Mathematical modeling of water quality in river systems.
Case study: Jajrood river in Tehran - Iran

S.A. Mirbagheri[1], M. Abaspour[2] and K.H. Zamani[3]

[1] Department of Civil Engineering, Khajeh Nasir Toosi University , Tehran , Iran.
[2] Department of Mechanical Engineering, Sharif University, Tehran , Iran.
[3] Science and Research Branch Islamic Azad University , Tehran- Iran.

Abstract: The present research work describes the mathematical model for the Jajrood River upstream of Latyan Dam. The river stretch studied is 25 Km long extending from Shemshak village (upstream) to Latyan Dam (downstream). The Latyan Dam is one of the main sources of water for Tehran metropolitan region. The Latyan Dam supplies 30% of the drinking water consumed by the citizens of Tehran. Due to the sewage of residential areas which is dumped at the river and the probable contamination, the quality of water along the river requires to be tested and the results of the qualitative analysis should be determined. Water quality parameters such as Dissolved Oxygen (DO), Biochemical Oxygen Demand (BOD$_5$), Phosphate Ion (PO$_4$), Nitrite Ion (NO$_2$), Nitrate Ion (NO$_3$),Ammonia Ion(NH$_4$), Organic Nitrogen (NORG), Temperature (T) were tested and modelled in the Jajrood River in north of Tehran province. A one - dimensional mathematical model written by C#2008 programming language with finite difference method and model can be computed hydrodynamic and water quality Parameters in Jajrood River for different reaches. This novel model, which is designed based on a technically robust and highly accurate graphic software, does qualitative calculations at a very short time. It also gives all the information about the occurrences during the dumping of sewage and even determines the highest concentration of sewage allowed to be dumped at the river. The model was calibrated and verified by using qualitative data collected from several stations along the study area form June 2006 to June 2007. The model was tested during different months of the year with satisfactory results. The simulated results of the model are in good agreement with measured values. The model can be useful in guiding engineering and management decision concerned with the efficient utilization of Jajrood River water and the protection of their quality.

Keywords: water quality parameters, finite difference, pollutant, concentration, river systems.

1. INTRODUCTION

Latyan's catchment has 698 km^2 area and 2340 m average height. The stretch of the Jajrood River extends from Shemshak village (upstream) to Latyan Dam (downstream). The structural features of the dam are as follows:

- Type: concrete buttress,
- Height from the foundation: 107 meters
- Gross capacity: 95 Mm^3
- Efficient capacity: 85 Mm^3

The Latyan's catchment is vast and lacks meteorological stations. Therefore, the data collected from the 6 neighbouring meteorological stations were used for hydrological and meteorological studies. The regression equations of the temperature and precipitation gradient are given below:

$$T = 28.21 - 0.0082Z \, , \, r^2 = 0.95 \, , \, r = 0.975 \, , \, n = 6 \, , \, T\sigma_{n-1} = 4.77 \tag{1}$$

$$R = 265.06 + 0.1159 \, Z \, , \, r^2 = 0.865 \, , \, r = 0.93 \, , \, n = 6 \, , \, R\sigma_{n-1} = 37.8 \tag{2}$$

where:
   T= annual mean temperature (^{o}C)

R= annual mean precipitation (mm)

The mean precipitation varied between 450 and 550 mm in Latyan's catchment.

Within the catchment, 4 cities and 36 villages are located. Now, raw sewage of these centers is directly discharged about 430 L/s to Jajrood River. Discharge of pollutants from domestic sewage, storm water, and other sources to Jajrood River, all of which may be untreated, can have significant effects of both short term and long term duration on the quality of river systems.

Jajrood River is the biggest river and starts at Shemshak village and ends at Latyan Dam. The river stretch was studied in 25 Kilometres. The field work was conducted from June 2006 to June 2007. The discharge amount of Jajrood River for that one-year period varied from 0.1- 30.1 m3/s.Water samples were analyzed bimonthly from 12 stations specified before. The locations of the 12 stations were considered in the upstream and downstream of the residential areas which their sewage is dumped at the river. The quality of Jajrood river can be greatly influenced by the point and non-point contaminating sources in the study area. Generally, the rate of growth of algae can be accelerated and it affects the quality of water, when the concentration of Nutrients such as PO4 and NO3 increases in the river water. A quantitative methodology is required to estimate the quantity of nutrients, suspended solids, biochemical oxygen demand and fecal coli-form in river systems and to predict the effects of expected future water quality. This methodology includes the development of water quality parameters transport model in the water body of interest.

