Support to the Caspian Centre for Water Level Fluctuations

Progress Report, September 2003

UNOPS

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1 INTRODUCTION

This Progress Report describes the work performed during the period 15 July to 15 September on the project *Support to the Caspian Centre for Water Level Fluctuations* under contract RER/03/Q08/WQ/31 between DHI Water and Environment (DHI) and United Nations Office for Project Services (UNOPS). The overall project period is from 15 July 2003 to 15 January 2004. A Final Report will be prepared by the end of the project period.

The work has been conducted by DHI, Denmark as consultant and the Caspian Centre for Water Level Fluctuations (CCWLF) in Almaty, Kazakhstan as sub-consultant.

These experts and specialists from CCWLF have contributed to the report:

Madi Kireyev:	Local coordination
Natalya Ivkina:	Storm surge modelling
Tatyana Stroyeva:	Storm surge modelling
Tatyana Gorkunova:	Hydrometeorological database

2 BACKGROUND

The Caspian Centre for Water Level Fluctuations (CCWLF) was established in 1998 with funding from the EU TACIS Programme, as part of the TACIS support to the first phase of the Caspian Environment Programme (CEP). It is situated in the offices of KazNIIMOSK, a research institute for environment monitoring and climate in Almaty, Kazakhstan, coordinated since 2000 through KazHydromet, a state-owned institute affiliated to the Kazakhstan Ministry of Ecology.

The TACIS support to the CCWLF was provided through a series of projects, the last of which ended in December 2001. The ToR for the last of these projects had as one of its objectives to assist each of the four TACIS-supported Caspian Centres[1] to become sustainable (i.e. less donor dependent) by developing business plans. At the end of 2001, this objective had not been achieved for the CCWLF, and no business plan for the future had been developed. A request for financing to continue the work of the CCWLF was forwarded to the Ministry of Ecology, but this request came too late in order for funding to be set aside in the government budget for 2002-2003. From December 2001 until summer 2003, the staff of the CCWLF worked to keep the Centre intact and to carry out daily key analyses.

The TACIS -supported work at the CCWLF has focused on two areas:

(1) the development of a state-of-the-art Grid Model for the Caspian region that integrated the latest climate change models and facilitation of twice-yearly meetings of the national experts from all littoral countries to review data and develop regional consensus on water level fluctuation trends;

(2) the development of capacity for daily forecasting of probabilities of storm surges five days into the future, so that warnings could be provided to local authorities in vulnerable areas in time to take preventive actions (Storm Surge Warning Centre).

The first area of work is regional in nature and heavily dependent on costly input from scientists in St. Petersburg and Great Britain. Continuation is unlikely without significant long-term donor support. The second area of work, however, has particular national importance, because of the vulnerability of Kazakhstan's low-lying Caspian coastline to storm surges.

The purpose of this project is to provide short-term technical assistance and other one-time support to the CCWLF to enable the Storm Surge Warning Centre to become fully operational and to sustain it until January 2004, when national funding is hoped to be available.

[1] During this period (1998-2001) TACIS also supported three other Caspian Centers: CC for Pollution Control in Baku, CC for Management of Bioresources in Astrakhan, and CC for Combatting Desertification in Ashgabad.

3 STATUS OF TASKS

The project has been divided in the following tasks:

- **Produce daily water level forecasts**. On the basis of digital meteorological data received from the European Centre for Medium-Range Weather Forecasts (ECMWF), Great Britain, carry out daily computer simulations of storm surge forecasts for the Kazakh coast of the Caspian Sea;

- **Update the existing storm surge model**. Adapt the storm surge warning model to take account of seasonal particularities such as ice cover, river inflows, evaporation and precipitation;

- **Develop quality check methods** for water level forecasts;

- **Update hydrometeorological database** held by the CCWLF by correlating hydrometeorological parameters among the basin stations and interlink this data with maps in ArcView format;

- **Prepare a business plan** for establishment of a Centre on storm surges on the basis of the CCWLF and within the framework of the National Caspian Action Plan (NCAP) of the Republic of Kazakhstan.

The status of each task is described below.

3.1 Produce Daily Water Level Forecasts

As part of the TACIS project an operational storm surge model has been established at the CCWLF. The model is based on DHI's 2D hydrodynamic model, MIKE 21. This model has been used on daily basis to produce 5-day forecasts of storm induced surges in the Caspian Sea.

The model is forced with meteorological forecast data of wind and air pressure. These data are received on a daily basis from the European Centre for Medium Range Weather Forecasts (ECMWF, UK). At present, data are received at no cost due to the lack of funding.

Within the project period water level forecasts will be prepared and issued daily. This work has already started and is continued on a daily basis.

