Support to the Caspian Centre for Water Level Fluctuations

Final Report

UNOPS

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January 2004

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Project	Project No
Support to the Caspian Centre for Water Level Fluctuations	52444
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Revision	Description	By	Checked	Approved	Date
o	Final Report	HRJ	HJV	HJV	30/01/04

Key words	Classification
Caspian Sea Storm Surge Data Base Business Plan	☐ Open ☐ Internal ☒ Proprietary

Distribution		No of copies
UNOPS	Mr Juan Luis Larrabure	2
CCWLF	Mr Madi Kireyev	By e-mail
DHI	HRJ, PHD	2

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1 INTRODUCTION

This Final Report describes the work performed during the period from July 15, 2003 to January 15, 2004 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 project has been conducted by DHI, Denmark as consultant and the Caspian Centre for Water Level Fluctuations (CCWLF) in Almaty, Kazakhstan as sub-consultant. The technical work as well as the business plan have been prepared by the staff at CCWLF with technical supervision by DHI.

From CCWLF these experts and specialists have contributed to the report:

Madi Kireyev:	Local co-ordination
Natalya Ivkina:	Storm surge modeling
Tatyana Stroyeva:	Storm surge modeling
Tatyana Gorkunova:	Hydrometeorological database

2 BACKGROUND

The Caspian Centre for Water Level Fluctuations (CCWLF) was established in 1998 with funding from the EU TACIS Program, as part of the TACIS support to the first phase of the Caspian Environment Program (CEP). It is located in the offices of KazNI-IMOSK, the Research Institute for Environment Monitoring and Climate in Almaty, Kazakhstan and is co-ordinated since 2000 by KazHydromet, a state-owned entity sub-ordinated to the Kazakhstan's Ministry of Environment Protection.

The TACIS support to the CCWLF was provided by a series of projects, the last of which ended in December 2001. The ToR for the last of these projects set forth 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 inter alias developing business plans. By the end of 2001, this objective had not been achieved for the CCWLF, and no business plan for the future had been developed. The request for financing the work continuation of the CCWLF was forwarded to the Ministry of Ecology, but this request arrived too late in order to set-aside funding in the government budget for 2002-2003. Since December 2001 until summer 2003, the staff of the CCWLF has worked to keep the Centre intact and to carry out key daily analyses.

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

(1) 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) Development of capacity for daily forecasting 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 inputs from scientists in St. Petersburg (Russia) and Great Britain. Continuation is unlikely without some significant long-term donor support; the second area of work has particular national importance, because of the vulnerability of Kazakhstani low-lying Caspian coastline to storm surges.

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

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

3 PROJECT TASKS

The project has been divided into 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 surges for the Kazakhstani coast of the Caspian Sea;

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

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

- **Update the hydrometeorological database** created by the CCWLF by correlating hydrometeorological parameters among the basin stations and interlink these data with maps in Arc View format;

- **Prepare a business plan** for setting up a Storm Surge Centre on the basis of the CCWLF and within the framework of the National Caspian Action Plan (NCAP) of the Republic of Kazakhstan.

The detailed description of each task status is provided 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 days 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 daily basis from the European Centre for Medium Range Weather Forecasts (ECMWF, UK). Presently, data are received at no costs due to the lack of funding.

Within the project period water level forecasts has been prepared and issued on a daily basis.

The following procedures have been applied daily to produce the water level forecasts:

1. Download meteorological analysis and forecast data from UK.

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

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

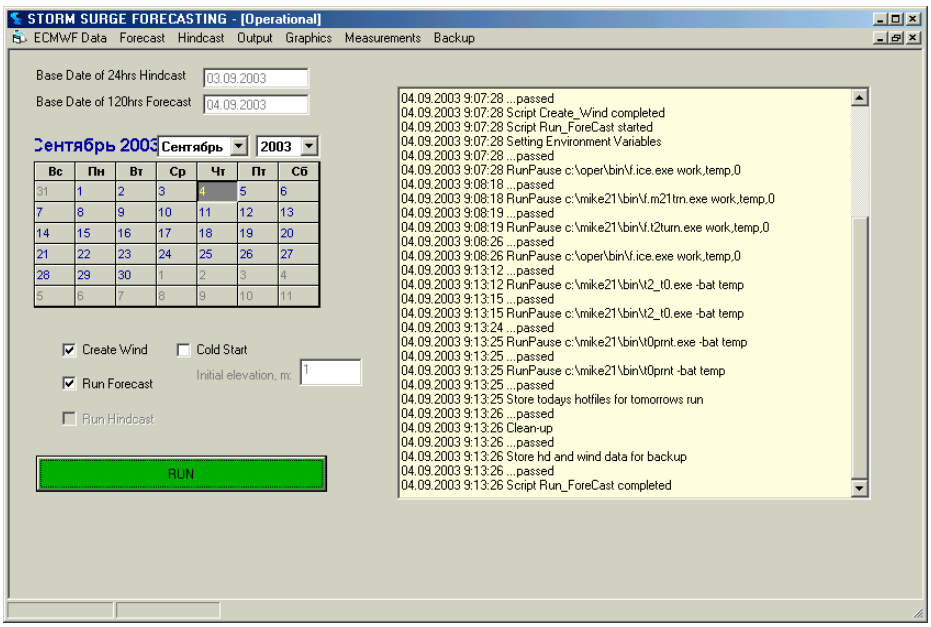


Figure 3.1 Window dialog used to execute the hydrodynamic forecast model of the Caspian Sea.

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

5. Receive (via email) the latest observations of water levels from available stations at the Caspian Sea. Presently, data is being received from the following Kazakhstani stations: Peshnoy Station, Island Kulaly Station and Fort-Shevchenko Station, and from the Russian station Tuyleniy Island.

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

Daily forecasts are produced using the latest and most updated version of storm surge models.

Comments:

Each day a simulation covers the period from –24 hours to +120 hours. The period from –24 hours to 00 hours is a so-called hindcast as it is based on meteorological analyses. The period from 00 hours to +120 hours is the forecast.

All the simulations (except the very first) start from a so-called hot-start-file. This file was generated during the previous simulation (at time 00 hours). In this way, the model hindcast is being updated daily to give the best possible starting conditions for the new forecast.

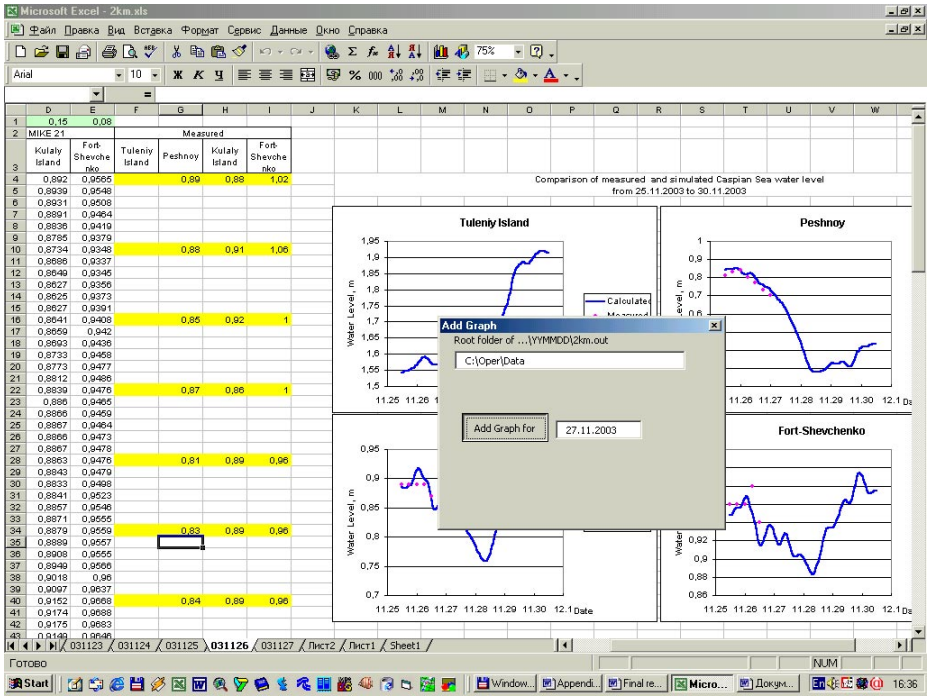


Figure 3.2 Automatic chart creation in Excel of calculated sea level forecasts and observations for the available stations.

All time series of the forecasted water levels are stored for further analyses.

3.2 Update the Existing Storm Surge Model

The version of the storm surge model applied until the start of this project 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 have been processed and implemented in the operational storm surge model. As access to actual data is not possible the data 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 has been implemented in the operational storm surge model.

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

The updated and improved model has been verified running a 12 months hindcast period. The year 1 August 2002 to 1 August 2003 was selected for this purpose.

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

The following model tests with the storm surge model for the verification year have been conducted:

- 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).

In this way it is possible to separate the improvements gained by each item.

The results of calculated water levels (surges) for selected stations have been compared with actual measurements for verification of the implemented improvements. After the verification the updated surge model has been applied on a daily basis for the production of the operational forecasts.

The results of the simulation with the present model setup are shown in Figure 3.3. This figure shows a comparison between measured (Hm) and calculated (Hcal) water levels at station Peshnoy. The correlation factor (R) between the measured and calculated water levels is 0.76.

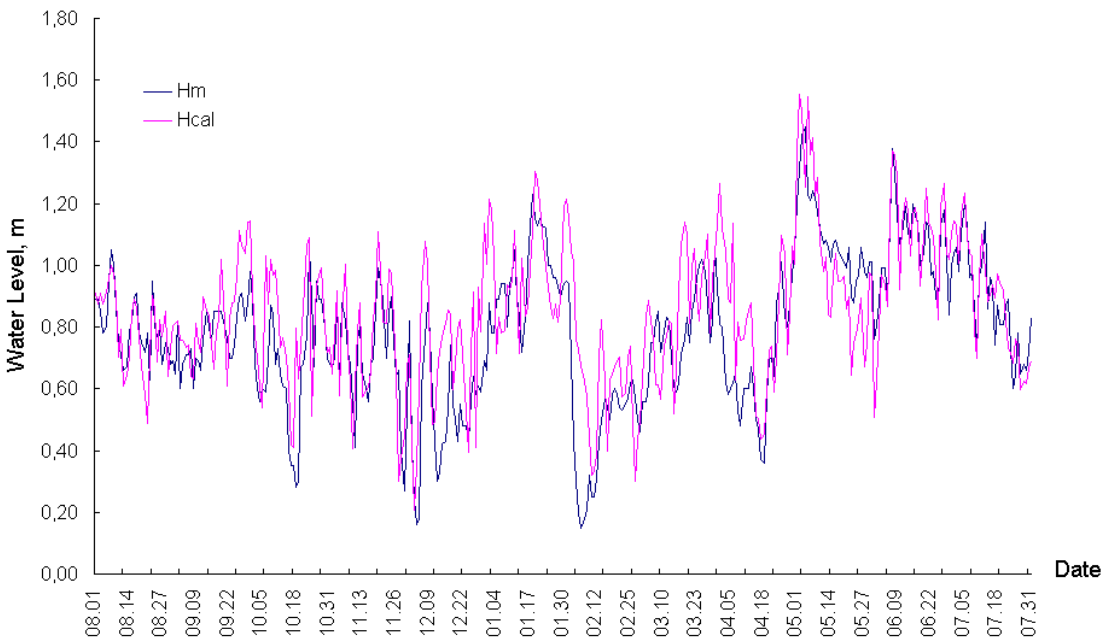


Figure 3.3 Comparison of the Caspian Sea measured and calculated water levels at the Peshnoy Station with the present set-up.

3.3 Update the Existing Storm Surge Model with the Water Balance Elements

Annual, inter-annual, seasonal and monthly fluctuations of the Caspian Sea level, as any closed water body, are stipulated by inconstancy of the ratio between receipt and expense items of the water balance, on which the values of sea level deformation changes will be applied. Analyses of the sea level fluctuation causes indicate that they are mainly determined by continental drainage, precipitation, falling onto the sea surface, and underground inflow (receipt items), evaporation and water drainage to the Kara-Bogaz-Gol bay (expense items). Table 3.1 indicates the average long-term water balance of the Caspian Sea as per the information of B.D. Zaikov (from book A.V., Frolov, 2003).

Table 3.1 The Caspian Sea multi-annual mean water balance.

Input	Layer		Output	Layer	
	mm	km^3		mm	km^3
Rainfall	177	71,1	Evaporation	978	392,3
Runoff	808	324,2	Inflow to Kara-Bogaz-Gol Bay	21	22,2
Underground flow	14	5,5			
Total:	999	400,8	Total:	999	400,8

As this table shows the most significant impact on the level fluctuation is rendered by the following elements of the water balance: surface inflow, evaporation and precipitation. Neglecting these features at the level of prognosis may result in errors. So one of the main tasks in the area of non-periodical water level fluctuation prognosis schemes is introduction of the main water balance features into the model.

