SISTEMA DE AVALIAÇÃO DA QUALIDADE ORIENTADA PELA WEB PARA ÁGUAS SUPERFICIAIS DA BACIA DO RIO

WEB-ORIENTED QUALITY ASSESSMENT SYSTEM FOR SURFACE WATERS OF RIVER BASIN

ВЕБ-ОРИЕНТИРОВАННАЯ СИСТЕМА ОЦЕНКИ КАЧЕСТВА ПОВЕРХНОСТНЫХ ВОД РЕЧНОГО БАСЕЙНА

JAMALOV, Jalal K.^{1*}; NURSEITOV, Daniyar B.²; GOTOVTSEV, Alexey V.³;

^{1,2} Satbayev University, Institute of Information and Telecommunication Technologies, Almaty – Republic of Kazakhstan

³ Russian Academy of Sciences, Institute of Water Problems, Moscow – Russian Federation

* Correspondence author
e-mail: j.jamalov@norlist.kz

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RESUMO

Este artigo apresenta o SaaS (software como serviço) que permite criar modelagem de cenário de transferência de poluição para fontes difusas de poluição usando o exemplo da bacia do rio Ili (República do Cazaquistão). Foi analisado o desenvolvimento de tecnologias que determinam o estado hidrológico do lago e da água. A praticabilidade de modelar as descargas e a distribuição de poluentes foi comprovada. O software FORTRAN (Programa de Simulação Hidrológica), um modelo de computador que nos permite modelar a concentração de compostos de nitrato (NO₃), amônia total e consumo de oxigênio bioquímico com resolução de um dia para o período de 1980 a 2016, foi descrito. O modelo foi calibrado usando os dados de observações de campo de seis postos hidrológicos, o que possibilitou a obtenção de valores satisfatórios de vazão de água. Para trabalhar com o sistema, foi desenvolvida uma interface gráfica que permite ao usuário que não está familiarizado com o software FORTRAN fazer cálculos. Foi implementado um algoritmo para o início automatizado de cálculos de cenário com pós-processamento e apresentação de resultados. A abordagem baseada na Web facilita o acesso multiusuário, único e rápido ao sistema de qualquer lugar do mundo. A eficiência dos resultados da programação foi investigada e a dinâmica das mudanças após o uso do software FORTRAN foi estabelecida.

Palavras-chave: rio Ili, modelagem, poluentes, sistema de informação geográfica, software.

ABSTRACT

This article presents the Software as a service system that allows creating scenario modeling of pollution transfer for diffuse sources of pollution using the example of the Ili river basin (Republic of Kazakhstan). The development of technologies that determine hydrological state of the lake and water in it are analyzed. The practicability of modeling the discharges and distribution of pollutants is substantiated. The FORTRAN Hydrological Simulation Program software, a computer model that allows us to model the concentration of nitrate compounds (NO₃), total ammonium, and biochemical oxygen consumption with one day time resolution for the period from 1980 to 2016 was described. The model was calibrated using the field observations data from 6 hydrological posts, which made it possible to obtain satisfactory water discharge values. To work with the system, a graphical interface was developed which allows the user who is not familiar with the FORTRAN Hydrological Simulation Program software to make calculations. Implemented was an algorithm for automated starting of scenario calculations with post-processing and presentation of results. The web-based approach facilitates multi-user, one-time and fast access to the system from anywhere in the world. The efficiency of results of programming was investigated and the dynamics of changes after using the FORTRAN Hydrological Simulation Program software was established.

Keywords: Ili River, modeling, pollutant, geoinformation system, software.