The following procedures are applied daily to produce the water level forecast:

1. Downloading of meteorological analysis and forecast data from UK.

2. Converting of the meteorological data into the Caspian Sea model grids and MIKE 21 data format.

3. Running the hydrodynamic model. The model is executed using a Windows Dialog Shell, *ForeCasp*, see Figure 3.1.

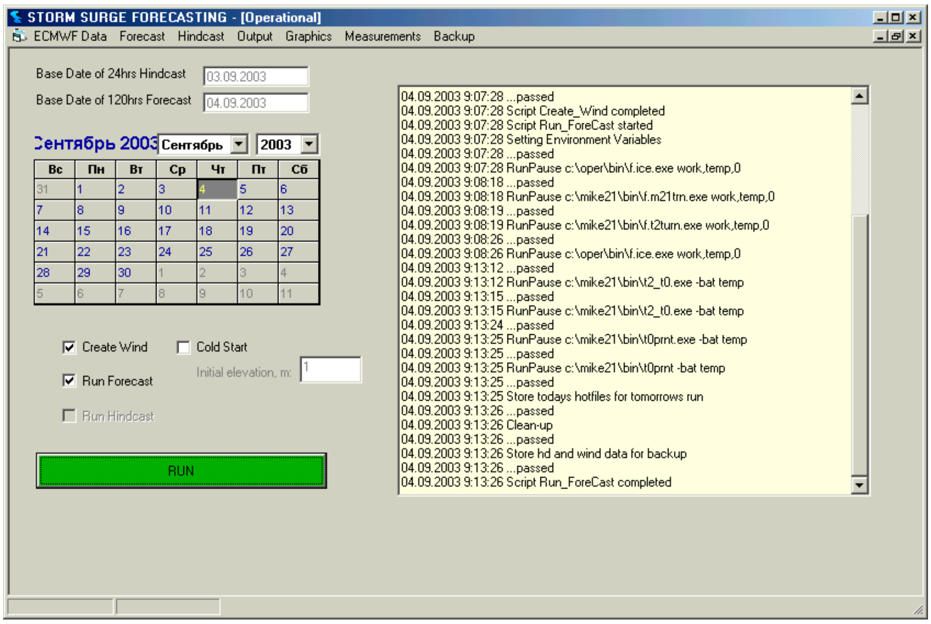


Figure 3.1 Window dialog used to execute the hydrodynamic forecast model of the Caspian Sea.

4. Extracting time series of water levels from the model results at selected locations (stations).

5. Receiving (by email) latest observations of water levels from available stations at the Caspian Sea. At present, data is received from these Kazakh stations: Peshnoy Station, Kulaly Station and Fort-Shevchenko Station.

6. Reading model results and measurements into Excel spreadsheets for further processing. An automatic routine has been developed for this purpose, see Figure 3.2.

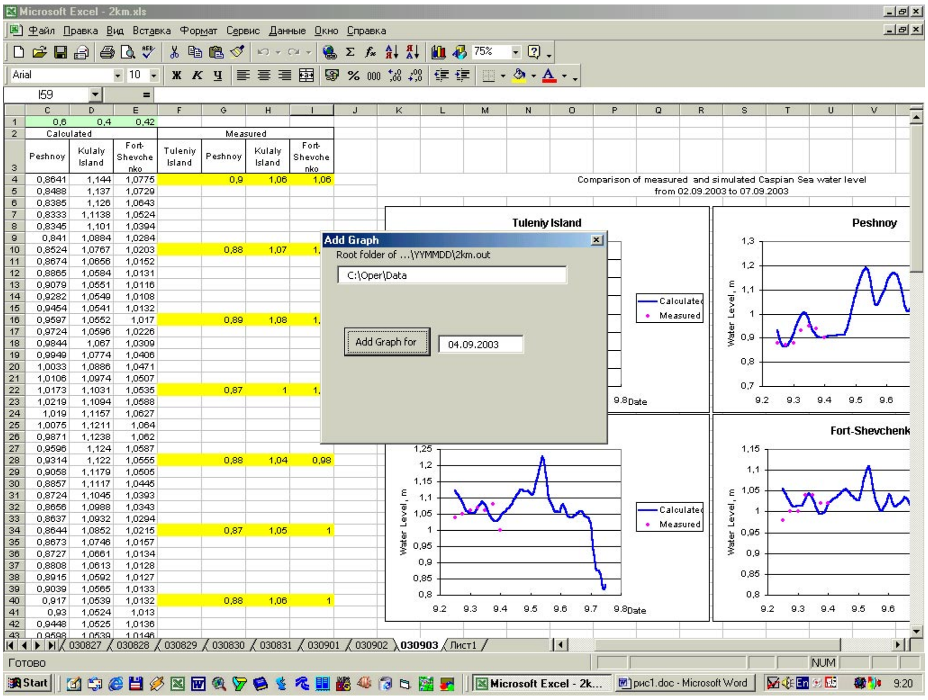


Figure 3.2 Automatic chart creation in Excel of calculated sea level forecast and observations for available stations.

7. Prepare a water level forecast bulletin and distribute it to the authorities in Atyrau and in Almaty.

The daily forecasts are produced using the latest and most updated version of the storm surge model.