A dynamic simulation approach can be developed on the basis of conservation of mass to describe the effect of BOD_5, DO, PO^4, NO_2, NO_3, NH_4, NORG, SS in the river systems. Suspended solids are the most important parameter among others that affect the quality of water, but it is not the major water pollutant.

Although excellent references are available in the discussions of water quality modelling in stream systems, it is known less about water quality parameters modelling in river systems in urban area. Many of water quality models that exist are theoretical research models, most of which have not been applied to real world systems as the required input parameters. Model coefficients are seldom measured in the field and thus computed results are difficult to verify. Several studies were reviewed on the issue of water quality models.

DOSAG1 is a model which was developed to solve the integrated form of the Streeter-Phelps equations and is applicable to the system which can be simulated as one-dimensional and steady state with no dispersion. The original DOSAG1 was modified for the U.S. Environmental Protection Agency (EPA) and the resulting product was called DOSAG III.

The QUALII model was an extension of the stream water quality model QUALI developed by F.D Masch and Associates and The Texas Water Development Board (1971). In 1972, water resources engineers, under contract to the U.S. Environmental Protection Agency, modified and extended QUALI to produce the first version of QUALII. Over the next 3 years, several different versions of the model evolved in response to specific users' needs. QUALII is perhaps the most comprehensive in a group of water quality models developed in the U.S. QUALII is written in FORTRAN77 and very difficult for users.

The majority of the models are solved by the finite difference technique. Major differences between the various models are the number of dimensions considered and the terms to be retained in the sources and sinks. Finite difference models (FDM) are usually restricted to rectangular grids and, at most, only grid spacing varies. The finite difference model is easy to apply to one-dimensional flow problems, but the finite element model (FEM) has been proved to process the great potential in solving two-dimensional flow problems. There have been other studies on water flow and water quality models using numerical FEM techniques, such as Chang (1970), Mirbagheri (1981).

Variable or process in model application is too complex for formulation and misapplication of model calibration. To overcome these deficiencies, the new model is written in C#2008 with finite difference method that user can work very easily with model without limitations. This novel model, which is designed based on a technically robust and highly accurate graphic software, does

qualitative calculations at a very short time. It also gives all the information about the occurrences during the dumping of sewage and even determines the highest concentration of sewage allowed to be dumped at the river. With all the basic data collected from other catchments, this model can also be applied to those in order to predict water quality parameters with a slight change.

2. MATERIAL AND METHODS

2.1 Model formulations

Model formulation is based on the mass balance for a particular substance. The statement of the mass balance can be given as:

Accumulation = inflow – outflow ± sources or sinks.

The mathematical model consists of one-dimensional advection-dispersion mass balance equation of the given pollution parameter, corresponding, initial and boundary conditions.
The assumptions in such model are:
1. The density of polluted water is constant and similar to clean water density.
2. The substance is well mixed over the cross section. (The assumption has been proved based on the measurements done.)
3. Only longitudinal hydrodynamic dispersion occurs.

The one-dimensional equation for the conservation of mass of a substance in solution, i.e. the one dimensional advection-dispersion equation for the concentration of Dissolved Oxygen (DO), Nitrate (NO_3), Nitrite(NO_2), Ammonia (NH_4), Orthophosphate (PO_4), Biochemical Oxygen Demand (BOD_5), Organic Nitrogen (NORG) and Temperature (T) can be written for a river flow systems assuming steady-state, non-uniform, as follows:

$$\underbrace{\frac{\partial c}{\partial t}}_{storage} + \underbrace{\frac{\partial (A.V\mathrm{x}.C)}{A \partial x}}_{advection} = \underbrace{\frac{\partial (A.D\mathrm{x}.\partial c / \partial \chi)}{A \partial x}}_{dispersion} + \underbrace{\frac{dc}{dt} + \frac{S}{V}}_{source \& sinks} \tag{3}$$

where:
    C=concentration of pollutant (mg/L)
    T=time (s)
    X=distance (m)
    A=cross-sectional area perpendicular to x (m^2)
    D_x=dispersion coefficient (m^2 /s)
    V_x=water velocity perpendicular to x (m/s)
    S=source or sink pollutant (mg/s)
    V=volume (L)