The Caspian Sea basin area is 3.5 million km^2. Landscape nature, climate conditions and river types are quite different. In spite of the basin extent, only 62.6% of its area falls on the drainage areas, and about 26.1% - to the internal-drainage area, the Caspian Sea area is 11.3%.

The largest rivers of the Caspian Sea basin are the Volga, Ural, Terek, Samur and Sulak rivers. Their drainage influences the Caspian Sea water level fluctuation, and therefore it was included in the model as one of the main elements of the model tests.

About 88% of all inflow into the Caspian Sea are delivered from the northern part of its basin, within which there are the Volga and the Ural rivers. The main volume of the inflow to the sea is delivered by the Volga river – up to 85%, 15% is delivered by other rivers of the basin (Figure 3.4). The discharge of Volga River is measured at Verkhneye Lebyazhye, the main gauging station, through which the estimations of the inflow to the sea are performed.

The discharge from the Ural River was measured at Topoli Village 200 km from the sea until 1972 where it was moved to Mahambet located 145 km from the sea border of the delta. The area of the Ural River catchment at Mahambet village is 235.000 km^2.

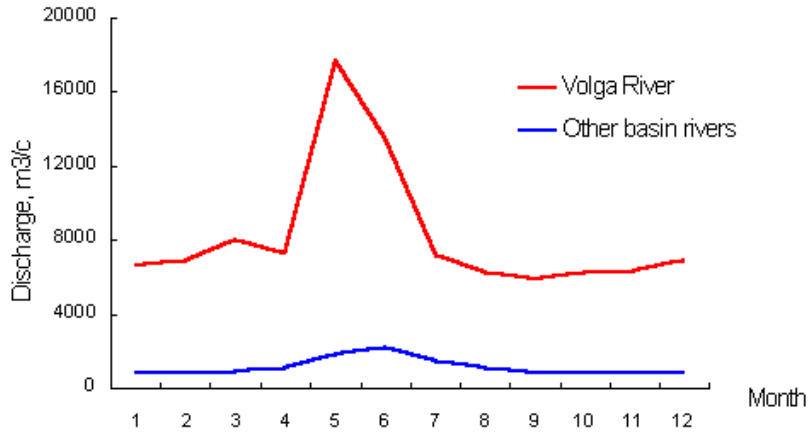


Figure 3.4 Comparison of the Volga discharges with other rivers running into the Caspian Sea

Discharge of the Terek River, characterized by large natural fluctuations has been significantly changed over the last years. Till 1973 the Terek flow was delivered to the Kizlyar gulf of the Northern Caspian Sea through the belt, since 1973 – directly to the Middle Caspian Sea through the artificial slit of Agrakhan peninsula. Currently, the Terek River, discharge that is measured at Kargalinskaya station, flows into the sea by a one-river arm on the open coast.

The Sulak River (outlet is located 123 km from the mouth in Miatly Village) flows into the sea, forming a one-branch channel. Since 1957 the river has been directed through the artificial slit to the South-East below the Glavnyi Sulak Village.

Samur River discharge is measured in Usukh Village.

The Kura River flows into the sea by two channels: a south-eastern, through which about 95% of the flow are discharged into the sea, and a north-eastern. The discharge is measured in Salyany Village, located 85 km from the top of mouth area and 85 km from the sea border of the delta.

In spite of the differences in physical and geographical conditions of the river basin and the features of the annual discharges of each river, the annual distribution of total surface inflow into the sea almost fully corresponds to the annual distribution of the Volga River discharge. In a seasonal trend of the Volga discharge the maximum is observed in May-June, during the peak of high water. At this time from 13% up to 26% of the annual discharge volume is delivered into the sea monthly. The smallest amount of water is delivered by the Volga during the winter months (December – February).

As river input to the model, the average water inflow for the latest ten years was calculated and distributed to five sources in the model. Due to the fact that the Terek and Samur rivers are close to each other, their runoff is united in one source. Undoubtedly, to obtain more accurate estimation of water inflow, one needs the actual runoff data and its forecast on a daily basis. However, it is not obviously possible to receive such data for the Caspian Sea in practice. Therefore, the long-term flow records of the main rivers in the Caspian Sea were established under the condition that the temporary resolution of the discharge time series was not less than one month (Table 3.2).

Table 3.2 Mean monthly runoff to the Caspian Sea, m^3/s

River	Month											
	1	2	3	4	5	6	7	8	9	10	11	12
Volga	6350	6060	7340	13200	22200	11500	7830	6610	6070	6650	6750	6590
Ural	224	214	259	465	782	407	276	233	214	235	238	233
Kura	448	427	518	929	1564	813	553	467	429	469	476	465
Sulak	149	142	173	310	521	271	184	156	143	156	159	155
Terek+ Samur	299	285	346	620	1040	542	369	311	286	313	318	310

The carried out calculation experiment shows that the rivers' inflow essentially increases the water level (Figure 3.5).

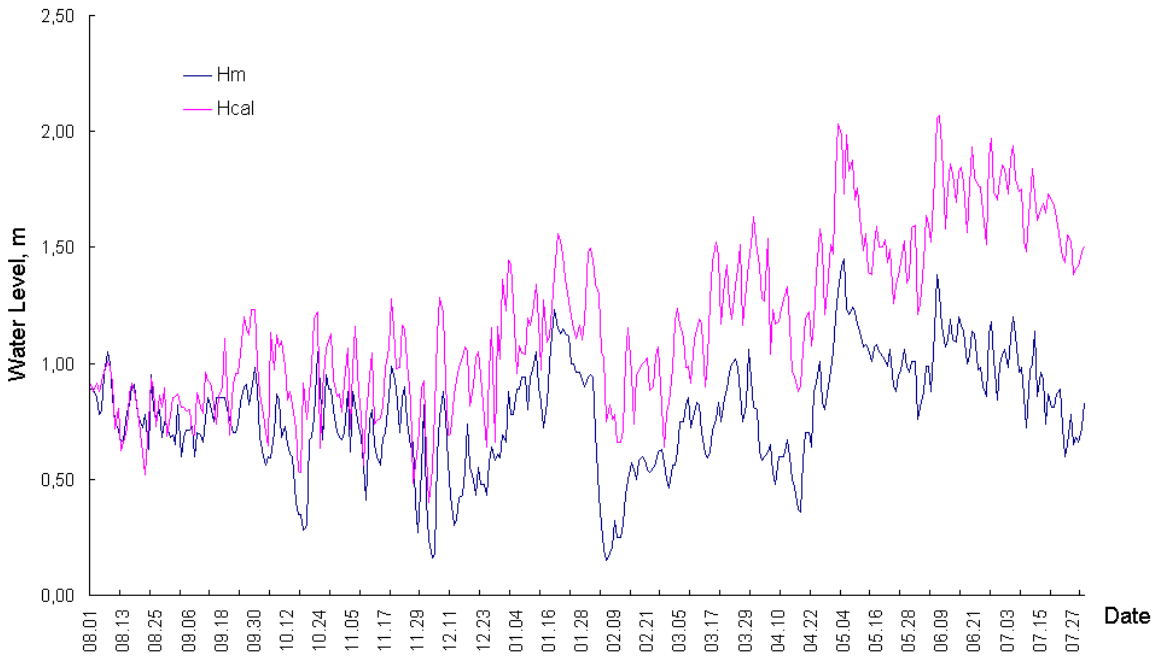


Figure 3.5 Comparison of the Caspian Sea measured and calculated water levels at the Peshnoy Station including river inflow.

It is clear, that using only river inflow in the model and ignoring the loss by evaporation will result in an increase of the water level. Therefore, the next task in the forecast quality improvement turned out to be the inclusion of the calculated values of net evaporation (precipitation minus evaporation) from the Caspian Sea surface. Since the storm surge model is not intended for modeling of the water balance elements, evaporation time series is calculated based on the water balance model developed as part of the TACIS project (Table 3.3). A Mean Sea Level of the Caspian Sea at –27m Baltic Datum was used as background level for the modeling.

Table 3.3 Average value of net evaporation from the Caspian Sea surface, m^3/s.

Month											
1	2	3	4	5	6	7	8	9	10	11	12
518	239	1132	1752	1489	2475	2499	3130	3837	2711	1861	1384

*From R.B. Wardlaw, 2000. Caspian Sea water balance studies: Model update report. *Caspian Environmental Program (CEP_II, EU funded), Almaty, November 2000.*

Including the net evaporation in the model results in a decreasing water level as shown in Figure 3.6.

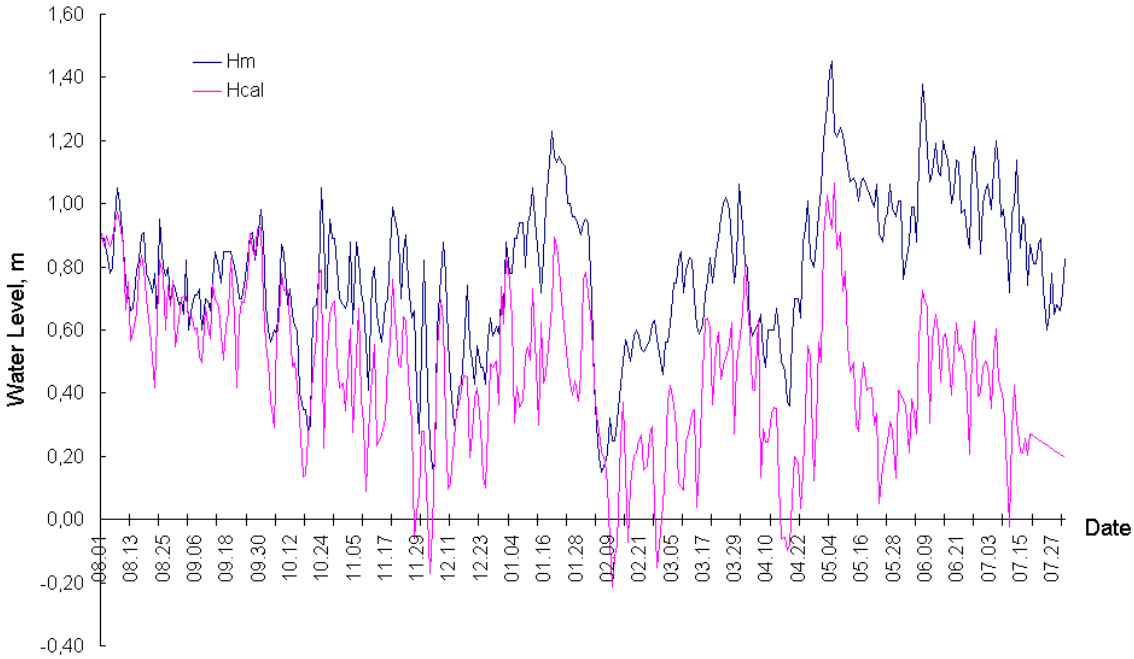


Figure 3.6 Comparison of the Caspian Sea measured and calculated water levels at the Peshnoy Station including net evaporation.

Naturally, it is necessary to include all main water balance elements in the model to obtain physically realistic results. The results are significantly improved using all water balance elements as shown in Figure 3.7.

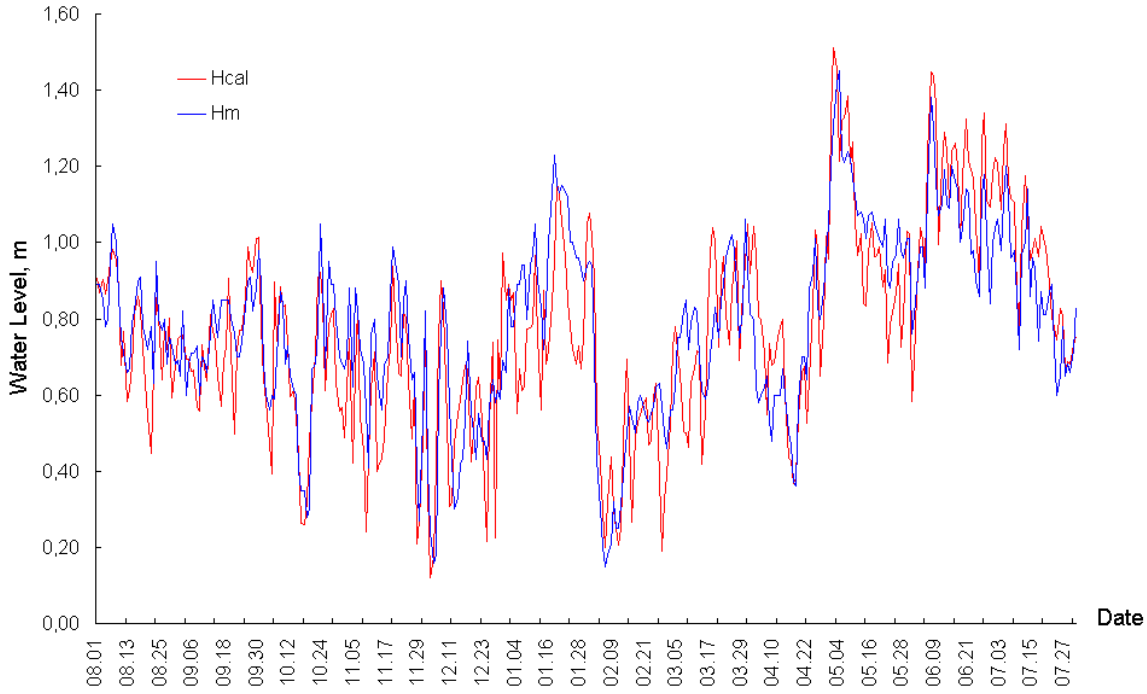


Figure 3.7 Comparison of the Caspian Sea measured and calculated water levels at the Peshnoy Station including both river inflow and net evaporation.