3.2 Update the Existing Storm Surge Model

The version of the storm surge model applied at present does not include the effects of river inflow, evaporation, precipitation and ice-cover.

The short term fluctuations created by the wind (storm surges) are included, but to predict the absolute water level also the long-term variations (seasonal variations) or water balance elements need to be included.

Data for river inflow, evaporation and precipitation were established As part of the TACIS project. As part of the present project these data will be processed and implemented in the operational storm surge model. As access to actual data is not possible the data will consist of climatological values calculated as monthly averages over a series of years.

During the winter period the northern shallowest part of the Caspian Sea is covered by ice. An effect of such ice cover is that the water level fluctuations (variations) are dampened. This effect will also be implemented in the operational storm surge model.

The extent of the ice cover will be determined based on in-situ observations from Peshnoi and from satellite data already available at KazHydroMet in Almaty.

The updated and improved model will be verified running a 12-month hindcast period. The period 1 August 2002 to 1 August 2003 has been selected for this purpose.

Implementation of the water balance elements has already been started. At present data from the TACIS project are being analysed for preparing the monthly averages (climatological) data of river inflow, evaporation and precipitation.

The 6-hourly meteorological ECMWF data covering the Caspian Sea for the verification year have been processed and prepared for model testing.

The following model tests with the storm surge model for the verification year are planned:

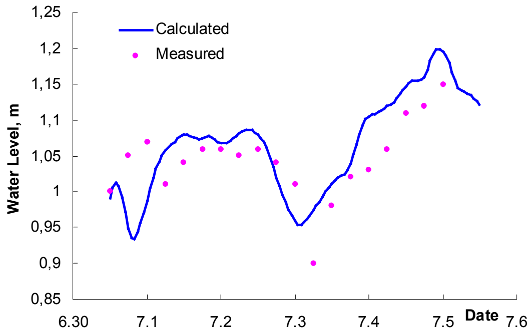
- Simulation with the present set-up.
- Simulation including river inflow.
- Simulation including evaporation and precipitation.
- Simulation including ice effects.
- Simulation including all water balance elements (river inflow, evaporation and precipitation).
- Simulation including all effects (river inflow, evaporation, precipitation and ice cover).

Thus it is possible to separate the improvements gained by each item.

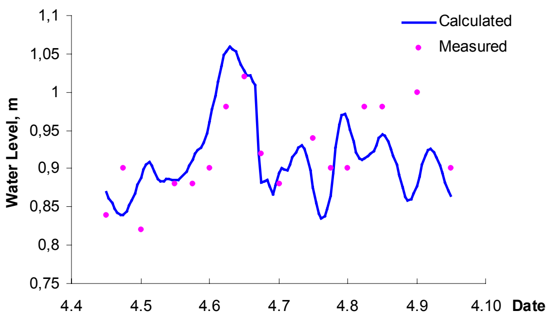
Results of calculated water levels (surges) for selected stations will be compared with actual measurements for verification of the implemented improvements. When the verification is completed the updated surge model will be applied on a daily basis for the production of the operational forecasts.

3.3 Develop Quality Check Methods

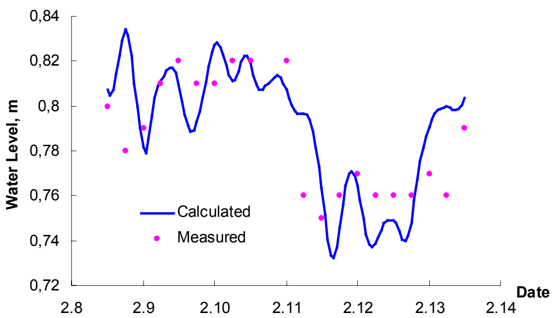
The quality of the produced forecasts can be checked in different ways. The simplest way is by comparing simple time series of calculated and measured water levels. Most checks until today have been based on this simple approach. Examples are shown in Figure 3.3.



Example of the water level forecast at Peshnoy Station



Example of the water level forecast at Kulaly Station



Example of the water level forecast at Fort-Shevchenko Station

Figure 3.3 Examples of comparison of calculated and forecasted water levels.

Each time series represents a daily simulation of 6 days (from -24 hours to +120 hours) which covers a one-day hindcast (-24 hours to 00 hours based on meteorological analyses) and a 5-day forecast (00 hours to +120 hours based on meteorological forecasts).

The uncertainty related to the meteorological forecast is included in these figures and accordingly these figures are not very suitable for an objective quality assessment.

More sophisticated comparisons will be introduced during the present project:

The quality of the forecasts will be estimated based on all produced forecasts (about 180 for the 6-month project period).

Calculated water levels every 12 hours (00, +12, +24,…..+120) from each of the forecasts will be extracted. All values at time 00 (ie. hindcast values) will be put together to form a time series (the time step becomes 24 hours = the time interval between each forecast simulation). The same will be done for the values at +12 hours, for +24 hours, etc.