АНОТАЦИЯ

В данной статье представлена SaaS (программное обеспечение как услуга) система, позволяющая производить сценарное моделирование переноса загрязнения для рассеянных источников загрязнения на примере бассейна реки Или (Республика Казахстан). Проанализировано развитие технологий, которые определяют гидрологическое состояние озера и воды в нем. Изучены текущие данные об исследуемом регионе, а именно о русле реки, озерах, суб-бассейнах и точках сбора метеорологической информации. Были определены входные данные, в том числе цифровая модель рельефа Или-Балхашского региона, карты речных сетей, карты землепользования, карты почв, метеорологические данные. Обоснована целесообразность моделирования сбросов и распространения загрязняющих веществ. Описана, полученная в программном обеспечении Hydrological Simulation Program FORTRAN, компьютерная модель, которая позволяет моделировать концентрацию нитратных соединений (NO_3), общего аммония (ТАМ), и биохимическое потребление кислорода с ежедневным временным разрешением на период с 1980 по 2016 года. Произведена калибровка модели с использованием данных натурных наблюдений 6 гидрологических постов, что позволило получить удовлетворительные значения расходов воды. Для работы с системой разработан графический интерфейс, позволяющий пользователю, не знакомому с программным обеспечением Hydrological Simulation Program FORTRAN, производить расчеты. Реализован алгоритм автоматизированного запуска сценарных расчетов с пост-обработкой и представлением результатов. Веб-ориентированный подход обеспечивает многопользовательский, единовременный и быстрый доступ к системе из любой точки мира. Изучена эффективность результатов программирования и выяснена динамика перемен после использования программного обеспечения Hydrological Simulation Program FORTRAN.

Ключевые слова: река Или, моделирование, загрязняющие вещества, геоинформационная система, программное обеспечение.

1. INTRODUCTION

A web-based system was developed using ASP.NET MVC technology, which provides the possibility to model the concentration of pollution and water flow for any part of the river network for a given time period. The river basin was selected as the region for study, or since the river is one of the largest transboundary rivers connecting the Republic of Kazakhstan and China, and is also one of the most important sources of fresh water for the Republic of Kazakhstan. It provides about 80% of the total water inflow to Lake Balkhash, of which 70% is formed in China (Kovalov *et al.*, 2017; Akbayeva *et al.*, 2019). This is described in detail in these publications (Dostay *et al.*, 2013; Pueppke *et al.*, 2018a). Since the beginning of intensive economic activity, the volume of pollution increased (Pueppke *et al.*, 2018b). A decrease in water flow has provoked a violation of the natural state of the ecosystem, including the hydrological state of the lake (Zonn *et al.*, 2018). With regard of these problems, it is necessary to analyze water consumption, to assess water quality and to apply effective water management (Talismanov *et al.*, 2017; Talismanov *et al.*, 2018a; Talismanov *et al.*, 2018b). The use of GIS technologies significantly simplifies the presentation of spatial information, and also provides a convenient and user-friendly interface for working with geo-data. Figure 1 demonstrates

the starting page of the system, which presents the current data on the studied region, namely:

- 1) the main bed of the Ili River, taking into account external tributaries;
- 2) bathymetry of Lake Balkhash and Kapchagai reservoir, obtained during the field studies described in paragraph 2.5;
- 3) the isolines of Lake Balkhash and Kapchagai reservoir, calculated based on bathymetry data and Landsat 8 image processing;
- 4) Divided into sectors the Ili River sub-basin, obtained as a result of processing digital elevation model and map of the river network described in clause 2.2;
- 5) points of collection of meteorological information obtained for the processing of the European Center for Medium-Range Weather Forecasts (ECMWF Reanalysis datasets ERA-Interim), described in clause 2.2.

Storage and visualization of layers is implemented by Geoserver tools and the OpenLayers open library. To simulate the assessment of changes in concentration of fertilizers, as well as scenarios for reducing the flow of water to the territory of the Republic of Kazakhstan, a hydrological model has been developed. Simulation modeling is considered as an essential methodical supplement for obtaining

information about dynamics of distributed parameters of water bodies. Similar studies assessing water quality using the HSPF model were presented (Alarcon and Sassenrath, 2017). Software integration of the model, as well as recommendations for model calibration are presented (Lampert and Wu, 2015; Lampert and Wu, 2018; Alarcon and Sassenrath, 2016; Alarcon *et al.*, 2017; Terleev *et al.*, 2019). The methodology of research is described in detail in paragraph 2.