Dispersion coefficient was determined by:

$$D_x = 2.10 \; n \; V_x \; D^{0.833} \tag{4}$$

where:
    D_x: Longitudinal dispersion coefficient (m^2 /s)
    n: Manning's roughness coefficient
    V_x: mean velocity (m/s)

D: mean depth (m)

Sources and sinks for the model in the unit of volume are as follows:
1. For Biochemical Oxygen Demand:

$$S = -k_1 L - k_3 L \tag{5}$$

2. For Dissolved Oxygen:

$$S = -K_1 L - K_2 o - K_{NH_4} NH_4 - K_{NO_2} NO_2 + K_2 O_s + K_A (A_1 + A2) \tag{6}$$

3. For Ammonia:

$$S = K_{NH_4} NH_4 + K_{Kg} NORG \tag{7}$$

4. For Nitrite:

$$S = K_{NH_4} NH_4 - K_{NO_2} No_2 \tag{8}$$

5. For Nitrate:

$$S = K_{NO_2} NO_2 - K_B (A_1 + A_2) \tag{9}$$

6. For Organic-N :

$$S = -K_{kg} NORG \tag{10}$$

7. For Orthophosphate:

$$S = -K_{PO41} PO_4 - K_{PO42} (A_1 + A_2) \tag{11}$$

where:
K_1 = Bioxidation coefficient for BOD (1/day)
K_3 = Coefficient of settling effects (1/day)
L = BOD Concentrations (mg/L)
K_2 = Re-aeration Coefficient (1/day)
O_s = Oxygen saturation point (mg/L)
O = DO Concentration (mg/L)
K_A = DO from chlorophyll-A (1/day)
A_1 = Chlorophyll- A Phytoplankton (mg/L)
A_2 = Chlorophyll-A sessile algae (mg/L)
K_{NO2} = Nitrite or nitrate rate (1/day)
NO_3 = Nitrate concentration (mg/L)
K_B = Nitrate uptake by algae (1/day)
NO_2 = Nitrite concentration (mg/L)
K_{NH4} = Ammonia decay rate (1/day)
NORG = Organic N concentration (mg/L)
NH_4 = Ammonia concentration (mg/L)

K_{kg} = Organic-N decay rate (1/day)
K_{PO41} = Orthophosphate decay rate (1/day)
K_{PO42} = Orthophosphate uptake by algae (1/day)
PO_4 = Orthophosphate concentration (mg/L)

2.2 Model conceptualization

The model conceptualizes the stretch of river studied in 12 stations specified before (11 reaches). The parameters of BOD_5, DO, Nitrification, Orthophosphate, and temperature have been measured for the period of one year. Reaches are further subdivided into units called computational elements. Each computational element is modelled as a constant volume, completely mixed reactor with input, output, and reaction terms. The mathematical model contains subroutine covering the quality parameters, determination of coefficients, temperature calibration and hydraulic subroutine. These subroutines interact together with the main model to simulate the water quality parameters of the Jajrood River.

Generally, these subroutines simulate each quality parameters by defining the nature of the source/sink, S, in the mass balance equation. The element consists of two parts: The first contains the forcing function inputs which enter directly into the mass balance equation. The second consists of the reactive components which are specific to the particular water quality variable being modeled.

The hydraulic parameters were calculated via the Manning's Equation:

$$Q = 1/n \; A \;\; R^{0.67} \; S^{0.5} \tag{12}$$

where:
Q: flow rate (m^3/s)
n: roughness
A: cross section area (m^2)
R: Hydraulic radius (m)
S: Slope

2.3 Calibration Coefficient

In the model, the coefficients of BOD, DO, Nitrification, Orthophosphate are calculated and calibrated according to the stream temperature by the general formulas:

$$k_{20} = (\log X_2 - \log X_1)/(t_2 - t_1) \tag{13}$$

$$k_T = k_{20} \times \theta(T-20) \tag{14}$$

where:
X = concentration of constituents (mg/L)
t: time (day)
k_T = chemical reaction coefficient at temperature T (1/day)
k_{20} = chemical reaction coefficient at 20 °C (1/day)
θ = temperature correction factor.
K_{20} is calculated by the measured data for the distance between the two stations and is compared with the data in the reference books. Then, considering the measured temperature, the coefficients are calibrated.