3.4 Update the Storm Surge Model Including Ice Effects

The Caspian Sea has a seasonal ice cover. It differs due to its large-scale heterogeneity of ice processes development as a result of various climate conditions in different parts of the sea. By character of ice processes Kazakhstan's sector of the Caspian Sea is subdivided into areas: the water area to the north-east of the Kulaly Island, which annually becomes covered by steady ice with the shore; the water area in the centre of the Northern Caspian Sea which becomes covered with floating or unstable, motionless ice practically annually; and also the coastal areas, bays and gulfs of the eastern coast of the Middle Caspian Sea, including the shallow Kazakh Bay where local ice is formed or floating ice from the Northern Caspian Sea is brought. The Caspian Sea annually freezes only in the shallow northern part. The deep areas of the Middle Caspian Sea are always free of ice.

Depending upon the features of the atmospheric processes developing above the sea, thermal condition anomalies in subwinter and winter create original ice conditions, which vary significantly from year to year. The ice period for the Caspian Sea has three natural-synoptic seasons: autumn (subwinter) - from October till December, winter - from January till March and spring - from late March till May. Reference and observation analysis have shown, that Northeast Caspian Sea is an area with 100% probability of ice formation during the cold period.

In the cold winter one observes that the first ice appears in the northeastern part of the Caspian Sea in the beginning of November. By late November the ice formation is quickly distributed across the water area covering the northeast coast, including the Volga and Ural beaches. In the first part of December ice appears in all shallow areas of the Northern Caspian Sea limited by three-meter depths. By late December the ice for-

mation is distributed into the deeper areas, but here the process occurs more slowly because of larger depths and warmer water flow. At this time ice appears in most parts of the Ural Borozdina, in the Tuyleniy Islands' archipelago area, along the western coast of Kulaly Island, in the Tyub-Karaganskiy Bay and also in some bays and gulfs of the eastern coast of the Middle Caspian Sea.

During subwinter and normal thermal conditions an ice formation process in the Northern Caspian Sea begins from the shallow coastal zones in the second part of November. All shallows become covered with ice during late November, and from the end of December ice is formed at Kulaly Island. In the warm winters the first ice can be formed at the Ural beach in the beginning of December and in mid December - in the deeper part of the sea. Throughout the whole winter season ice is being unstable. Newly formed October ice quickly breaks down under air temperature rise during thaws, and also under wind and wave action. Repeated formation of more steady ice cover occurs 15-30 days after the first clearing of the previous one. In such winters an ice cover in late December covers almost all coastal and water areas of the Northern Caspian Sea. In January distribution of ice cover to the deep-water sea areas continues but its intensity increment is reduced compared to December. It explains the beginning of an ice formation process in the open sea zones where this process is influenced not only by the air-water heat exchange but also by intrawater heat exchange with warm deep water of the Middle Caspian Sea.

The influence on ice cover caused by dynamic factors, which promote shore breaking, compression and ice destruction tends to get increased in the second half of the ice season.

Basically, wind ice drift takes place closer to shore edge. In Ural Borozdina breaking and drift of ice can proceed within all winter. Usually, while breaking shore lengthways isobathic line cracks and ice openings are formed. Sometimes their length equals to tens of kilometers. Under large wind set-ups in the winter beginning drift and hummocking are possible at coastal flooded territory of the eastern coast.

Under average annual hydrometeorological conditions ice destruction starts from the second half of February. At first open areas of the Northern Caspian Sea are cleared, and then its northeastern ones are. From late March till- the beginning of April the sea is completely cleared from ice.

Quite apparently it is necessary to take ice cover into consideration while modeling the water levels. The applied storm surge model, MIKE 21, includes the effect of ice cover in a simple way by reducing the wind drag over ice covered sea areas. Input to the model is digital maps of the ice cover during the winter season. To create such maps it was required to analyze all available observation material and to determine the characteristic dates of ice cover changes for the selected simulation year. The most typical periods of the ice cover change were: 20-31.12; 1-31.01; 1-28.02; 1-15.03.

The next stage was the creation of the ice cover maps. To accomplish this, all the satellite images available for the various years and the observation material of Kazakhstan's four stations (Peshnoy, Kulaly, Fort-Shevchenko, Aktau) were used. As examples satellite images of various ice cover stages are illustrated in Figures 3.8-3.11.

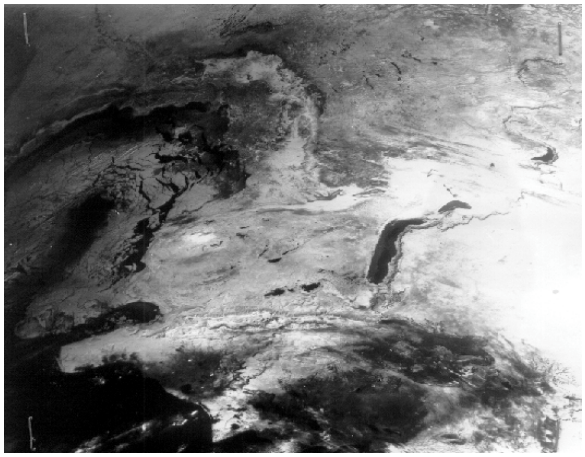


Figure 3.8 An ice cover condition in December 24, 1990 (formation phase of a steady ice cover)

Figure 3.9 An ice cover condition in February 18, 1988 (stage of a compact ice)

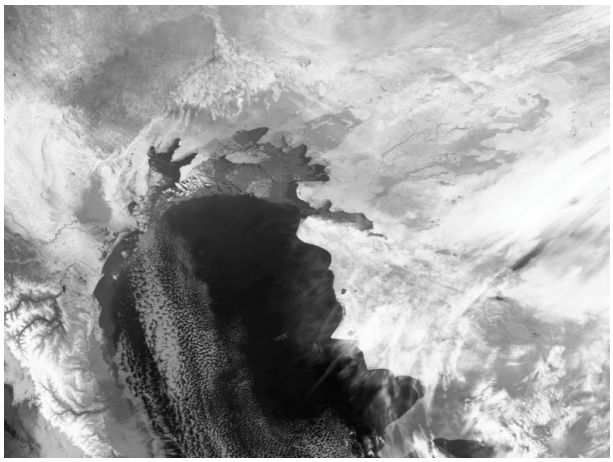


Figure 3.10 An ice cover condition in March 01, 2003 (beginning of an ice cover break)

Figure 3.11 An ice cover condition in March 10, 1991 (an ice cover break).

On the basis of the satellite image analysis and observation material ice cover modeling maps have been compiled by means of MIKE 21. For all Caspian Sea the maps have been made on a scale 10 km to10 km, for the Northern Caspian Sea – 2 km to 2 km. Maps for the testing period are shown in Figures 3.12-3.15.

The testing has shown (Fig. 3.16) that in order to increase the accuracy of the forecasts it is necessary to take into account the ice cover which limits the wind influence on the water surface during the winter period. In an operative regime during any winter season the maps used in the modeling can be adjusted to the actual ice cover situation.

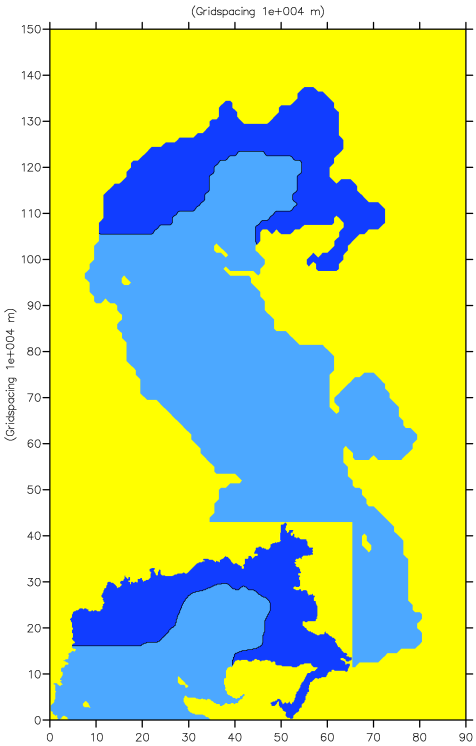


Figure 3.12 Modeling ice cover map of the Northern Caspian Sea on the scale 10×10 and 2×2 kms for the period December 20 to December 31.

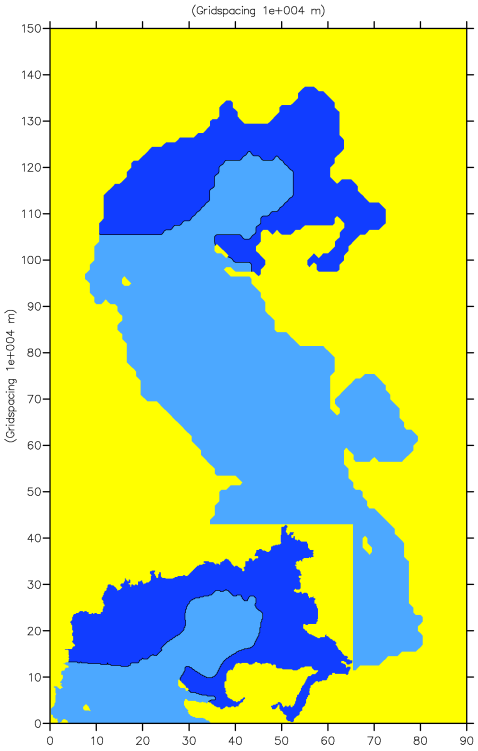


Figure 3.13 Modeling ice cover map of the Northern Caspian Sea on the scale 10×10 and 2×2 kms for the period January 01 to January 31.

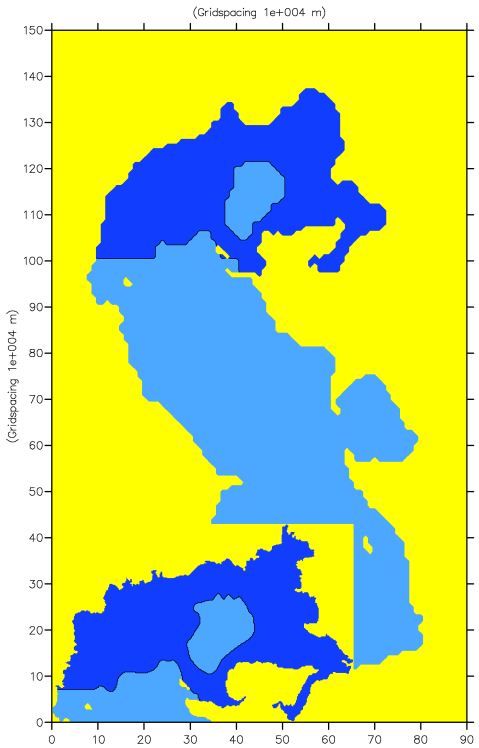


Figure 3.14 Modeling ice cover map of the Northern Caspian Sea on the scale 10×10 and 2×2 kms for the period from February 01 till February 28.