Each established time series of model results will be compared to actual measurements in the form of a scatter-plot (x-y-plot of measured water level versus calculated water level) for each forecast lead-time as well as a calculated correlation coefficient. The final result will be an overview of the reached forecast quality for the lead time: 00 hours (hindcast), +12 hours (short term forecast), +24 hours,....120 hours (long term forecast). The correlation coefficient is expected to be slowly decreasing from 00 hours to approximately +48 hours and faster towards +120 where the accuracy of the meteorological forecast (ECMWF) is expected to decrease.

To get a visual impression of the forecast quality also "normal" time series plots with direct comparisons will be prepared of these data and statistical measures like Mean Absolute Error (MAE) and Root Mean Square Error (RMSE) for each lead-time will be calculated.

As measured water levels are available at a few forecast stations, it is possible to improve the operational forecasts (the water level time series) further using this information. The improvements gained using this information to adjust the starting conditions (the water level offset) of the daily forecast at these stations will be evaluated.

3.4 Update Hydrometeorological Database

Status after TACIS Project

The database "Hydrological and Meteorological Data for the Caspian Sea Basin" has been developed within the framework of the CEP TACIS project at the CCWLF with the aim of entering, storing, processing, analyzing, printing and mapping the information available for the Caspian Sea Basin.

The database consists of the following blocks:

- meteorological data (data, graphs, and reports)
- hydrological data (data, graphs and reports)
- Caspian Sea (data)
- Schemes (maps)
- Additional data (data)

The database has been implicated in Microsoft Access-97 for Windows 98 and developed in the form of linked tables with a user-friendly interface allowing the overviewing, editing and printing of hydrometeorological data as well as characteristics of hydrological and meteorological stations. There is a large flexibility and many possibilities for grouping and analyzing initial data in informational tables as well as in diagram plotting mechanism.

The information system allows receiving station data, displaying graphs, printing hard copies and exporting to Excel.