2.4 Solution scheme

In the present study, an implicit finite difference scheme is used for the numerical solution of the advection-diffusion equation. In this method the finite difference approximation expresses the values and the partial derivative of each function within a four point grid formed by the intersections of the space line i-1 , i and i+1 with the time lines t_n and t_{n+1}. A control volume is defined and situated around the grid point i. The boundaries of this control volume are river bed, the water surface and the two cross-sections situated at i-1 and i+1, respectively, as shown in Figure 1.
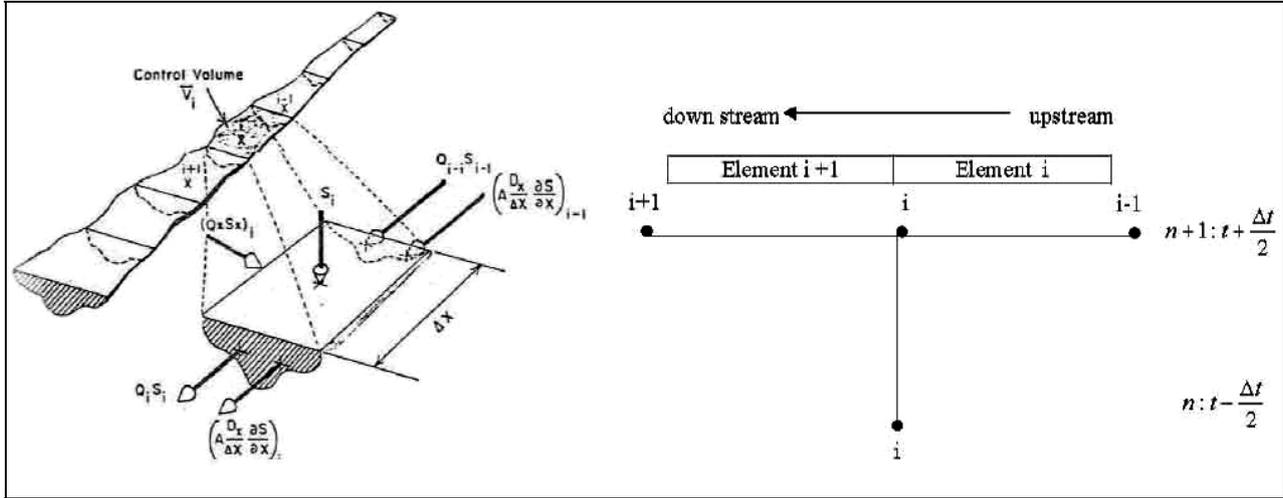

Figure 1. Classical Implicit Nodal (Obtained from Qual2E Manual)

For a discrete time interval Δt, beginning at t_n and collecting term in concentration (C), the resulting finite difference form of Equation (3) is:

$$-\left\{\left[Q_{i-1} + (\frac{AD_x}{\Delta x})_{i-1}\right]\frac{\Delta t}{v_i}\right\}.C_{i-1}^{n+1} + \left\{1.0 + \left[Q_i + (\frac{AD_x}{\Delta x})_i + (\frac{AD_x}{\Delta x})_{i-1}\right]\frac{\Delta t}{v_i}\right\}C_i^{n+1} - \left\{\left[(\frac{AD_x}{\Delta x})_i\right]\frac{\Delta t}{v_i}\right\}C_{i+1}^{n+1} = Z_i \tag{15}$$

where:

$$z_i = C_i^n + S_i\Delta t + \Delta t Q_{xi}.C_{xi} \tag{16}$$

$$v_i = \frac{1}{2}(A_i\Delta x_i + A_{i-1}.\Delta x_{i-1}) \tag{17}$$

$$\Delta t \le \Delta x / Vx \tag{18}$$

By using Equation (17) in Equation (15) and assigning the letters α, β and γ for all terms on the left-hand side of Equation (15), the following coefficient results for time step n+1:

$$\alpha_1 = -(D_X)_{i-1}\frac{\Delta t}{\Delta x_i^2} - Q_{i-1}\frac{\Delta t}{v_i} \tag{19}$$

$$\beta_i = 1 + \left[(D_x)_i + (D_x)_{i-1}\right]\frac{\Delta t}{\Delta x_i^2} + Q_i\frac{\Delta t}{v_i} \tag{20}$$

$$\wp_i = -(D_x)_i \frac{\Delta t}{\Delta x_i^2}$$

(21)