2. MATERIALS AND METHODS

In order to create a hydrological model, the following input data were defined in the HSPF software: 1) Digital elevation model of the Ili-Balkhash area; 2) River Networks Maps; 3) Land use map; 4) Soil map; 5) Meteorological data. The algorithm for automated data processing was developed and presented in Figure 2. As can be seen from Figure 2, the following tools were involved in algorithm:

1) The Watershed Delineation Tool (WDT) is a tool implemented in Better Assessment Science Integrating point & Non-point Sources software (BASINS 4.1) (EPA: Better Assessment..., 2019), which provides for the separation of collecting basin into sub-basins, described in section 2.2.

2) Hydrological Simulation Program - Fortran - a program that builds a hydrological model (Donigian *et al.*, 1983).

3) WDMUtil (Watershed Data Management Utility) is an utility for processing time series of meteorological information (Brignoli *et al.*, 2017).

4) Publish module - module of automatic publishing of vector layers at the server

5) Geoserver - a server for storing and presenting spatial information

The mechanism of changing the configuration file User Control Input (UCI) has been implemented via web interface, which allows generating various modeling scenarios.

2.1. Computational tools

By using HSPF, a computer model was obtained for modeling the basin hydrology, diffuse sources of pollution and water quality, Figure 3. Figure 3 shows a model in the HSPF software. But physically, the model is a generated UCI file, which can be changed using any

programming language with the observance of the syntax of the HSPF. The developed writing mechanism, written in the Python programming language, provides the correct file changing, and allows to make changes without opening the software. Figure 4 shows a recording functions.

The `write_to_uci` function writes to configuration file. An entry includes a set of parameters, based on which the function defines the following: 1) the section of river for which the calculation is performed; 2) pollutant, function of pollutant can be used for both point and not point sources of pollution; 3) number of time series in which the result of calculation will be written. The `write_to_wdmout` function creates a time series in the file. A time series must be created for each new parameter written in UCI file, otherwise the calculations will be performed with an error.

In order to obtain most accurate results, the model is calibrated using data from 6 hydrological posts of Table 1 and cross-section data obtained during field observations described in clause 2.4. Table 1 presents the data of hydro stations that constantly monitor the Ili River. They provide the data on hydrological and hydrochemical regimes of the river.

2.2. Processing of data

Data sets (DEM, River net, Land Use) with a spatial resolution of 30 m were used to divide catchment basin into sub-basins. DEM and River net data were obtained from the ASTER Global Digital Elevation Model V2 open database (ASTGTM) and USGS HydroSHEDS. Land use data are taken from the Global Land Cover 2000 Project (GLC 2000) of the Science and Knowledge Service of the European Commission. The results of the processing of land use data are in Table 2, which shows land cover for the studied region. For a visual representation of the land use data, sub-basins were shown in Google Earth software in Figure 5.

As it can be seen from Figure 5, the cover of shrubs, evergreen areas comprise up to 30% of the current cover of the Ili river basin. Grass cover, closed-open areas cover approximately 12% of the catchment area, and tree cover, areas of mixed type of leaves reach up to 8%. Eroded soils and badlands take 32% of the catchment area. Hydrological processes, in its turn, vary over time and depend on changes in the state of environment, and to assess pollution of dispersed sources, a sequence of hourly precipitation, evaporation, temperature, and other meteorological data is required. Table 3 shows all

the meteorological parameters that were used in calculations.

Meteorological data from ECMWF ERA-Interim reanalysis data set for the period 1979–2016 was used. Data from 6 points, which are displayed in Figure 1, were extrapolated to the catchment area. Temperature data were used to estimate potential total evaporation (PEVT) for the catchment of Ili river. The Penman-Monteith equation was used to generate the PEVT dataset to develop the model.