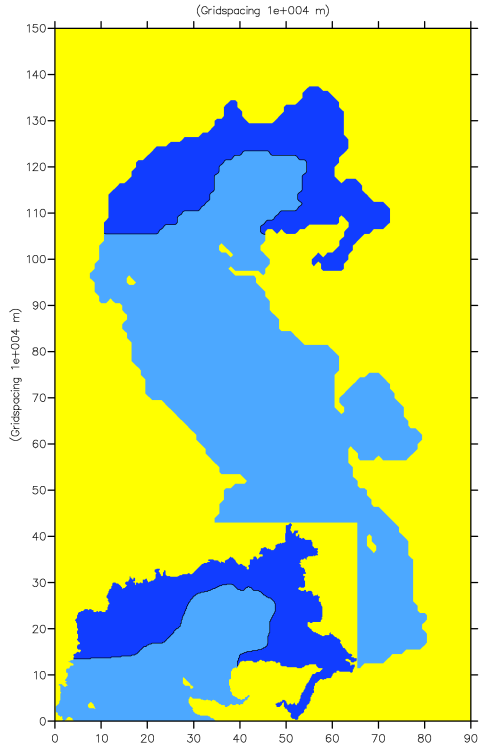


Figure 3.15 Modeling ice cover map of the Northern Caspian Sea on the scale 10×10 and 2×2 km for the period March 01 to March 15.

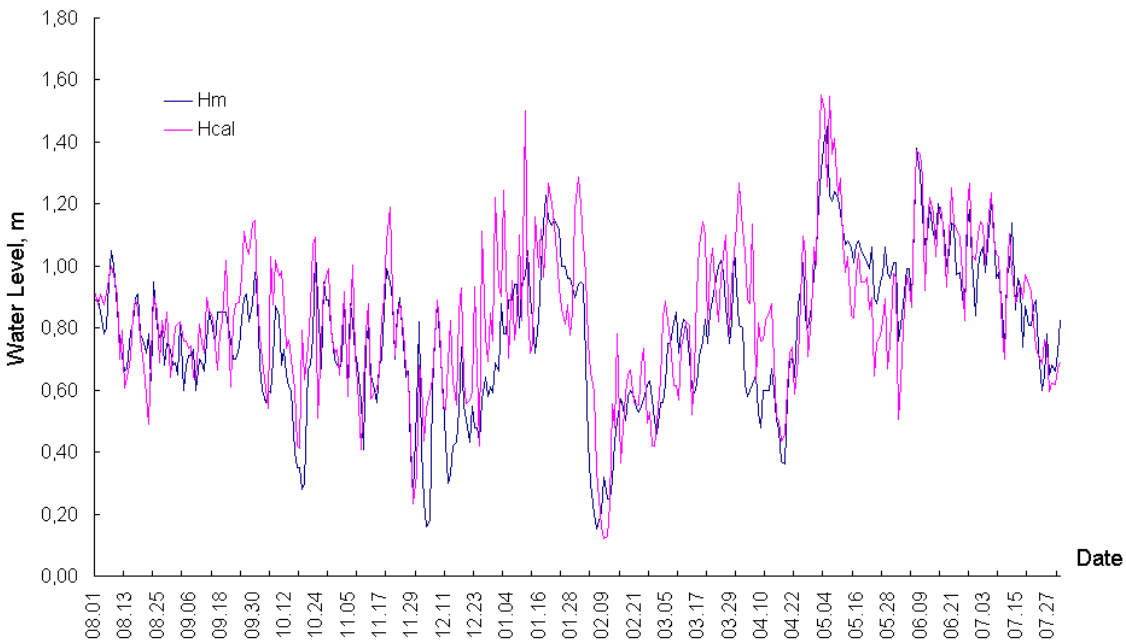


Figure 3.16 Comparison of the Caspian Sea measured and calculated water levels at the Peshnoy Station including the effect of ice cover.

In remote areas of the earth satellite ice cover observations are usually the only regular repeated information available related to ice cover. In all cases while forecasting storm

surges in winter time and particularly in large areas with poor ground information, the capacities of satellite ice cover should be taken into consideration (Fig. 3.17):

- Though satellite observations are not expected to replace the existing ground survey information totally, it surely can complement and enhance it;
- In remote areas where ground survey data are not available, satellite data are often the only source of information dealing with ice cover. Simple methods as well as more sophisticated ones should be accessible to make use of satellite information;
- The methods for ice cover estimation have to be further developed.

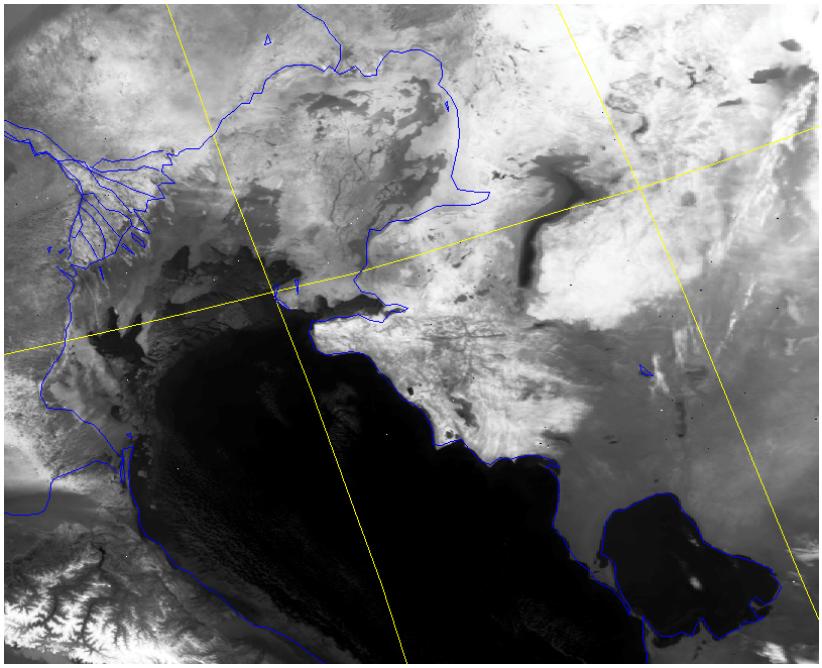


Figure 3.17 Example of satellite image from the NOAA station

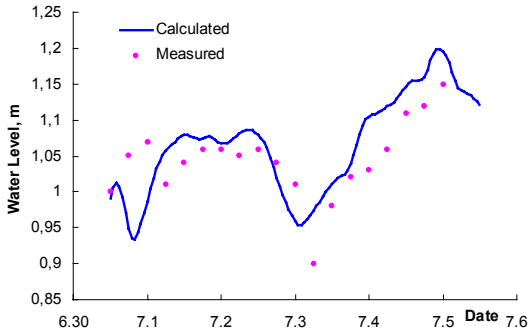
Summing up the results of the validation tests, it is possible to draw the conclusion that the inclusion of the water balance elements (river inflow and net evaporation) and the effect of ice cover (reduced wind drag over ice) in the storm surge model have significantly improved the accuracy of the calculated water levels. This is also shown by the increased correlation coefficient obtained at station Peshnoy in the different validation tests as listed in Table 3.4.

Table 3.4 Correlation coefficient for the various testing variants

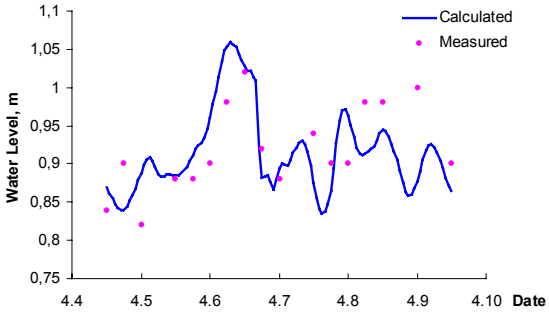
Original model	With ice cover	With river inflow	With evaporation and precipitation	With all water balance elements	With ice cover and all water balance elements
0,76	0,78	0,72	0,65	0,85	0,91

3.5 Develop Quality Check Methods

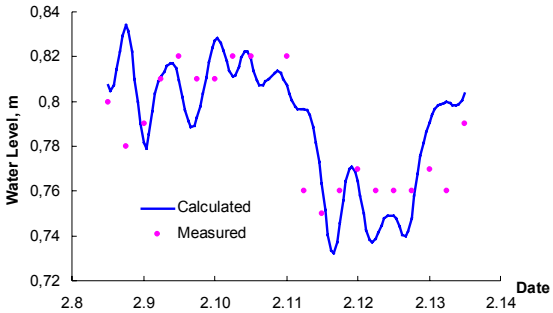
The quality of the produced forecasts can be checked in different ways. The simplest way is by visually comparing simple time series of calculated and measured water levels. Most checks until today have been based on this simple approach. Examples are shown in Figure 3.18.



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 3.18 Examples of comparison of calculated and forecasted water levels

Each time series represent 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 were introduced during the present project.

Daily forecasts for the year August 2002 to August 2003 were produced for statistical analyses.

Calculated water levels every 24 hours (00, +24, +48, +120) from each of the forecasts were extracted. All values at time 00 (ie. hindcast values) were put together to form a time series (the time step becomes 24 hours = the time interval between each forecast simulation). The same was done for the values at +24 hours, +48 hours, etc.

Each established time series of model results was 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. Examples for the stations Peshnoy, Kulaly Island and Fort-Shevchenko at +24 hours are shown in Figures 3.19-3.21.

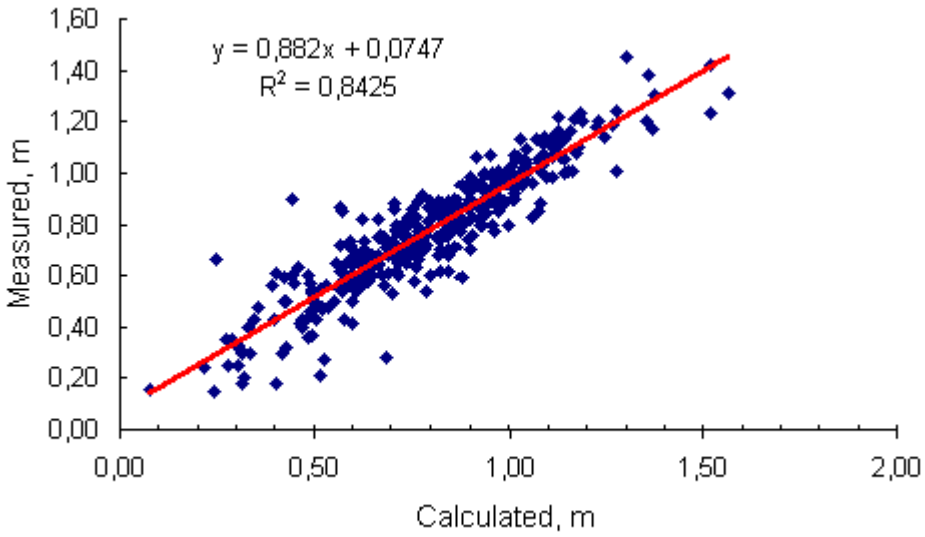


Figure 3.19 Comparison of the measured and forecasted (+24 hours) water levels at Peshnoy Station (August 2002 – August 2003).

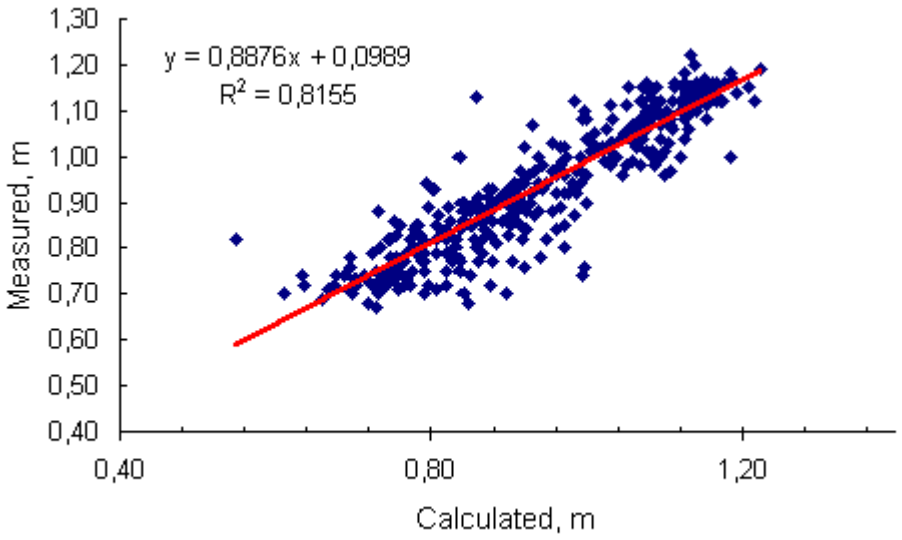


Figure 3.20 Comparison of the measured and forecasted (+24 hours) water levels at Kulaly Is land (August 2002 – August 2003).