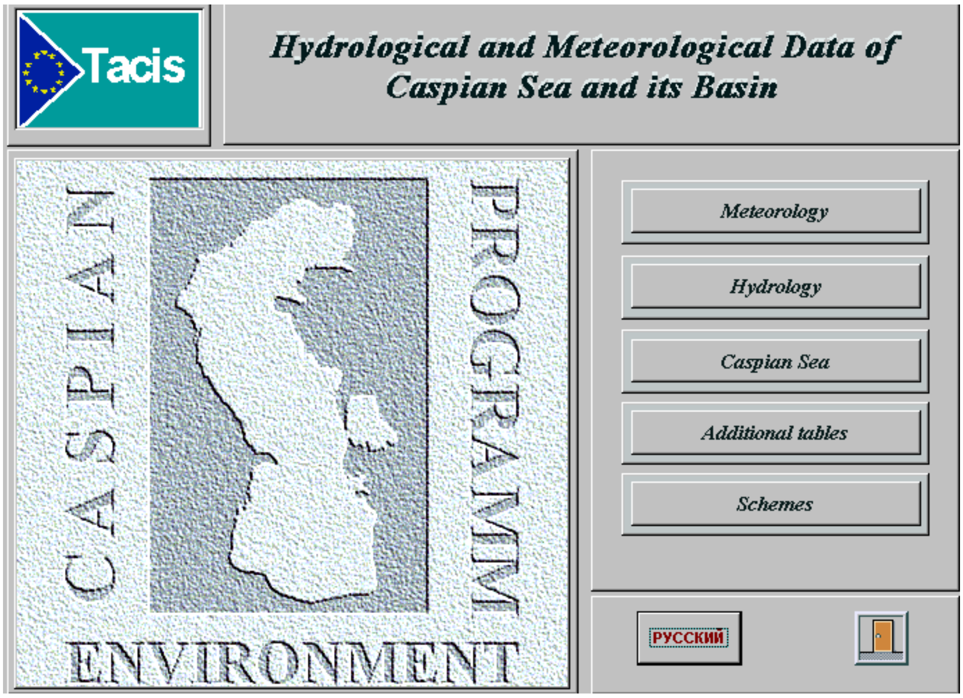


Figure 3.4 Hydrological and Meteorological Data of the Caspian Sea Basin

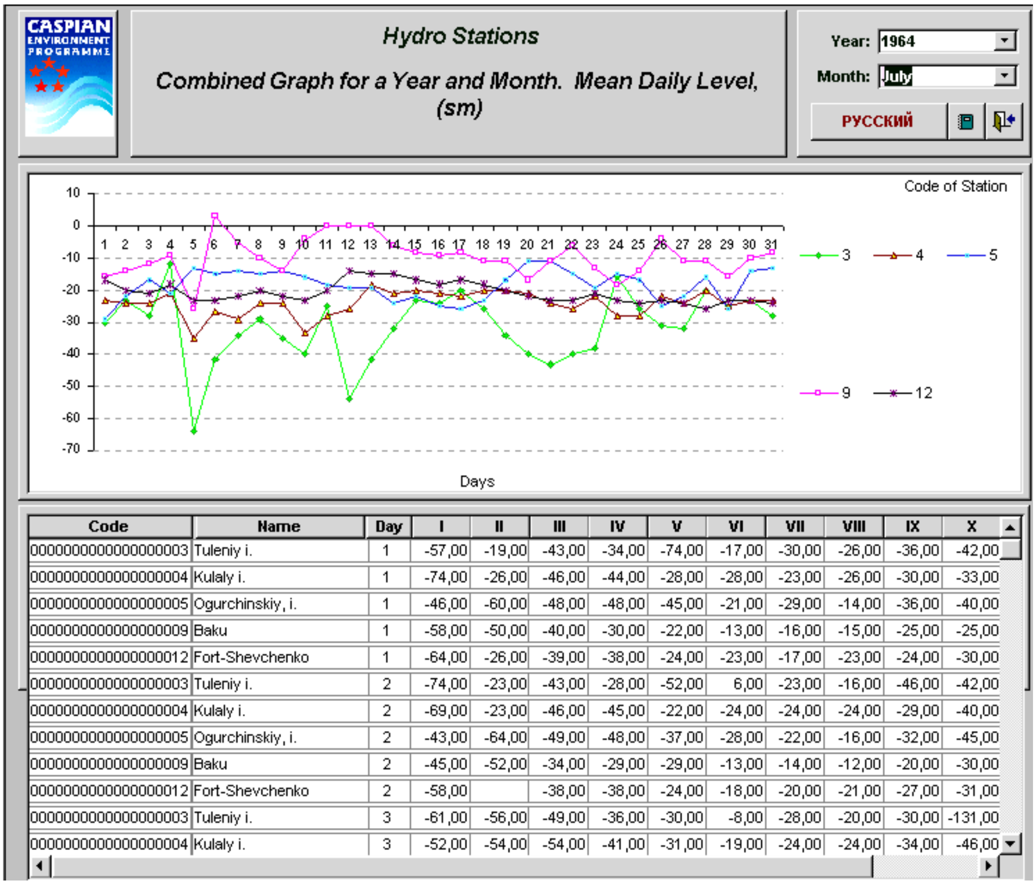


Figure 3.5 Example of combined water level graph for several stations (July 1964).

Table 3.1 List of the Parameters available in the "Hydrological and Meteorological Data for the Caspian Sea Basin"

Data Type	**Periodicity**
Air Temperature	Daily, Monthly, Annual
Water Temperature	Daily, Monthly, Annual
Solar radiation	Monthly
Precipitation	Monthly
Relational humidity of air	Monthly
Wind Velocity	Daily, Monthly
Cloudiness	Daily, Monthly
Discharge (m^3/s)	Daily, Monthly
Flow (km^3)	Monthly
Water Level	Daily, Monthly
Evaporation	Monthly