2.3. Hydrological modeling and water quality modeling

A field survey was done to measure the baseline flux as well as to collect water samples and measure the total concentration of pollutants during May-June 2017. During the research work, field data were obtained from 20 cross-sections. Figure 6. Starting from the hydrological border post - the quay of Dubun approximately every 20 km downstream in the straight sections of the river with one canal, transverse profiles were constructed. The cross-sectional area of the river was instrumentally measured to determine the flow of water, which, in turn, is necessary to determine the transferred mass of the solute. Along the entire length of the river, without taking into account the Kapshagai reservoir, in the upper flow of the Ili River, 10 transverse profiles were built (Figure 6: red line with points) before merging with the Kapshagai reservoir, and 9 transverse profiles (Figure 6: green line with points) downstream the Ili River from the Kapshagay HPP to Kunaevsky Automobile Bridge. Samples of water and bottom sediments were sampled for chemical analysis in the stationary laboratory of the Institute of Geography for ionic composition of water (NO_3^- , NH_4^+ , BOD, Ca^{2+} , Mg^{2+} , Na^+ , K^+ , SO_4^{2-} , Cl^- , HCO_3^-) and so on.

These field and laboratory measurements were utilized to partially validate the simulated results. Table 4 shows the data of measurements. As it can be seen from table 3, the concentration of suspended sediments increases with decreasing water consumption, regardless of the direction of movement.

2.4. Development of the web system

The web application was developed on the ASP.NET MVC platform. An ASP.NET MVC application works on the Model View Controller model. This model makes it possible to separate the presentation (interface), model (data) and

application logic into 3 separate components, so that each component can be changed independently, which greatly increases the efficiency and flexibility of the system. The system interface is comprised of two functional parts. The first panel was developed to render the map. All manipulations with geospatial data were visualized for this area (markers, scaling, geolocation, contours, etc.). Another panel was used to display information on both the initial (space-time coordinates) and calculated concentrations of pollutants.

The information panel also allows to see the coordinates of the mouse pointer as it moves around the map. A function that facilitates map display is functionality based on two APIs: ESRI ArcGIS for JavaScript and OpenLayers. Depending on the request, the scripts in the application may work with one or both of them. This makes the system an easy object-oriented technology for embedding maps into web applications.

The scheme of user interaction with system is shown in Figure 7. CreateOrder and ShowResult views were developed for working with the system (Bespalov *et al.*, 2019). The CreateOrder view is for dispersed sources of pollution; it should be selected from the options offered, and for point sources it is possible to create with the designation of the name and the indication of the daily load, Figure 8

The ShowResult view is intended to show the calculation results. The main part of the screen is dedicated to a map with layers of the river basin. The layers are interactive and by clicking on one of them, the information about it can be revealed. The ShowResult view is presented in Figure 9. In the upper right corner there is a panel for managing layers, with which you can enable or disable the corresponding layers. In addition, the results can be displayed as a table by clicking the "View data" button. Initialization of the map and displaying of layers is implemented using the OpenLayers open library:

```
var basemap = new ol.layer.Tile({
  source: new ol.source.XYZ({
    attributions: new ol.Attribution({
      html: 'Tiles &copy; <a
href="http://services.arcgisonline.com/ArcGIS/" +
      'rest/services/World_Imagery/MapServer">ArcGIS</a>'
    }),
    url:
      'http://server.arcgisonline.com/ArcGIS/rest/services/' +
        'World_Imagery/MapServer/tile/{z}/{y}/{x}'
  })
})
```