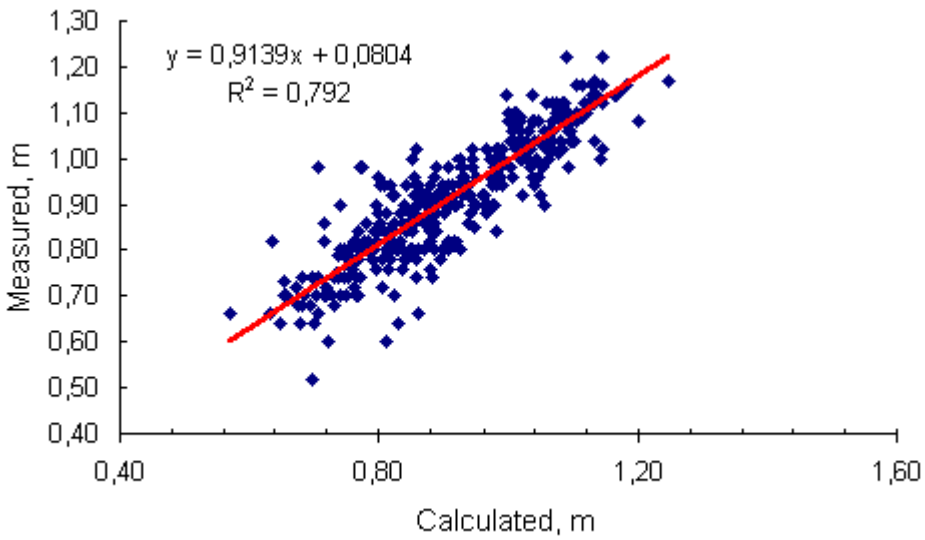


Figure 3.21 Comparison of the measured and forecasted (+24 hours) water levels at Fort-Shevchenko Station (August 2002 – August 2003).

In the figures also the linear regression line is shown together with the calculated correlation coefficient, R.

In Tables 3.5-3.7 the calculated correlation coefficients for all lead-times are shown.

The results for Peshnoy Station shows that the correlation between the measured and the forecasted time series of water levels is 0.92 with an absolute error of 7.4 cm at +24 hours ahead (Fig. 3.19). The correlation is 0,86 and the absolute error 10 cm at +72 hours ahead and the correlation is 0.80 with an absolute error of 12 cm at +120 hours ahead. Similar results were obtained for the stations at Kulaly Island and Fort–Shevchenko.

It is seen, as expected, that the general tendency is that the correlation coefficient is decreasing with the forecast length, which is due to the decreased accuracy of the meteorological forecasts (wind and air pressure).

The defined statistical measures for the storm surge forecast verification pursued two purposes:

- Setting up the degree of accuracy of the forecasts.
- Establishing a quality criterion of the forecasts.

Estimation of method reliability and forecast accuracy was carried out according to the current normative documents, namely:

- Klibashev, K.P., Goroshkov, I.F., Hydrological calculations.- Leningrad, 1970.- 170 p.;
- Forecasts' Service Manual, 1982. Part 3. Section III. Sea Hydrometeorological forecasts' Service;
- The Methodical Instructions on Realization of the Operational Tests the New Hydrometeorological Forecasts' Methods, 1977;
- The Methodical Instructions, 1991. Production (Operative) Tests' Realization of the New and Advanced Methods Hydrometeorological and Heliogeophysical Forecasts. Guideline 52.27.284-91.

According to these documents, quality criteria of the forecast method should characterize simultaneously both reliability of the method, and its efficiency. Relating standard error (S) to mean-square deviation (δ) is accepted as a criterion of method applicability and quality. The ratio S/δ is simultaneously characteristic of reliability and efficiency, as it shows a gain in allocation of errors, which the forecast method gives compared to allocation of errors in case of acceptance of expected value to its norm. As follows from Tables 3.6-3.8, the quality criteria are in acceptable limits even for 120 hours earliness of forecast ($S/\delta<0,5$ is good and $S/\delta<0,6$ is satisfactory), and hence, method use is effectual. As expected, the correlation coefficient (R), and also the Mean Absolute Error (Δ) slowly decreases with the forecast length.

Table 3.5 Calculated Statistics of Surge Forecast Quality at Peshnoy Station for period from August 2002 to August 2003.

Lead-time, Hr	R	Δ, m	S, m	δ, m	S/δ
0	0,91	0,07	0,11	0,24	0,45
24	0,92	0,07	0,10	0,24	0,42
48	0,90	0,08	0,11	0,24	0,46
72	0,86	0,10	0,14	0,24	0,56
96	0,83	0,11	0,15	0,24	0,62
120	0,80	0,12	0,16	0,24	0,68

Table 3.6 Calculated Statistics of Surge Forecast Quality at Island Kulaly Station for period from August 2002 to August 2003.

Lead-time, Hr	R	Δ, m	S, m	δ, m	S/δ
0	0,89	0,05	0,07	0,14	0,47
24	0,90	0,05	0,06	0,14	0,45
48	0,90	0,05	0,06	0,14	0,44
72	0,90	0,05	0,06	0,14	0,45
96	0,89	0,05	0,07	0,14	0,48
120	0,84	0,07	0,10	0,15	0,63

Table 3.7 Calculated Statistics of Surge Forecast Quality at Fort-Shevchenko Station for period from August 2002 to August 2003.

Lead-time, Hr	R	Δ, m	S, m	δ, m	S/δ
0	0,87	0,05	0,07	0,14	0,50
24	0,89	0,05	0,06	0,14	0,46
48	0,90	0,04	0,06	0,14	0,44
72	0,88	0,05	0,07	0,14	0,48
96	0,87	0,05	0,07	0,14	0,50
120	0,83	0,06	0,08	0,18	0,43

Extreme surges:

The study of storm surge dynamics in the coastal zone represents both theoretical and applied interest. The attention to the practical part is stipulated by the fact that storm surges frequently cause catastrophic consequences on a coast. Therefore, during designing and protecting hydraulic engineering objects and civil structures sea level forecasts are of great interest.

The Kazakhstan north-eastern part of the Caspian Sea has a number of contrastive features compared to other regions of the Caspian Sea. It represents a half-closed, almost isolated reservoir, characterized by special shallow water (with maximum depth up to 10m) and weak coastal slopes. The coastal line is not stable and practically all the time it is being migrated. Under average wind conditions the range of this migration is 3-5 km. The large area of water surface and small water volume makes the hydrological regime of this part of the sea low-stable to the effects of external factors, including storm surges.

An analysis of more than 400 cases of the wind setups, which have been observed on Kazakhstan's coast from 1940 to 2002, has been conducted. This analysis allowed stating that the wind setups had the greatest repeatability in April and November. The wind setups with an extreme surge height were observed in May - October. The storm surge statistics from the Peshnoy Station on northeastern Caspian Sea shows that the frequency is equal to 3-5 events in average per month. The maximum frequency of wind set-ups is observed in spring and autumn. The storm surges have maximum height in this period too (Fig. 3.22). A sea level rise of one meter is generated by wind velocities of 10-15 m/s with duration from 10-12 hours to 1-2 days. Under strong wind at 15-25 m/s surges reach 1,0-1,5 m and more.

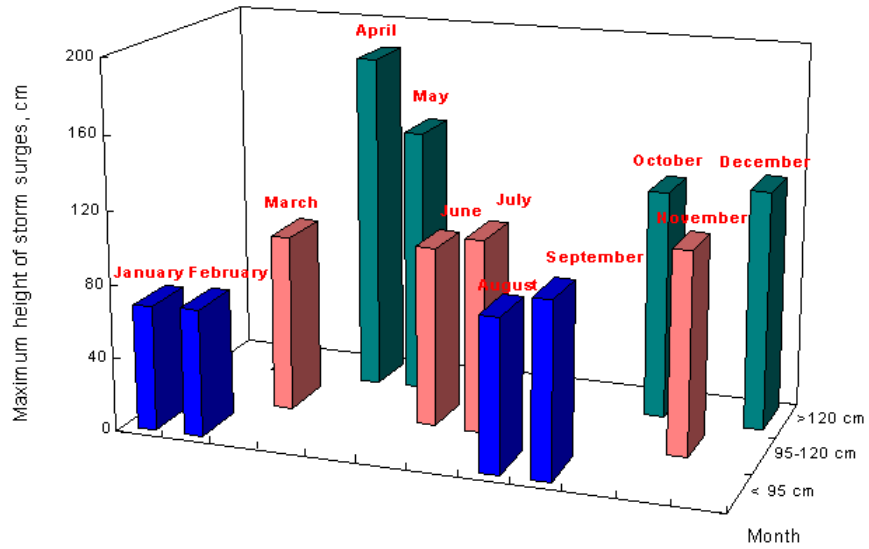


Figure 3.22 Storm surge statistics based on observations from 1940 to 2002 at Station Peshnoy at the coast of the north-eastern Caspian Sea.

In hydrological statistical calculations the binomial asymmetric frequency curve or the curve of distribution (Pirson curve of III type) has the widest application. For calculation of the frequency curve of storm surges it was necessary to establish the following parameters: H_o – average height wind set-up for the investigated period; C_v – coefficient of variation; C_s – coefficient of asymmetry. After calculations of the variation and asymmetry coefficients, the coordinates of the smoothed theoretical curve in necessary limits of probability were calculated.

Coefficients of variation and asymmetry were calculated by the equations 3.1 and 3.2.

$$c_v = \sqrt{\sum (k-1)^2 / n} \quad , \tag{3.1}$$

$$c_s = \sum (k-1)^3 / n\, c_v^3 \quad , \tag{3.2}$$

where $k = \dfrac{H}{H_0}$ - is the modular coefficient, H - height of the storm surge.

The parameters of the frequency curve, based on 382-series, are shown in Table 3.8. As C_s is not equal to $2C_v$, the equation of binomial curve of distribution, integrated by A. Foster (in book: Bolshev, L.N., Smirnov, N.V. "Mathematical statistic tables") was used for calculation of modular coefficient of the set frequency k_c. The normalized deviations from the average value of the logarithmic normal frequency curve (F_c), are taken from corresponding tables in view of the coefficient of asymmetry. Height surge set-up the set frequency H_c was determined as multiplying k_c to average level.

Table 3.8 Calculation of empirical frequency curve for storm surge heights.

P, %	0.01	0.1	1	2	5	10	25	50	75	80	86	95	99
$C_s = 2{,}10$ $C_v = 0{,}32$ $H_o = 0{,}61$													
F_c	9.79	6.39	3,55	2.82	1.89	1.24	0.4	-0.24	-0.68	-0.76	-0.88	-1.18	-1.25
$F_c C_v$	3.13	2.04	1,14	0.90	0.60	0.40	0.13	-0.08	-0.22	-0.24	-0.28	-0.38	-0.40
$k_c = F_c C_v + 1$	4.13	3.04	2,14	1.90	1.60	1.40	1.13	0.92	0.78	0.76	0.72	0.62	0.60
$H_c = H_0 \times k_c$	2.52	1.86	1,30	1.16	0.98	0.85	0.69	0.56	0.48	0.46	0.44	0.38	0.37

The mean-root square error of the curve parameters can be calculated by D.L. Sokolovsky's (3.3), S.N. Kritsky's and M.F. Menkel's (3.4) equations (In book: K.P. Klibashev, I.F. Goroshkov "Hydrological calculations", 1970).

$$\sigma C_v = \sqrt{1 + 2C_v^2} \big/ 2n \times 100\,\%, \tag{3.3}$$

$$\sigma C_s = \sqrt{\frac{6}{n}} \times 100\,\%, \tag{3.4}$$

where n - series length

The mean-root square error of the coefficient of variation calculation is 4%, and the average quadratic mistake of coefficient of asymmetry calculation is 12.5%.

As these errors are insignificant, the calculated values are accepted for the further calculations of the empirical frequency curve.

Table 3.8 shows that the surge height for station Peshnoy is: at 0.01%-frequency (every 10,000 year): 2.52 m and at 0.1%-frequency (every 1,000 year): 1, 86 m.

Comparison of the combined curves has allowed inferring that the theoretical curve of frequency constructed at C_s =2.1 (Fig. 3.23), corresponds to the empirical curve, constructed with observation data in all ranges and consequently can be accepted as settlement.