Using Equation (19) through (21) in Equation (15), yields the algebraic equation:

$$\alpha_i \ C_{i-1}^{n+1} + \beta_i \ C_i^{n+1} + \delta_i \ C_{i+1}^{n+1} = z_i$$

(22)

The term Z_i^n in equation (16) varies depending on the constituent being considered. This term is, as it is defined in equation (16), takes into account the source and the sink. At each time step, Equation (22) is written once for each computational element, i, n+1; therefore, $1 \leq I \leq N$, which results in a system of N simultaneous equations and N unknown.

2.5 Initial and boundary condition

If the concentrations at first station in upstream river are known at the beginning of the simulation period, they can be used as initial conditions, and user can calculate the concentration of constituents in the other application.

Since the ratio $\Delta x / \Delta t$ in the numerical scheme should be approximately equal to the current velocity of water in the prototype, constituents will travel a distance x in a time interval t. Thus if, only advection operates the downstream boundary condition can be given approximately by $c_i^n = c_{i+1}^{n+1}$, where c_{i+1}^{n+1} is the concentration just downstream from the end of the system.

2.6 Model application

The model was applied to simulate Dissolved Oxygen, Biochemical Oxygen Demand, Nitrite, Nitrate, Orthophosphate, Ammonia, Organic Nitrogen and Temperature in the Jajrood River. Jajrood River is located between Shemshak village and Lavasan city. The length of the river is 25 Kilometers. The peak flow of the Jajrood River was measured 30.1 m³/s for the period of one year and the average precipitation in Latyan dam's catchment is 500mm per year. Jajrood River was divided into eleven reaches and twelve sampling sites for model calibration and validation. The total primary station is nine.

The number of stations, rate of flow, velocity, cross-section area, and the size of the grid are shown in Tables 1-3 for 3 months. The water quality tests were performed from June 2006 to June 2007. Each reach was then divided into several computation elements, having their own hydraulic, physical, chemical and biological characteristics. The input data for model validation are topographical and hydraulic data and water quality in the sampling site. Topographical data are river cross-section measured at all sampling sites. Required hydraulic data were: flow rates, water depth and velocity. They were measured monthly in one year. River branches between the stations were input to the model as incremental flow. The temperature of the stream during the survey period was measured directly in the field.

The main data required for this model are as follows:
- Number of major stations
- Geometric and hydraulic characteristics of the stations
- Qualitative parameters measured at the first station
- Length between the major stations
- Number of the branches leading to the main river with the geometric and hydraulic characteristics
- Distance to the other stations
- Temperature at the stations

- Location of the intersection point of the sewage and the main river with hydraulic and qualitative characteristics
- Roughness coefficient for the length of the river

The hydraulic, hydrodynamic, qualitative coefficients and the concentration are calculated and simulated in the model. Also the model draws and compares the profiles of the simulated and measured concentration of the constituents in a diagram.

Table 1. Number of primary station, Rate of flow, Velocity, Cross section area and the Size of the grid (Nov. 2006)

Primary Station	Elevation (m)	Length (m)	Cross section area (m²)	Velocity y(m/s)	Rata of flow (m³/s)	Number of division between two station	Size of grid (m)
1	2330	-	1.5	0.6	0.9	-	-
2	2127	2160	1.1	0.8	0.9	9	240
3	2052	2700	1.5	0.8	1.2	10	270
4	1936	2430	3.0	0.4	1.2	9	270
5	1903	2160	2.9	1.3	3.8	8	270
6	1855	1350	3.8	1.0	3.8	5	270
7	1800	1350	5.4	0.8	4.3	5	270
8	1675	9450	4.4	1.0	4.4	21	450
9	1630	2430	4.5	1.0	4.5	9	270

