	121	155	73	8.88	3.21	184
	年間流出負荷	1814	486	151	209	125	10.11	4.30	344
比季節毎流出負荷		(mm)	(t/km^2)	(t/km^2)	(t/km^2)	(t/km^2)	(t/km^2)	(t/km^2)	(t/km^2)
A 加茂川	2002/10〜12	199	0.26	0.17	0.10	0.07	0.0053	0.0029	0.33
	2003/1〜3	272	0.40	0.29	0.16	0.12	0.0078	0.0042	0.84
	2003/4〜6	569	1.44	0.89	0.60	0.28	0.0397	0.0209	1.89
	2003/7〜9	692	2.13	1.35	0.93	0.44	0.0607	0.0344	3.17
	2003/10〜12	281	0.42	0.26	0.19	0.14	0.0103	0.0062	0.72
B 高野川	2002/10〜12	199	0.30	0.13	0.16	0.09	0.0087	0.0035	0.32
	2003/1〜3	272	0.52	0.26	0.31	0.22	0.0101	0.0059	0.75
	2003/4〜6	569	2.64	0.74	1.04	0.60	0.0537	0.0208	1.59
	2003/7〜9	692	3.72	1.10	1.67	1.03	0.0791	0.0342	2.78
	2003/10〜12	281	0.53	0.23	0.33	0.23	0.0133	0.0076	0.70

4．まとめ

本研究では定期調査と雨天時調査の結果から流出負荷量を算定した。その結果、季節ごと、集水域ごとに異なる値が得られ、降水量や流域特性が河川水質に与える影響が把握された。

参考文献

1)　國松孝雄・村岡浩爾 編著、河川汚濁のモデル解析、技報堂出版、1989

(3－8)水道原水保全における地理情報システム（GIS）の活用

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1. はじめに

流域の視点で、水循環の状態や管理のあり方を検討する試みが行われてきている。

流域内の多種多様な水に関する情報を統合化し、活用していくためには、地理情報システム(GIS)機能の利用が有効と考えられる。

また、近年、河川の水質情報の一部が時間データとしてリアルタイムで利用可能となってきており、今後とも水環境情報ソースの拡充・強化が図られていくことが期待される。このため、新たに整備された流域環境情報を活用し、どのような取り組みが可能か水道の立場より種々検討することが重要と考えられる。

本稿においては、今後、水道の立場より流域の視点で GIS を用い、どのような取り組みが可能かの検討に資するためケーススタディとして汚濁濃度（濁度）予測を行ったので、その概要を紹介する。

2. 方法

（1）対象流域及び対象物質

本研究ではケーススタディの対象流域を、埼玉県南部に位置する 1 級河川荒川水系入間川流域とした（図－1）。本流域末端の菅間地点において 2002 年 5 月より水質情報の一部が時間データとしてリアルタイムで公表されている。対象物質としては菅間地点での公表データの一つである濁度を選んだ。

濁度は浄水処理の基本的な水質指標であるとともに、流域内土地利用や工事状況とも関連する。また、降雨流出に伴う突発的な濁度の上昇の予測と対応は、水質リスク管理方法を検討する上からも示唆に富むと考えられる。

（2）濁度予測

工場、事業場等の点源からの濁度負荷については、原単位法を用い推計した。面源からの降雨流出に伴う濁度負荷については表層タンクモデルからの流量と負荷量関係式から推定した。

調査時点では、菅間地点の 2002 年の日平均流量データが公表されていなかったので、公表されていた 1998 年から 2000 年の日平均流量データと雨量データを用い 4 層複合タンクモデルのパラメータ係数合わせを行った。高い相関性が得られたモデルパラメータを用い、2002 年の雨量から 2002 年の日平均流量を推定し、濁度予測を行った。

3. 結果と考察

雨量と流量の相関及び濁度予測結果の一部を図－2 及び図－3 に示す。

タンクモデルを用い、3 ヶ年間の雨量データと流量データのパラメータ係数合せを行い 0.76～0.93 の相関係数が得られた。0.76 と相関係数の低い年間データには、上流ダムの放流等の雨量と関係しない流量による影響が考えられたので、以下の濁度予測には 0.93 の比較的高い相関係数が得られた 1998 年のモデルパラメータ値を用いることとした。