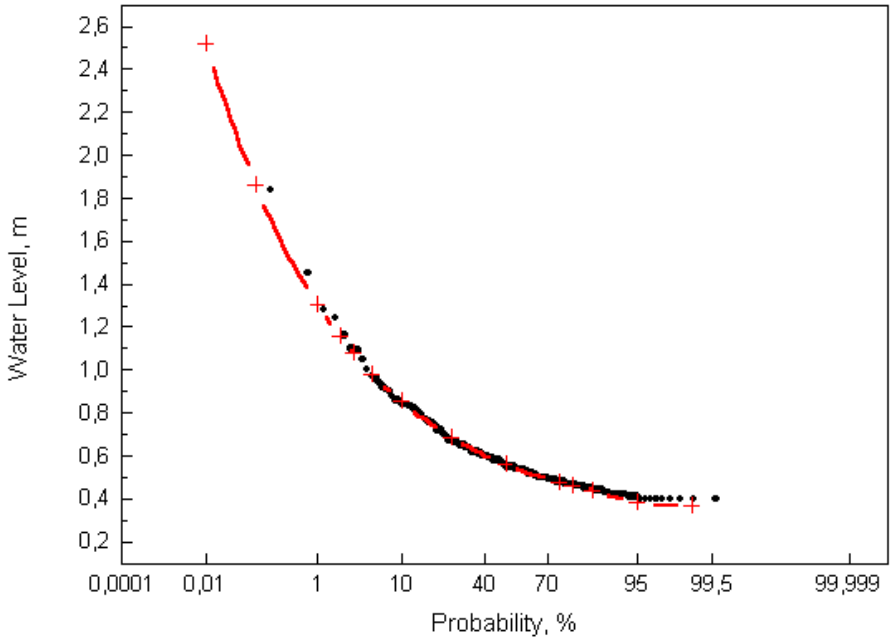


Figure. 3.23 Frequency Curve of Surge Height for Island Big Peshnoy Station (1940-2002).

3.6 Update of Hydrometeorological Database

3.6.1 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 aiming at 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

The database has been implicated in Microsoft Access-97 for Windows 98 and developed in the form of linked tables having a user-friendly interface allowing to overview, edit and print hydrometeorological data as well as characteristics of hydrological and meteorological stations. There is a large flexibility and a lot of possibilities for grouping and analyzing initial data into information tables as well as in diagram plotting mechanisms.

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

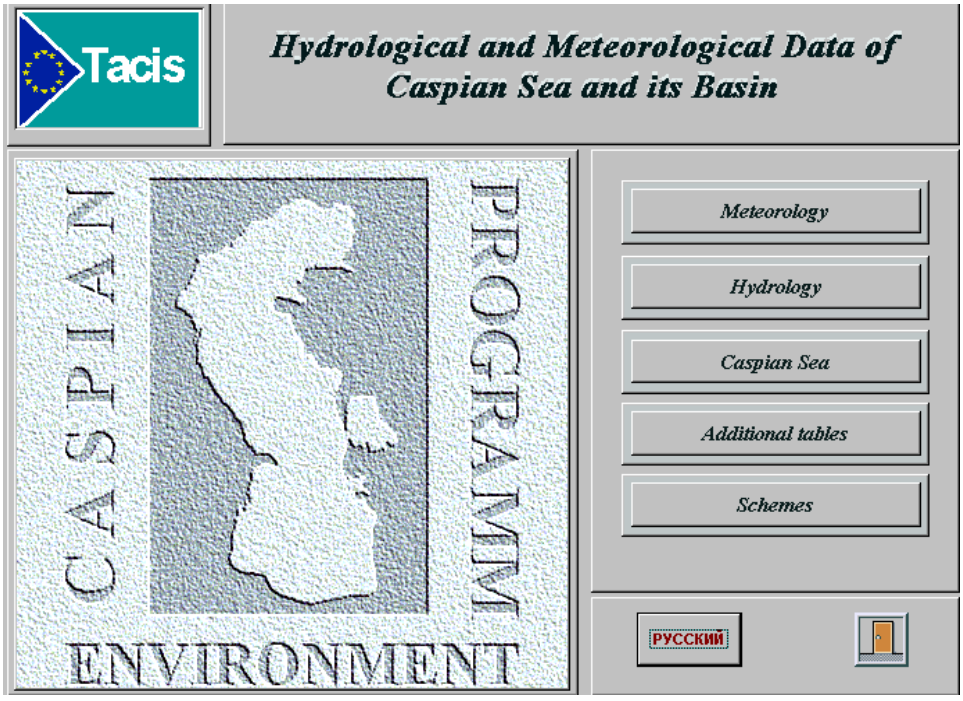
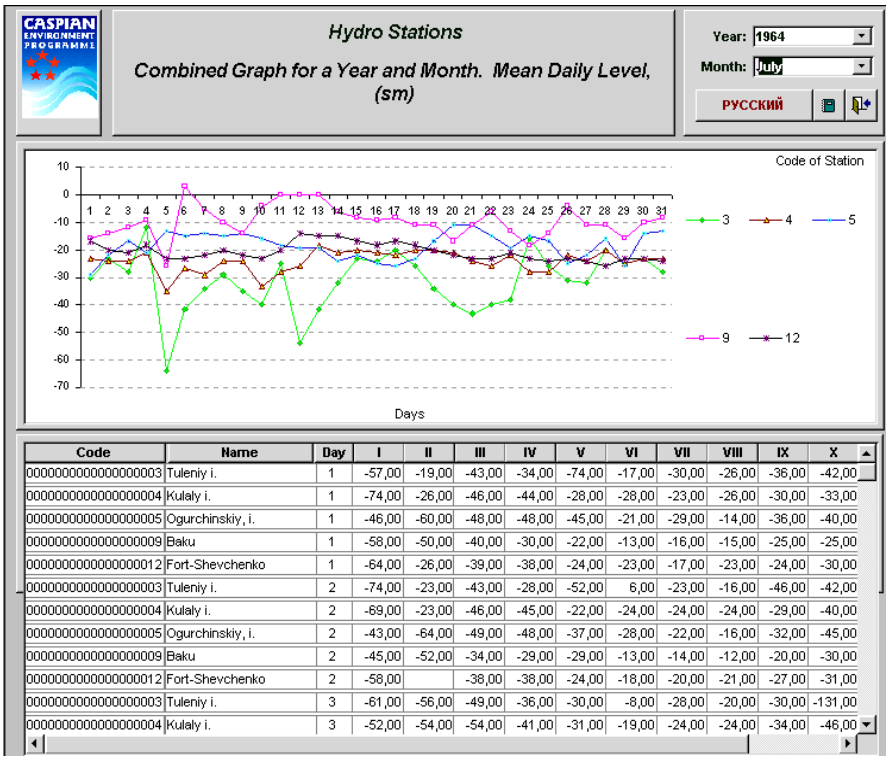


Figure 3.24 Hydrological and meteorological data of the Caspian Sea basin.



Code	Name	Day	I	II	III	IV	V	VI	VII	VIII	IX	X
0000000000000000003	Tuleniy i.	1	-57,00	-19,00	-43,00	-34,00	-74,00	-17,00	-30,00	-26,00	-36,00	-42,00
0000000000000000004	Kulaly i.	1	-74,00	-26,00	-46,00	-44,00	-28,00	-28,00	-23,00	-26,00	-30,00	-33,00
0000000000000000005	Ogurchinskiy, i.	1	-46,00	-60,00	-48,00	-48,00	-45,00	-21,00	-29,00	-14,00	-36,00	-40,00
0000000000000000009	Baku	1	-58,00	-50,00	-40,00	-30,00	-22,00	-13,00	-16,00	-15,00	-25,00	-25,00
0000000000000000012	Fort-Shevchenko	1	-64,00	-26,00	-39,00	-38,00	-24,00	-23,00	-17,00	-23,00	-24,00	-30,00
0000000000000000003	Tuleniy i.	2	-74,00	-23,00	-43,00	-28,00	-52,00	6,00	-23,00	-16,00	-46,00	-42,00
0000000000000000004	Kulaly i.	2	-69,00	-23,00	-46,00	-45,00	-22,00	-24,00	-24,00	-24,00	-29,00	-40,00
0000000000000000005	Ogurchinskiy, i.	2	-43,00	-64,00	-49,00	-48,00	-37,00	-28,00	-22,00	-16,00	-32,00	-45,00
0000000000000000009	Baku	2	-45,00	-52,00	-34,00	-29,00	-29,00	-13,00	-14,00	-12,00	-20,00	-30,00
0000000000000000012	Fort-Shevchenko	2	-58,00		-38,00	-38,00	-24,00	-18,00	-20,00	-21,00	-27,00	-31,00
0000000000000000003	Tuleniy i.	3	-61,00	-56,00	-49,00	-36,00	-30,00	-8,00	-28,00	-20,00	-30,00	-131,00
0000000000000000004	Kulaly i.	3	-52,00	-54,00	-54,00	-41,00	-31,00	-19,00	-24,00	-24,00	-34,00	-46,00

Figure 3.25 Example of combined water level graph for several stations (July 1964).

Table 3.9 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

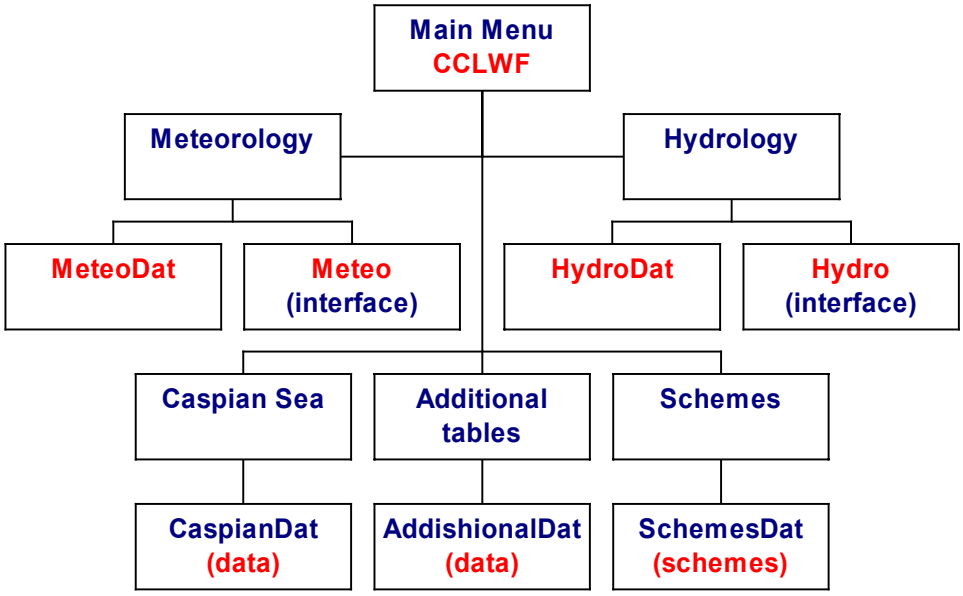


Figure 3.26 Scheme of the information system of the meteorological and hydrological database for the Caspian Sea basin.

3.6.2 *Improvements within present project*

The database has been further developed within the present project.

The 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 are data containing the geographic location of features on the surface of the earth, along with attributed 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 measurement and distances on maps.

6. Selection of map projection. Having analyzed the Data Base CCWLF information (coordinates of basic hydrometeorological items) the case of display of the data without definition of a projection at present is selected (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 of existing map layers for presentation.

Examples of maps created are shown in Figures 3.27-3.29.

Figure 3.27 Fragment of the map of the Caspian countries.

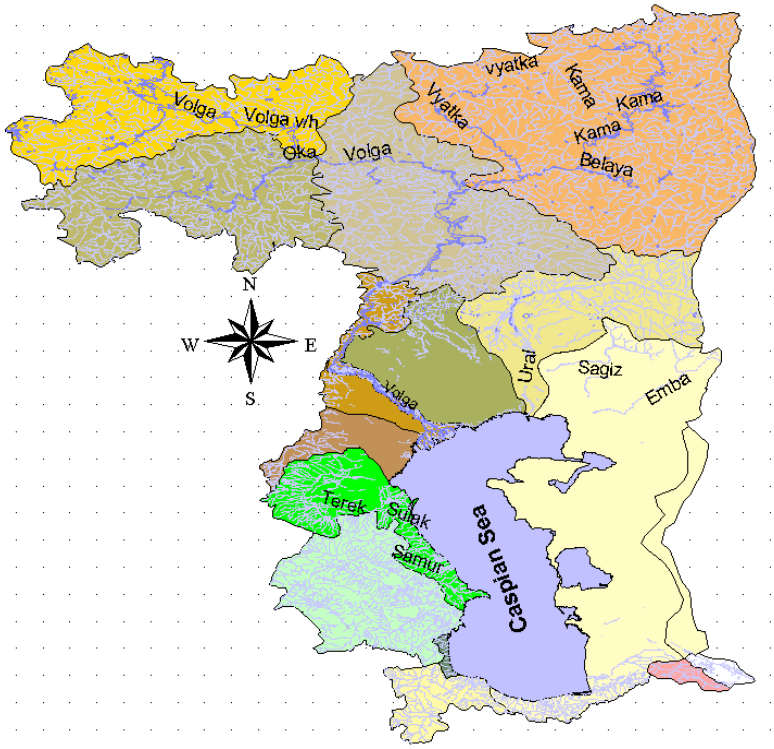


Figure 3.28 Caspian region map (draft).