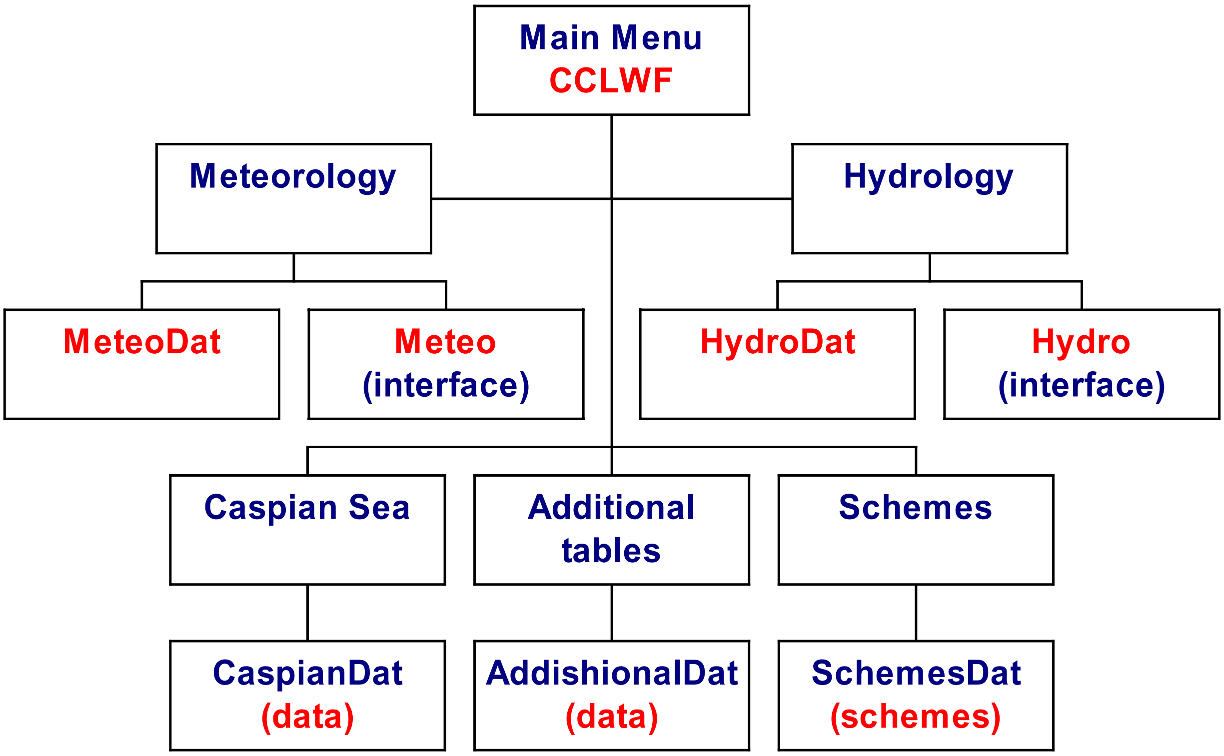


Figure 3.6 Scheme of Information System of the Meteorological and Hydrological Database for the Caspian Sea Basin

Improvements

The database has been further developed within the present project.

A main update consists of using ArcView software to get more demonstrative and attractive displays of the hydrometeorological information available.

ArcView maps are based on spatial data. Spatial data is data containing the geographic location of features on the earth's surface, along with attribute information describing what these features represent.

New updates are:

1. Transformation of database from Microsoft Access-97 for Windows 98 to Microsoft Access-2000 for Windows 2000.

2. Studying ArcView GIS software for creation of the Caspian region maps.

3. Selection of new spatial data:

    - Spatial data from ArcView cd-rom (from the projects "World", "Europe");

    - Spatial data created within the framework of the Caspian Ecological Program (from the projects "Caspcat", "Volga");

- Free-of-charge spatial data from the Internet (the entire Caspian Sea, the entire Volga).

4. Selection of cartographical units for definition of a map scale (decimal degrees).

5. Installation of measurement units for the display of measurements and distances on maps.

6. Select of a map projection. In result analysis of Data Base CCWLF information (co-ordinates of basic hydrometeorological items) the case of display of the data without definition of a projection at present is select (coordinates of a longitude are transformed to x, y-coordinates).

7. Creation of the first version of Caspian Sea maps by ArcView tools.

8. Creation of new and editing existing map layers for presentation.

Examples of maps created are shown in Figures 3.7 to 3.9.

Figure 3.7 Fragment of the Caspian Countries Map

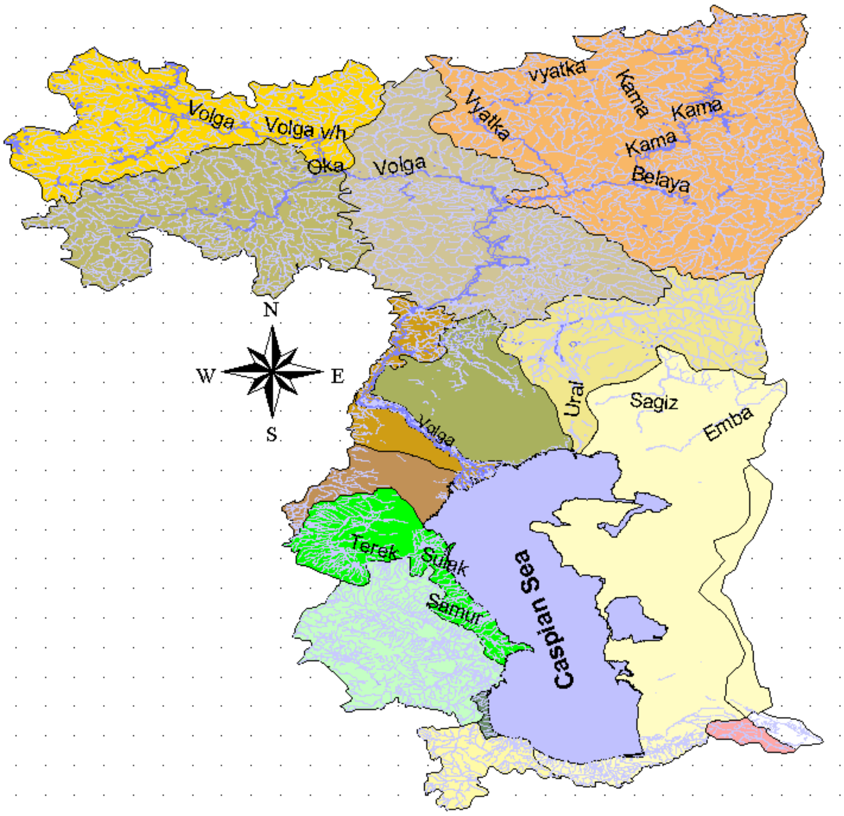


Figure 3.8 Caspian Region Map (draft)