Table 2. Number of primary station, Rate of flow, Velocity, Cross section area and the Size of the grid (Feb. 2007)

Primary Station	Elevation (m)	Length (m)	Cross section area (m²)	Velocity y(m/s)	Rata of flow (m³/s)	Number of division between two station	Size of grid (m)
1	2330	-	2.9	0.7	2.0	-	-
2	2127	2160	2.3	0.9	2.1	9	240
3	2052	2700	3.0	0.9	2.7	10	270
4	1936	2430	4.5	0.6	2.7	9	270
5	1903	2160	5.5	1.5	8.3	8	270
6	1855	1350	6.4	1.3	8.3	5	270
7	1800	1350	10.5	0.9	9.5	5	270
8	1675	9450	6.4	1.5	9.6	21	450
9	1630	2430	6.5	1.5	9.7	9	270

Table 3. Number of primary station, Rate of flow, Velocity, Cross section area and the Size of the grid (Apr. 2007)

Primary Station	Elevation (m)	Length (m)	Cross section area (m²)	Velocity y(m/s)	Rata of flow (m³/s)	Number of division between two station	Size of grid (m)
1	2330	-	4.0	1.6	6.4	-	-
2	2127	2160	3.4	1.9	6.4	9	240
3	2052	2700	4.3	2.0	8.6	10	270
4	1936	2430	5.4	1.6	8.6	9	270
5	1903	2160	8.8	3.0	26.4	8	270
6	1855	1350	9.5	2.8	26.5	5	270
7	1800	1350	15.8	1.9	30.0	5	270
8	1675	9450	10.0	3.0	30.1	21	450
9	1630	2430	10.0	3.0	30.1	9	270

3. RESULTS AND DISCUSSION

Functional relations for suspended solids, flow rate, total nitrogen, and nitrate were also obtained through monthly sampling in the last station from June 2006 to June 2007 with regression methods. The number of samplings was 25 for the afore-mentioned one year period.

The functional relations are:

$$N_{TOT} = -1.98 + 2.57 \ Ln \ Q, \ r^2 = 0.76, \ r = 0.87, \ n=25, N\sigma_{n-1} = 0.12, \ \bar{N} = 0.33 \tag{23}$$

$$SS = -0.011Q^4 + 0.71Q^3 - 14.5Q^2 + 108.07Q - 238.88, \ r^2 = 0.90, \ r=0.95, \ n=25, \ \overline{SS}\sigma_{n-1} = 26, \ \overline{SS} = 103 \tag{24}$$

$$N_{TOT} = 1.028 \ NO_3 + 0.363, \ r^2 = 0.988, \ r=0.99, \ n=25, \ N\sigma_{n-1} = 0.12, \ \bar{N} = 0.33 \tag{25}$$

Using Eq. (25) in Eq. (23), yields the anther Equation:

$$NO_3 = -1.83 + 2.0 \ Ln \ Q \tag{26}$$

where:

N_{TOT} = concentration of total nitrogen (mg/L)

Q= flow rate (m^3/s)

SS= concentration of suspended solids (mg/L)

NO_3 = concentration of nitrate (mg/L)

The water quality parameters such as BOD_5, DO, NH_4, NO_2, NO_3, NORG, PO_4 are given to the model after conducting the sampling test in the first station and then, the same parameters are simulated for other 8 stations by the model. The results of the model are shown and compared with the measured values in Tables 4-6 from 9 primary stations.

The above-mentioned tables show that simulated values of water quality parameters have acceptable compatibility with the measured values and the discrepancies between the measured and simulated are small. Therefore, the application of this model was proved for calculating water quality parameters.

4. CONCLUSION

A one-dimensional dynamic mathematical model calculates Dissolved Oxygen, Biochemical Oxygen Demands, Nitrate, Nitrite, Orthophosphate, Ammonia, Organic Nitrogen, and Temperature in river systems. This model is based on the mass balance equation including advection and diffusion transport, chemical and biological transformation and inflow of point and non-point sources. The solution is obtained by a finite difference implicit method. The model was calibrated and verified by using qualitative data collected from several stations along the study area form June 2006 to June 2007.