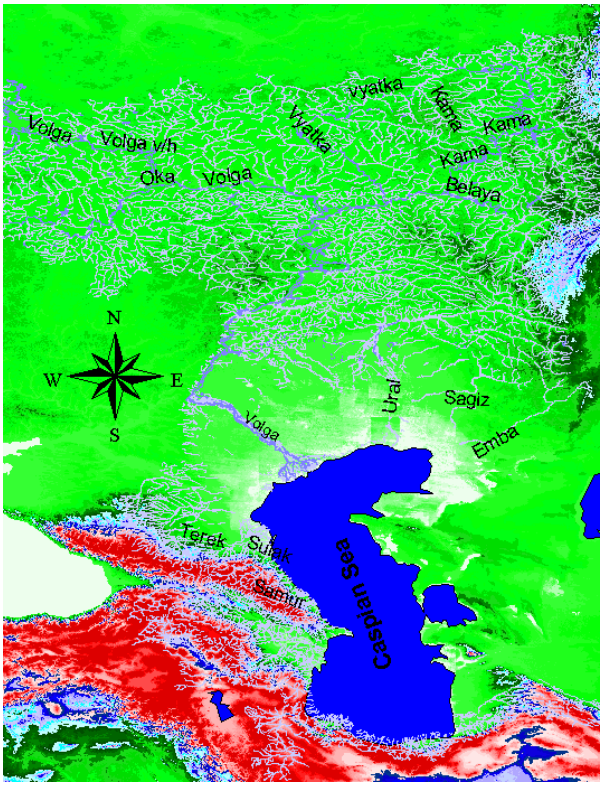


Figure 3.29 Caspian region relief map.

The following work has been done at present.

1. Data base improvement
   - Module structure is optimized, elimination of non-used procedures and variables
   - Regular viewing of programs and deleting of out-of-date blocks
   - Optimization of necessary disk space for hydrometeorological information

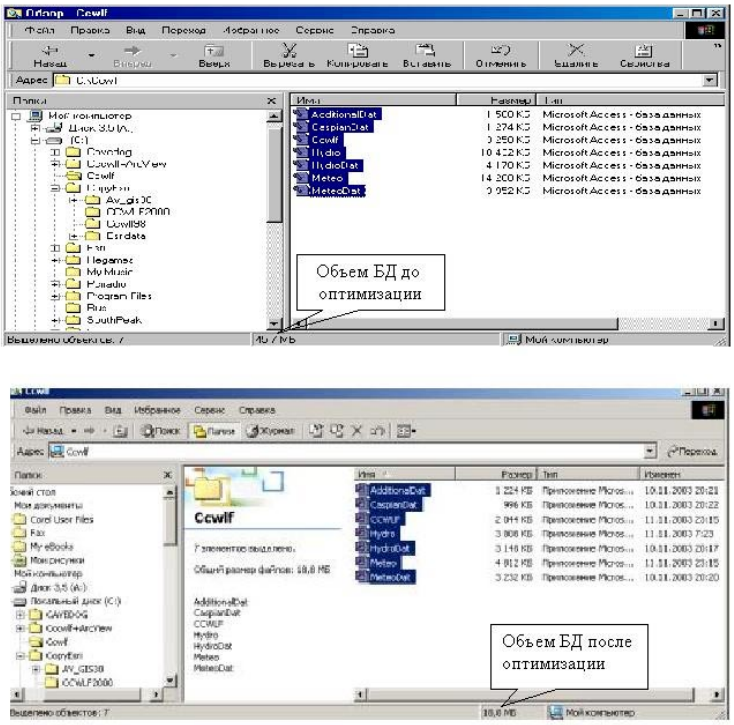


Figure 3.30 Volume of Data Base before and after optimization.

- Data updating

ArcView gives an opportunity to display the data from the Data Base geographically in the most visual and convenient form for perception. The opportunity has appeared to work with the data in a new fashion using maps to finding out, analyzing and correcting imperfect data available in the Data Base.

Examples of new maps are shown in Figures 3.31-3.35.

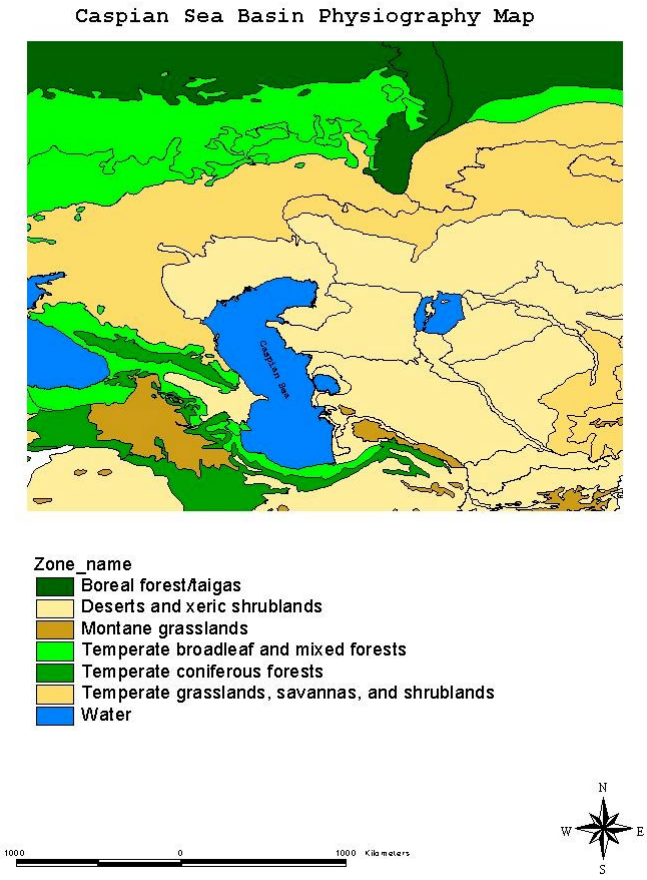


Figure 3.31 Caspian Sea basin physiographic map.

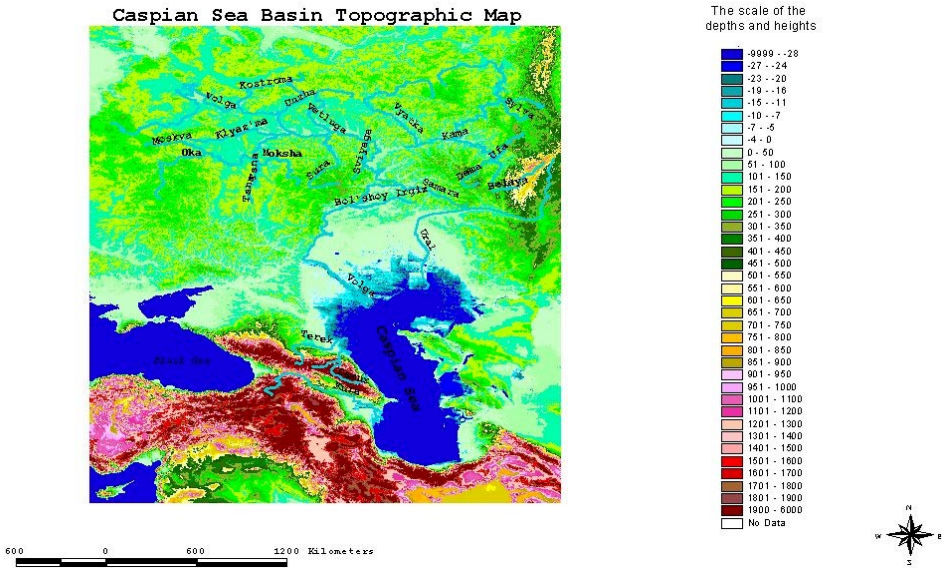
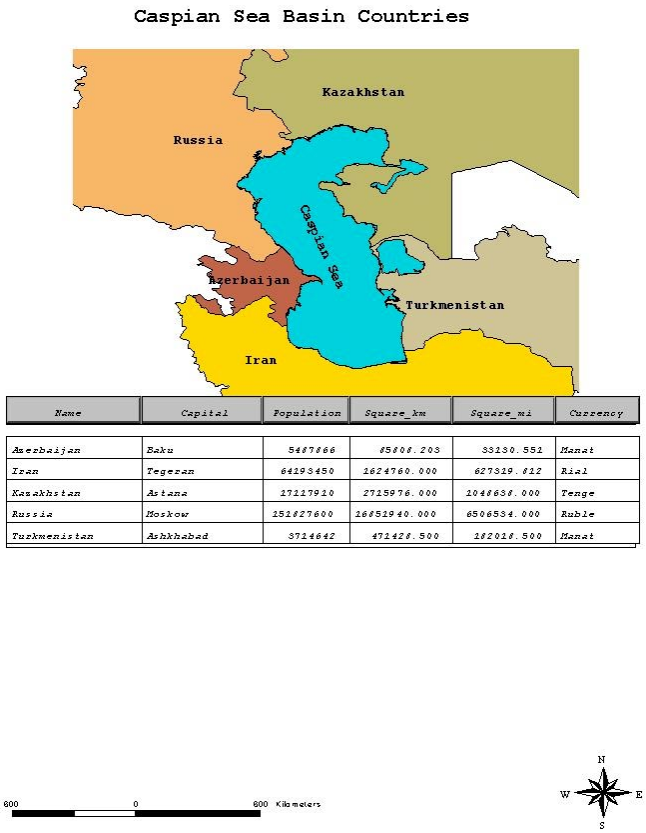


Figure 3.32 Caspian Sea basin topographic map.



Name	Capital	Population	Square_km	Square_mi	Currency
Azerbaijan	Baku	5487866	85808.203	33130.551	Manat
Iran	Tegeran	64193450	1624760.000	627319.812	Rial
Kazakhstan	Astana	17117910	2715976.000	1048638.000	Tenge
Russia	Moskow	151827600	16851940.000	6506534.000	Ruble
Turkmenistan	Ashkhabad	3714642	471428.500	182018.500	Manat

Figure 3.33 Caspian Sea basin countries.

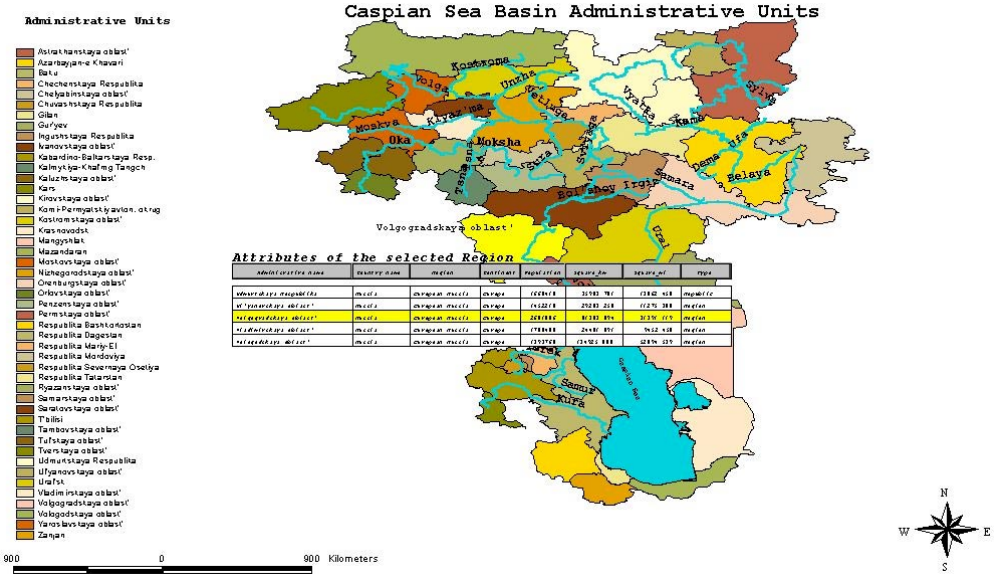
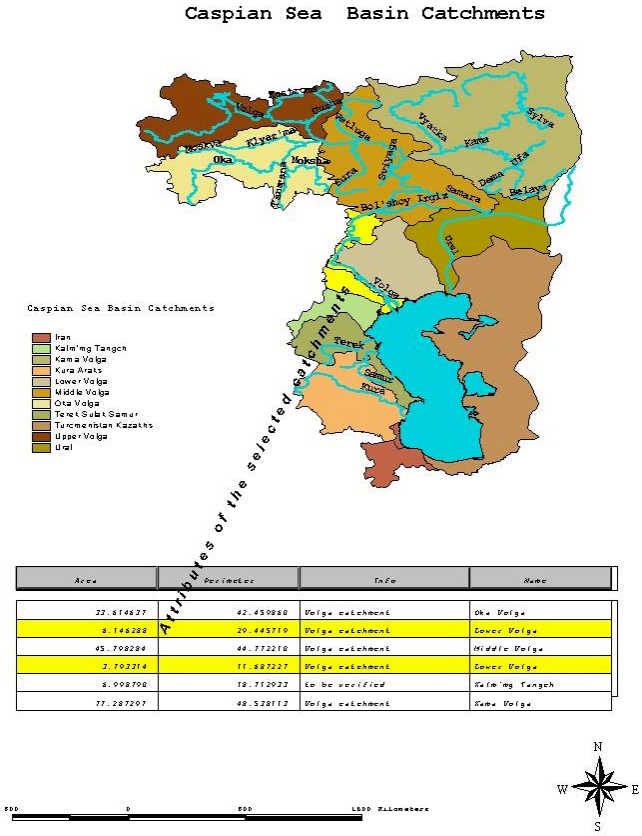


Figure 3.34 Caspian Sea basin Administrative Units.