The source of geo-data is the open source software Geoserver, integrated with PostgreSQL DBMS, Figure 10. The layers that have been manipulated in Geoserver can be obtained via Web Map Service WMS protocol:

```
var wmsUrl = '@geoserverUrl/geoserver/localhost/wms';
var meteoLayer = new ol.layer.Tile({
  visible: true,
  source: new ol.source.TileWMS({
    ratio: 1,
    url: wmsUrl,
    params: {
      'LAYERS': 'localhost:balkash_meteo',
      'FORMAT': 'image/png',
      'VERSION': '1.1.1',
      'STYLES': '',
      'SERVICE': 'WMS',
      tiled: true,
    },
    serverType: 'geoserver'
  })
},
  zIndex: 3
});
```

In addition to the basic map, there are three more layers: a layer of catchment basins, a layer of river sections and a layer of meteorological data points. These layers are requested from the web application controller, which, in turn, receives them from Geoserver and sends them to display, where they are shown as vector images.

2.5. Scenario calculations

The performed scenario calculations are aimed at predicting changes in ecology of the Ili-Balkh region in order (hypothetically) to reduce the likelihood of depletion of Lake Balkhash. Four technical reports (Pueppke *et al.*, 2018a; Zonn *et al.*, 2018; Severskiy *et al.*, 2016; Propastin, 2012) were employed to approximate “natural” conditions (that is, not disturbed by human activity). Besides increasing anthropogenic load, there are natural factors that reduce inflow, such as climate change and changes in the glaciers of the basin, described in detail in the report (Severskiy *et al.*, 2016). Based on the report data, glacial systems in large basins, such as Balkhash (Central Asia), change simultaneously, linearly and with identical speeds. The average reduction rates of the Zailiysky – Kungei glaciers (the mountain system of Tien Shan, Central Asia) and the upper reaches of Ili for the period 1955/56–2008. amounted to 0.76%, 0.75% and 0.73% per year, respectively. The decrease in water inflow will cause a decrease in the level of Lake Balkhash, which will bring the following problems: increasing water salinity; increasing

the concentration of pollutants; desertification of the area.

The research described in the report (Propastin, 2012) show that the maximum value of the absolute height of a water mirror was observed in July 2005 with a value of 342.52 m. This level of water in the lake was accompanied by an increased amount of sediment and temperature. This research will be taken into account for the further development of the hypothesis. Therefore, the following experiments will be conducted: 1. scenario with decreasing inflow by 13%, increase in precipitation; 2. scenario with decreasing inflow by 22%, reduced evaporation value; 3. scenario with decreasing inflow by 28%.

3. RESULTS AND DISCUSSION:

3.1 Results of simulation with reduced inflows

The monthly average water inflow for July 2005 was - 29,420 cubic feet per second or ~ 900 cubic meters per second (m^3 / s). The Figure 7 represents that at the maximum level, the average annual inflow into the lake is ~ 500 cubic meters per second. Although, the shallowing dynamics of the lake were observed until 2004 (Guillaume and Rizzolio, 2004). Losses were estimated at approximately 150 square kilometers of water surface. Accordingly, the hypothesis that when the inflow value is $500 \text{ m}^3 / \text{s}$, the maximum value of the lake level is reached. Figure 11 shows the results of inflow modeling at the river mouth.

Water inflow determines the amount of water flowing through the cross-sectional area of flow per unit of time. There is a pronounced low value of water inflow in 1991, due to low precipitation and high evaporation. The reverse situation was monitored in 2002, when high precipitation and low evaporation were recorded. In general, the average value of the water inflow is around ~ $450 \text{ m}^3 / \text{s}$.

3.2. Results of modeling changes in concentration of nitrogenous compounds

Figure 12 presents modeling of BOD (biochemical oxygen demand) for 3 scenarios. The mass concentration of oxygen dissolved in water, which is necessary under certain conditions of biological oxidation, is turning into water by organic and / or inorganic substances. Figures 13 and 14 sum up the annual volumes of nitrogenous compounds calculated using water consumption. In conditions of the considered

scenarios, where this influence (exact discharges) is not taken into account, the initial sources were expressed in increasing concentration with decreasing amount of water in all three scenarios, Figures 12, 13, 14. In the presence of external discharges this ratio will be even greater.