The obtained data were measured with great accuracy based on which the functional relations were also created between (N_{TOT} and Q), (SS and Q), and (N_{TOT} and NO_3) with acceptable regression coefficient. The model was tested during different months of the year with satisfactory results. The simulated results of the model are in good agreement with measured values. The model can be useful in guiding engineering and management decision concerned with the efficient utilization of Jajrood River water and the protection of their quality. The simulated results have acceptable compatibility with the measured values.

The advantages of this model are as follows:

1. Being applied easily with technically robust, highly accurate computer software with high speed
2. Drawing the profile of water quality parameters along the river
3. Calculating the water quality parameters
4. Determining critical concentrations
5. Planning to control the pollutants
6. Applying to other rivers with the smallest changes in the structure of the model
7. Being updated easily in the future

Table 4. Comparison of measurement amount of water quality of Jajrood river with the simulated result of model (Nov. 2006)

Primary Station	BOD₅(mg/L) M*	S**	DO(mg/L) M	S	NH₄(mg/L) M	S	NO₂(mg/L) M	S	NO₃(mg/L) M	S	NORG(mg/L) M	S	PO₄(mg/L) M	S
1	2	2	8.7	8.7	0.03	0.03	0.002	0.002	0.23	0.23	0.25	0.25	0.09	0.09
2	2.2	2.21	9	10.17	0.1	0.1	0.004	0.008	0.22	0.17	0.08	0.12	0	0.05
3	2	1.87	7.3	6.96	0.07	0.075	0.032	0.029	0.29	0.32	0.19	0.15	0.32	0.4
4	0.7	1.05	8.8	9.24	0.03	0.037	0.004	0.0016	0.26	0.14	0.18	0.23	0.97	0.99
5	2.2	2.14	8	7.71	0.06	0.062	0.004	0.008	0.47	0.52	0.08	0.08	0.01	0.05
6	2.7	3.06	10.2	10.89	0.08	0.087	0.004	0.0019	0.42	0.08	0.22	0.18	0.17	0.21
7	0.4	0.42	8.2	7.85	0.06	0.056	0.004	0.006	0.5	0.36	0.21	0.29	0.01	0.03
8	1.5	1.59	9	8.83	0.05	0.056	0.004	0.003	0.64	0.65	0.17	0.16	0.2	0.26
9	0.9	1.13	9	9.7	0.06	0.057	0.004	0.008	0.7	0.78	0.11	0.12	0.41	0.36

* Measured
** Simulated

Table 5. Comparison of measurement amount of water quality of Jajrood river with the simulated result of model (Feb. 2007)

Primary Station	BOD₅(mg/L) M*	S**	DO(mg/L) M	S	NH₄(mg/L) M	S	NO₂(mg/L) M	S	NO₃(mg/L) M	S	NORG(mg/L) M	S	PO₄(mg/L) M	S
1	1.6	1.6	8.7	8.7	0.07	0.07	0.004	0.004	2.6	2.6	0.04	0.04	0.0	0.0
2	2.0	2.1	8.9	8.5	0.06	0.05	0.004	0.006	2.8	2.5	0.5	0.45	0.66	0.6
3	5.5	5.7	8.7	8.4	0.12	0.10	0.004	0.003	3.0	3.2	0.48	0.40	0.5	0.45
4	2.5	2.7	9.2	9.0	0.12	0.11	0.004	0.003	2.2	2.5	0.38	0.30	1.32	1.2
5	2.9	2.7	9.4	9.1	0.09	0.07	0.002	0.002	3.3	3.2	0.49	0.36	0.0	0.30
6	3.6	3.3	8.7	9.0	0.10	0.08	0.006	0.005	3.2	3.1	0.51	0.42	0.03	0.05
7	2.4	2.1	8.7	8.8	0.06	0.05	0.0	0.003	3.4	3.3	0.46	0.40	0.0	0.07
8	1.8	1.9	8.7	8.8	0.03	0.10	0.004	0.004	3.9	3.8	0.63	0.57	0.0	0.03
9	2.1	2.2	9.2	9.0	0.13	0.11	0.006	0.005	3.8	3.7	0.34	0.03	0.0	0.03

* Measured
** Simulated

Table 6. Comparison of measurement amount of water quality of Jajrood river with the simulated result of model (Apr. 2007)