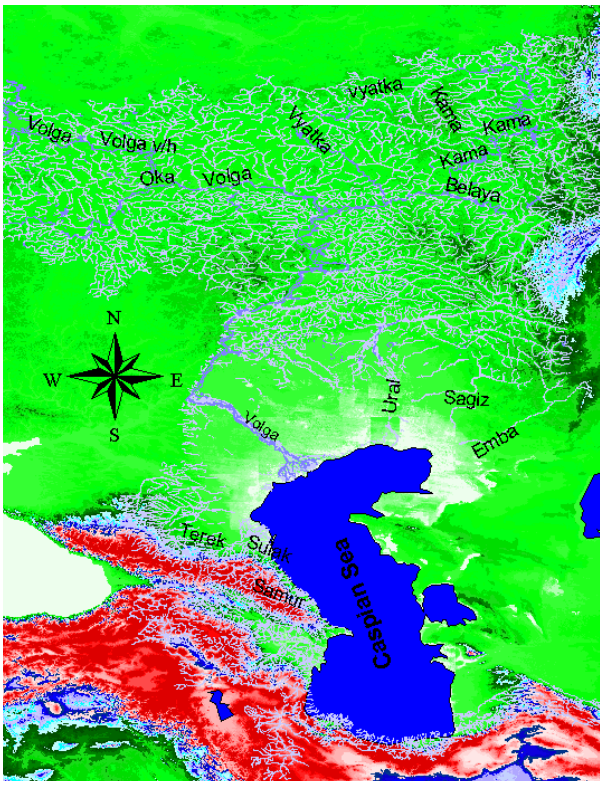


Figure 3.9 Caspian Region Relief Map

Future Improvements
Further planned improvements within the project are listed below:

1. Improvements of database:
   - Module structure optimisation, destruction of unused procedures and variables;
   - Regular viewing of programs and deletion of out-of-date blocks;
   - Updating of data.
2. Increase of map load.
3. Formations of ArcView Project for the Caspian region.
4. To attach the database to ArcView, using a communication facility.
5. To include hydrometeorological supervision points from the database to the ArcView map.
6. Classification of hydrometeorological supervision points and the display of this classification using ArcView.
7. Output of hydrometeorological stations' attributes using the ArcView map.
8. Location of some ArcView maps to "Schemes" section of database.

Basically, these improvements include that more available historical data enter the database and that data from the database is accessible through clicking on the maps in ArcView.

3.5 Business Plan

Work on preparing a business plan for the CCWLF has commenced. Below is a draft *List of Contents*.

1. Name and address of project applicant
2. Brief Information about the Water Level Fluctuation Center
3. Business Plan Purpose and Center Tasks
4. Economical situation, which applies to the project
5. Prognosis of services provided for the potential consumers
6. Project financing
7. Analysis of service market capacity, competition status
8. Main advantages of proposed project

9. Main barriers for project implementation

10. Strategy and project promotion program, submitted feasibility study implementation

A draft version of the first five sections is given below:

1. Name and Address of Project Applicant

Water Level Fluctuation Center at Caspian Environmental Program

Kazakhstan, Almaty, Seifullin Ave., 597

2. Brief Information about the Water Level Fluctuation Center

The Sea Level Fluctuation Center was created in November 1998 under the financial support of the TACIS program. The Center performed work on the issues of Caspian level fluctuations (in short-term, seasonal and long-term periods). Development according to the Caspian Environmental Program tasks include, in particular, the following issues:

- Analyses of causes of current sea level rise;
- The development of methods for the calculation of the water balance elements to include evaporation, precipitation and inflow from the Volga and other rivers;
- The assessment of air circulation impact on the water balance elements;
- The research of long-term seasonal and non-periodical water level fluctuations
- The modelling of storm surges/retreats;
- The establishment of a sectional model for the Caspian Sea basin "Grid–model".

3. Business Plan Purpose and Center Tasks

The current phase of the Caspian Sea level rise resulted in the watering of extended lands and provided serious environmental problems for five Pre-Caspian states. These problems dictate the necessity to develop and perform the strategy of the Caspian region sustainable development plan. Sustainable development of Pre-Caspian states is impossible without a united sea level monitoring system or prognoses of its fluctuation for the nearest and long-term outlook. At the present time the sea level monitoring network in all states, except Iran, is significantly reduced and runs based on out-of-date technology with gross distortions of monitoring data. Forecast centres in the individual states are not equipped with up-to-date computers or work stations and need radical improvements of information exchange and prognosis systems.

In conjunction with this all Pre-Caspian states need to review existing measurements, notifications and prognosis and prepare recommendations on the optimisation of the hydrometeorological monitoring network in order to introduce the united automated Caspian Sea level monitoring system.