The dynamics of increasing BOD concentration is observed in conditions of decreasing water inflow, so an increase in concentration will entail a disruption of the biological self-purification process of the reservoir. The processes of biological self-purification are associated with consumption of oxygen dissolved in the water of the reservoir. To prevent disruption in the oxygen regime in a water body, the amount of organic matter entering the water bodies with sewage should not exceed a certain value corresponding to the amount of oxygen coming from the atmosphere. With the increase in household load the use of nitrate fertilizers increases, which in turn leads to an increase in the concentration of nitrogenous compounds in the water. Therefore, the dynamics of a sharp increase in the concentration of NO_3 and NH_4 in 1991 under conditions of low consumption were monitored. The specifics of increasing concentration prevail in each of the scenarios.

4. CONCLUSIONS:

This study shows that a web-based approach makes it easier for users to work with models targeted for specialized users. The implementation of this system allows users who have no experience with BASINS or HSPF to make scenario calculations. In the current implementation, only one geographic region has been considered, but thanks to MVC technology, it will be sufficient to add a new hydrological model for another region and it will not take much effort. The hydrological model and sediment transport model presented in this study can provide good estimates of sediment concentrations and inflow values on a daily, monthly, and annual time scale. The model calculates the total concentrations of pollutants that follow a seasonal pattern corresponding to what actually happens in the Ili river basin. The peak precipitation concentration values coincide with peak fluxes. This demonstrates that higher loads and deposits are formed during events with low flow rates. Scenarios 1, 2 and 3 decrease the power of peak flow events. While decreasing flow peaks, these scenarios also lead to an increase in pollutant concentrations. Scenario 3 provides

the highest concentration for each year. The maximum increase for indicators is following: 1) BOD (biochemical oxygen demand) - in 2002, with an increase in water consumption - by 37%; 2) NO_3 (nitrates) - in 1991, at the lowest water consumption - by 39%; 3) TAM (Ammonium ion (NH_4^+)) - in 1992, with a reduced water flow rate - by 22%

In conclusion, the results of scenario modeling demonstrate that the hypothesis is correct in terms of reducing the volume of peak flows in total flow, i.e. If the drainage basin of the Ili river is restored to the approximate initial (natural) discharge of water, sediment transport and water will be more appropriate in current land use / land cover conditions.

5. ACKNOWLEDGMENTS:

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Figure 1. Start window of the system with current data on the region

Figure 2. Schematic representation of calculation algorithm

Figure 3. Computer model of the Ili river basin

```

File Edit Format Run Options Window Help
import os, sys, re, datetime
def write_to_uci(ucifile_path, operation_type, operation_number,
                operation_section, section_variable_name, dataset_number, constituent_name):
    # -operation type (e.g., PERLND, IMPLND, RCHRES)
    # -operation number (e.g., 101, 102)
    # -operation section (e.g., PWATER, SEDMNT, HYDR)
    # -section variable name (e.g., PERO, SURO, SURS)
    if os.path.isfile(ucifile_path):
        try:
            file=open(ucifile_path,"r")
            indata=file.read().split('\n')
            outdata=""
            for line in indata:
                ext_target_line = re.search("END EXT TARGETS", line)
                if ext_target_line is None:
                    outdata+=line+"\n"
                else:
                    outdata += operation_type + " " + operation_number + " " + operation_section + " " + section_variable_name + "
                    | 1 AVER WDM1 " + dataset_number + " " + constituent_name + " 1 ENGL AGGR REPL\n"
                    outdata += "END EXT TARGETS \n"
            file.close()
            file=open(ucifile_path,"w")
            file.write(outdata)
            file.close()
        except:
            exit(1)

def write_to_wdmout(wdmfile_path, scenario, location, dataset_number, constituent_name):
    from pyhpf import WDMUtil
    wdm = WDMUtil()
    if os.path.isfile(wdmfile_path):
        try:
            wdm.open(wdmfile_path,'rw')
            #dsns = wdm.get_datasets(wdmfile)
            #print(dsns)
            #tstypes = [wdm.get_attribute(wdmfile, n, 'TSTYPE') for n in dsns]
            #print(tstypes)
            attributes = {
                'TSTYPE': constituent_name,
                'TCODE': 4,
                'TSTEST': 1,
                'TSTFORM': 1,
                'IDSCEN': scenario,
                'IDLOCN': location
            }
            wdm.create_dataset(wdmfile_path, dataset_number, attributes)
            wdm.close(wdmfile_path)
        except:
            exit(1)