Primary Station	BOD₅(mg/L) M*	S**	DO(mg/L) M	S	NH₄(mg/L) M	S	NO₂(mg/L) M	S	NO₃(mg/L) M	S	NORG(mg/L) M	S	PO₄(mg/L) M	S
1	4.0	4.0	6.5	6.5	0.02	0.02	0.001	0.001	3.4	3.4	0.38	0.38	0.07	0.07
2	1.1	1.3	6.9	6.7	0.0	0.01	0.001	0.005	3.8	3.7	0.22	0.20	0.15	0.12
3	1.5	1.8	7.1	7.0	0.04	0.03	0.001	0.003	3.8	3.6	0.40	0.35	0.16	0.13
4	1.9	1.7	7.1	7.0	0.04	0.03	0.001	0.003	4.4	4.2	0.29	0.33	0.26	0.24
5	2.0	2.1	7.1	7.3	0.03	0.04	0.002	0.002	5.6	5.8	0.38	0.37	0.25	0.25
6	1.0	1.2	7.3	7.2	0.13	0.17	0.002	0.005	5.6	5.8	0.36	0.33	0.03	0.02
7	2.0	2.2	7.5	7.8	0.04	0.03	0.001	0.004	5.4	5.3	0.45	0.40	0.37	0.32
8	2.3	2.1	7.9	7.7	0.05	0.04	0.004	0.004	6.5	6.3	0.26	0.23	0.43	0.39
9	1.9	2.0	7.6	7.7	0.04	0.05	0.004	0.005	6.5	6.4	0.30	0.27	0.42	0.40

* Measured
** Simulated

REFERENCES

Argent, R.M., 2004. An Overview Of Model Integration For Environmental Application – Components, Frameworks And Semantics. Environmental Modelling And Software.19 (3), 219-234.

Chapra S.1997:Surface Water Quality Modeling, New York,McGraw Hill,McGraw Hill Series In Water Resources And Environmental Engineering,ISBN 0-07-843306-1.

Fogler, H.S.,1999. Elements Of chemical Reaction Engineering.Prentice Hall, Upper Saddle River, NJ,USA.

Graham. F. Carey., 1995.Finite Element Modelling Of Environmental Problem.John Willey.

Lambardo, P.M. and Otto, R.F., 1974. Water Quality Simulation And Application. Wat. Resour. Bull, 10 (1): 15-21.

Linfield, C., Brown And Thomas O. Branwell Jr., 1987. The Enhanced Stream Water Quality Models Qual2E And Qual2E-Uncase: 3-87.

Linfield, C., Brown, 1987. The Enhanced Stream Water Quality Models Qual2E, Documentation And User Manual.

Mirbagheri, S. A., And Tanji, K.K., 1993. "Dynamic Simulation Model Of Algae And Nutrient In Coulsa Basin Drain" Iranian Journal Of Science And Technology: 204-227.

Mirbagheri, S. A., And Tanji, K.K., 1993. "Statistical And Dynamic Modelling Of Algae And Nutrient In Stream Systems" International Journal Of Environmental Research, 1 (3): 198-208.

Nemerrow, N. L., 1974. Scientific Stream Pollution Analysis. 1st edn, McGraw-Hill, New York (USA)

Norton, W. R., King, I.P., and Orlob, G.T., 1973. A, Finite Element Model For Lower Granit Reservoir , walla District , U.S. Army Report Prepared By Water Resources Engineers Inc .

Rutherford, J.C. and Sullivan, M. J., 1974. Simulation of Water Quality In Tarawera River. J.Env Eng .Div .ASCE 100 (EE2): 369-390.

Tchobanoglous,G.,Schroeder, E.D., 1985.Water Quality-Characteristics,Modelling,Modification.Addision-WesleyPublishing Company,USA

Texas Water Development Board., 1970. Simulation Of Water Quality In Stream And Canals: DOSAG1. System Engineering Division, Austin, Texas, USA.

Texas Water Development Board., 1971. Simulation Of Water Quality In Stream And Canals: Report NO.128, Austin, Texas, USA.

Thomann, R. V., and O'Connor, D, J., 1970. System Analysis and Water Quality Management, Environmental Science Service Publ. Co., Stanford, Connecticute.