Pre-Caspian region nature users need reliable sea level prognoses. Settlements and industrial facilities are flooded, communications, including water supply systems, are disturbed owing to the rise of the background sea level. All of this requires several research projects for scientific sea level prognosis development.

The periodical rise and fall of the water level under the wind impact, so-called storm surges/retreats, is typical for Caspian Sea. They have significant impact on the coastal infrastructure of all Pre-Caspian states. This is especially the case with Kazakhstan and Russia, located within the area of Pre-Caspian lowland, which are most of all liable to flooding by seawater (up to 30 km) during storm surges/retreats. Thus, the results of the Storm Surge Center activity should be the following:

- Providing Pre-Caspian states with effective and periodical sea level information on the basis of a united automated monitoring system;
- The notification of Pre-Caspian states with reliable prognoses of coastal flooding for the nearest and long-term outlook;
- The development of steps to protect nature through sustainable development of the coastal area using Caspian Sea Geographic Information System and submitting these to the Pre-Caspian state governments.

For these purposes the work should focus on the following activity types:

1. Continuing the work with various climatic models and alternative prognosis methods. Further research on the adaptation of a hydrological Network Model for the Caspian Sea basin;
2. Improvement of the database and hydrometeorological information system with the introduction of GIS;
3. The transfer of software and information to the Pre-Caspian states;
4. The development of sea level prognosis methods for the nearest and long-term outlooks using the general air circulation model;
5. Additional MIKE 21 storm surge modelling in order to:
    - Assess the Northern Caspy coast flood through various scenarios;
    - Estimate the probabilistic features of surges for various coastal areas;
    - Prepare maps of coastal flooding and drying during surges/retreats;
    - Propose the system of flood prevention.

This business plan is proposed in order to solve the above-mentioned needs.

4. Economical Situation, which Promotes the Project

The Caspian region of the Republic of Kazakhstan, which is an oil-gas producing area, has experienced a rapid development over the last ten (10) years. The hydrocarbon production volume in only two coastal areas – Atyrau and Mangistau – has increased more than fourfold and reached about 30 million tonnes by 2002. Potential hydrocarbon reserves in the Kazakhstan sector of the Caspian Sea will allow the production of oil in the future on a level of 150-200 million tonnes and will maintain this level for 25-30 years. As a result, a high-capacity oil-gas coastal infrastructure, oil field facilities, oil-pipeline network, transport communications, municipal and social facilities will be constructed. Aktau, Bautino, Kuryk and Atyrau ports will be significantly developed. A program for the development of the Northern Caspy area suggests the construction of 56 oil platforms and artificial islands before the year 2015. More than 1100 oil-gas wells are planned to be drilled. About $32 billion are planned to be invested during the period 2003-2015. Infrastructure facilities will mainly be within coastal areas, which are liable to periodic storm surges/retreats and are required to develop an early warning system and make protective arrangements. According to the State Program for Caspian Sea Kazakhstan Sector Development, the infrastructure development is to take into account the fluctuations in the sea level of the Caspian Sea. For these purposes the Storm Surges Center and its activities are greatly required.

5. Prognosis of Services Provided for Potential Consumers

For the planning of works in the Pre-Caspian region it is necessary to develop regional and industrial programs to solve the task of scientifically developing the hydrocarbon reserves in the Kazakhstan sector of the Caspian Sea. In order to do this and to develop the industrial and social infrastructure, long-term forecasts of sea level fluctuations and real-time predictions of surge/retreats are necessary. In the coming ten (10) years, oil companies, construction companies, transportation companies and many service companies will begin their activities based on the present sea level fluctuations. Early information about future sea level fluctuations, the main elements of steps taken to protect nature, the prevention of coastal infrastructure flooding, as well as the prevention of Caspian shelf contamination will be of great importance.

On the basis of preliminary calculations it is necessary to make storm surge forecasts for at least 25 locations in the main oil-gas sector facility and settlement areas, including such cities and villages as Atyrau, Aktau, Eraliyevo, Fetisovo, Bautino, Fort-Shevchenko, Prorva and Buzachi fields, Tengiz field and Ural-Volga interfluves fields. Moreover, such information is necessary for more than 50 anticipated oil platforms and artificial islands in the Northern Caspy water zone.

Another future service for the Center is long-term prognoses of the background sea level over periods of 3, 5, 10 and 20 years ahead for industrial planning and all economic development in the Caspian region.

The developed and tested forecast models of the Center are important for use in the Caspian Environmental Program for coastal zone management. In addition to this, the Center will be able to coordinate the activities of other Pre-Caspian state experts in the second phase of this program and will be able to attract these experts to research sea level fluctuation issues, which are of importance to all countries of the region. Thus, the Center's output (services) is distributed by the following:

- Oil-gas and other economic sector enterprises and companies
- Governmental agencies

- Regional authorities
- International organisations

The remaining sections of the business plan, as well as additional information to the present sections, will be prepared during the second part of the present project. The final business plan will be part of the final report.