```

Figure 4. Screenshot of UCI file write code

Figure 5. Land use and land cover map for the Ili river catchment area. The research area is covered mainly by shrubs, patches of stony and eroded soil. For the purpose of hydrological modeling, the catchment area was divided into 7 sub-basins (red lines)

Figure 6. Geolocation of data collection points

Figure 7. The diagram of sequence

Figure 8. CreateOrder view

Figure 9. ShowResult view

Type of	Headline	Title	Storage	Included	Native SRS
	balkash_isolines	localhost:balkash_isolines	postgres_database	✓	EPSG:32643
	balkash_meteo	localhost:balkash_meteo	postgres_database	✓	EPSG:32643
	balkash_rivers	localhost:balkash_rivers	postgres_database	✓	EPSG:32644
	balkhash	localhost:balkhash	postgres_database	✓	EPSG:32643
	balkhash_bathymetry	localhost:balkhash_bathymetry	postgres_database	✓	EPSG:32643
	kapshagai_bathymetry	localhost:kapshagai_bathymetry	postgres_database	✓	EPSG:32643
	kapshagai_topo_isolines	localhost:kapshagai_topo_isolines	postgres_database	✓	EPSG:32643
	river_net	localhost:river_net	postgres_database	✓	EPSG:32643
	sub_basin	localhost:sub_basin	postgres_database	✓	EPSG:32643
	sub_basin_3857	localhost:sub_basin_3857	postgres_database	✓	EPSG:3857

Figure 10. Layers published in Geoserver

Figure 11. Results of water inflow modeling (m^3 / s)

Figure 12. Results of BOD concentration modeling (mg / L)

Figure 13. Nitrate modeling results

Figure 14. Total Ammonia modeling results

Table 1. The main points of quality control of surface waters in the Ili river basin

Waterbody code	Location	Post code	Distance from the outfall, km	Catchment area, square km
113200001	pier dobyn	14003	723	64388
113200002	Tekes village	14022	331	1770
113200001	164 km above the Kapchagai hydroelectric station	14004	607	85400
113200483	Malybay village	14160	40	4300
113200001	Kapchagai hydroelectric station	14011	434	111000
113200001	Ushzharma village	14014	264	129000

Table 2. Land use and land cover in Ili river catchment

Land use or land cover	Percent cover
Shrub Cover, closed-open, evergreen	30%
Bare areas	32%
Herbaceous cover, closed-open	12%
Tree Cover, regularly flooded, saline water	2%
Tree Cover, mixed leaf type	8%
Shrub Cover, closed-open, deciduous	9%
Others	7%

Table 3. Meteorological data

Data set	Description of parameter
PREC	Amount of precipitation (mm / hour)
CLOU	Overcast (0-10)
ATEM	Air temperature (°F)
WIND	Wind speed (mph)
SOLR	Solar radiation (MJ / m ²)
PEVT	Evaporation (inches)
Dewp	Temperature of dew point

Table 4. Measured stream flow and total suspended sediment concentration at or near the Ili river delta

Location	Stream flow (m ³ /s)	Total suspended sediment (mg/L)
Downstream	400	860
Upstream	500	780
Upstream 1	480	820
Average	460	820