濁度予測については、菅間地点における水質情報の公表が 2002 年 5 月以降であったので、2002 年と 2003 年について、濁度の予測データと実測データの比較を行ったところ、相関関係は 0.35～0.41 であった。

濁度予測にあたり、さらに高い相関を求めるには降雨強度の予測式への反映方法や対象流域内での土木工事等による発生負荷量の把握を行う必要があると考えられる。

以上のように水質データと流量データが同時に必要な場合、タンクモデルを用い流量予測を行い、流量データが欠落している時点の流量データを補完し、濁度予測を行えることが確認できた。

このことにより、観測点の公表データをさらに、上流側にある水道取水点の濁度予測に活用できる可能性が考えられる。

4．おわりに

従来、水環境分野においてはGIS の利用事例が少なく、その原因の一つとして、水関係の情報はそれぞれの主体の業務目的に応じ、整備されており、他の主体が活用する上で不便が生じることが指摘されていた。

今後、水環境分野において、GISの利用を発展させていくうえで今回のような予測モデルを利用したデータ補完が有効であると考えられる。

なお、本研究は平成14年度厚生労働科学研究費補助金により行った。また、研究の実施にあたっては、本院特別課程水道工学コース三宅正弘、津田秀樹、横山浩二の各氏に御尽力頂いた。ここにこの場を借りて御礼を申し上げる。

参考文献：

増田貴則等；流域汚濁負荷算定におけるデータ整備の現状とツール開発によるGIS利用の迅速化、地理情報システム学会講演論文集、Vol.11,409-412,2002

図-1 対象流域図

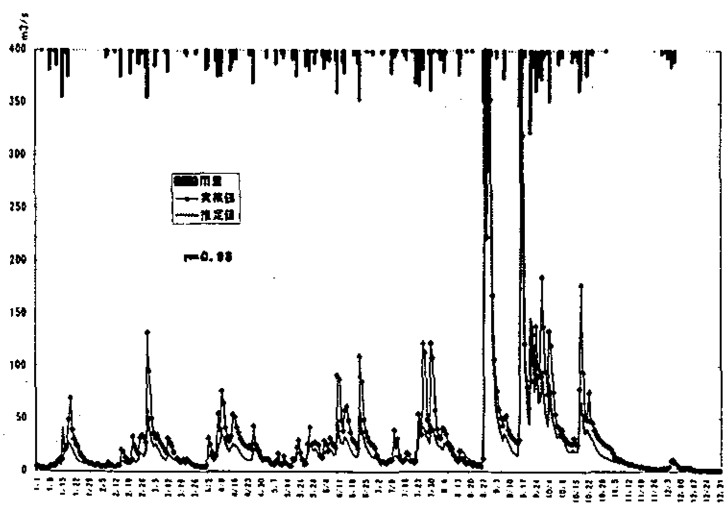

図2 1998年の雨量と流量の相関

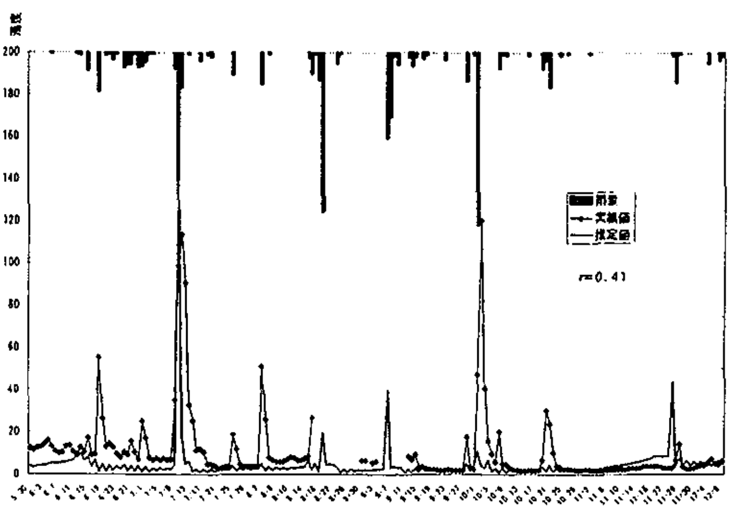

図3 2002年の濁度予測結果