Attributes of the selected catchments

Area	Perimeter	Info	Name
22.814627	42.450888	Volga catchment	Oka Volga
5.145288	20.445719	Volga catchment	Lower Volga
45.798284	44.772210	Volga catchment	Middle Volga
2.792314	11.887227	Volga catchment	Lower Volga
5.998790	18.712923	to be verified	Kalm'mg Tangch
77.287297	48.528113	Volga catchment	Kama Volga

Figure 3.35 Caspian Sea basin catchments.

2. Formations of the ArcView Project for the Caspian region.

An ArcView project file does not contain the spatial data and tabular data added to the maps in that project. Instead, a project stores references to the location of these data sources on disks. In this way, the same data can be used in any number of projects without duplication. If data changes, the updates will be reflected in all the projects that refer to these data.

While working on the project the following spatial data were used:

- Spatial data created within the framework of the Caspian Ecological Program (from project “Caspcat”, “Volga”);
- Free-of-charge spatial data from the Internet (whole Caspian Sea, whole Volga). While receiving the necessary information from the other projects, the unique CCWLF06 Project has been formed. It is necessary in order to:
- Exempt disk space from the data of the other projects
- Exclude influence of the changes in these project data on other projects

The catalogue of this project is enclosed.

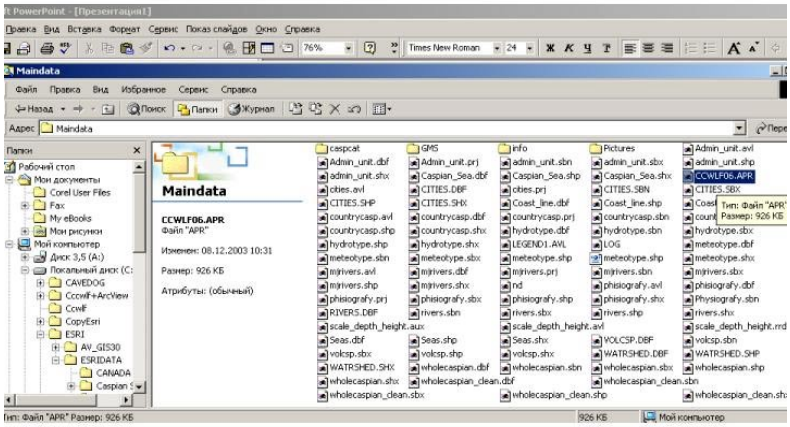


Figure 3.36 Catalog of the Caspian Sea basin ArcView Project.

3. To attach the database to ArcView, using a communication facility.

   The DB is connecting the ArcView Project with use of the ODBC Data Sources. Now it is possible to carry out any SQL queries about the Data Base records.

4. To include hydrometeorological supervision points from the database to ArcView map.

   The information about the hydrometeorological observation points is included in ArcView as the tables are connected to the attributive table of the appropriate theme. Now there is an opportunity to look through the selected stations and to receive their attributes.

5. Classification of hydrometeorological observation points was carried out. Now it is possible to show it in ArcView.

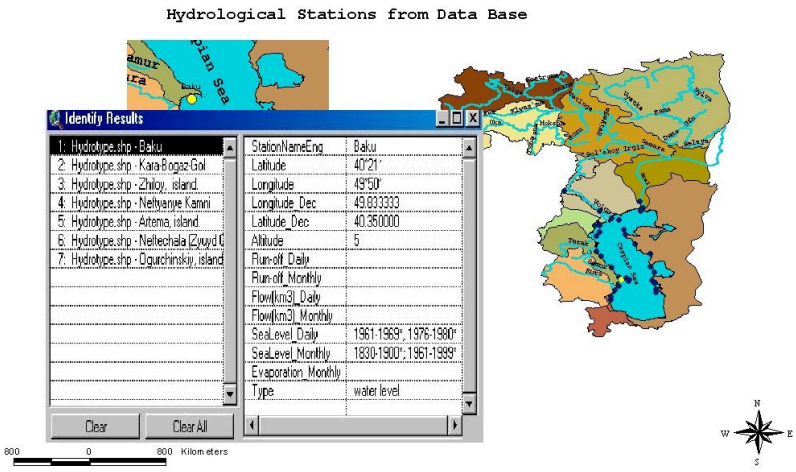


Figure 3.37 Hydrological stations from Data Base.

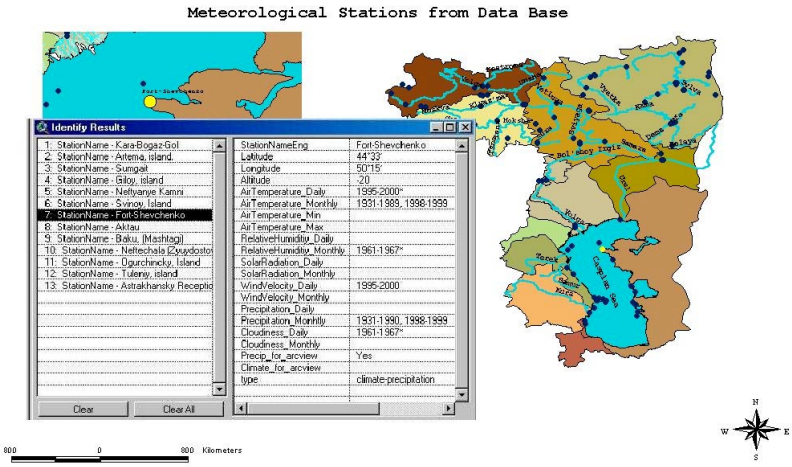


Figure 3.38 Meteorological stations from Data Base.

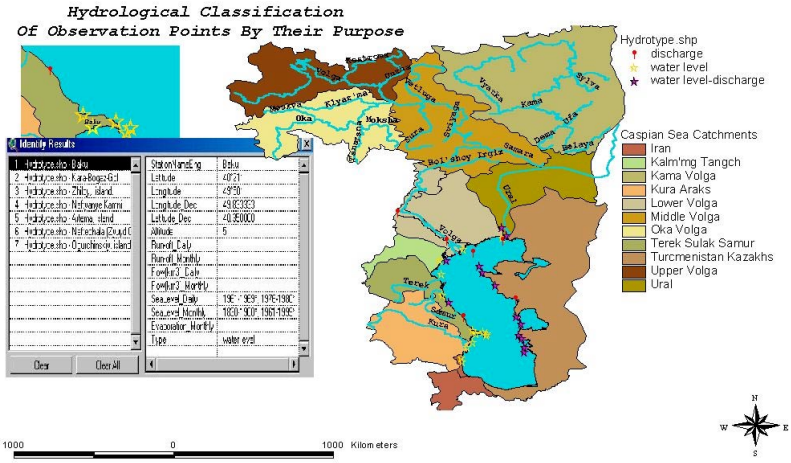


Figure 3.39 Hydrological classification of the observation points by their purpose.

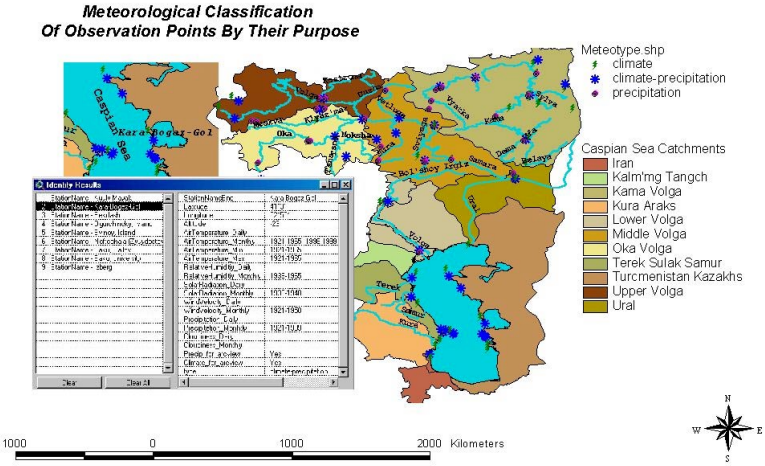


Figure 3.40 Meteorological classification of the observation points by their purpose.

6. Carrying out SQL inquiries it is possible to load any hydrometeorological data from the Data Base in ArcView and to represent them on maps in a simple and accessible view, for example as diagrams. It is shown by some examples.

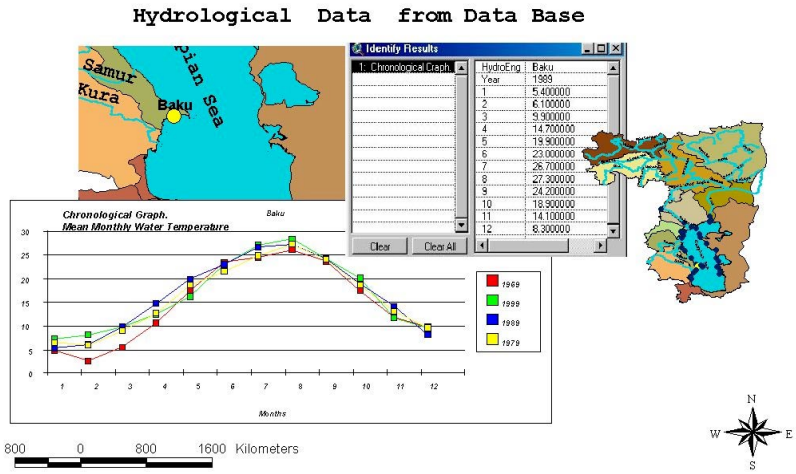


Figure 3.41 Chronological graph. Mean monthly water temperature.

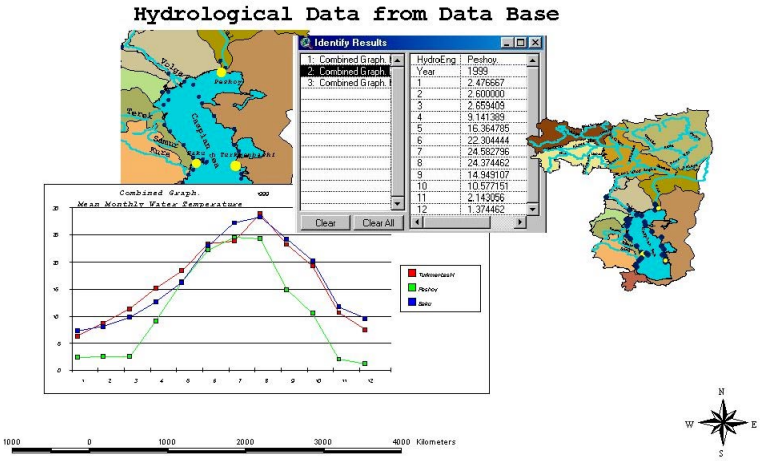


Figure 3.42 Combined graph. Mean monthly water temperature.

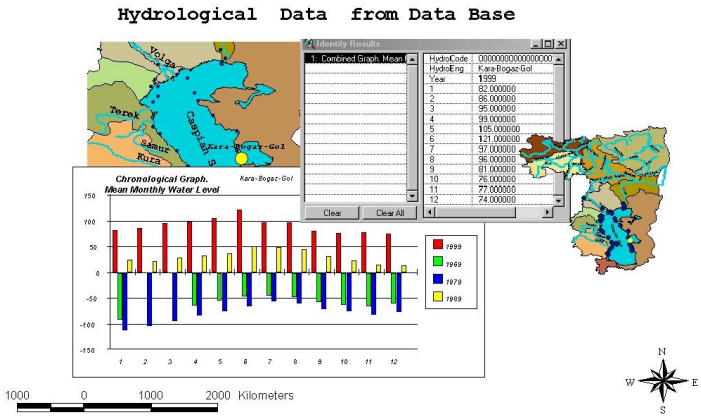


Figure 3.43 Chronological graph. Mean monthly water level.

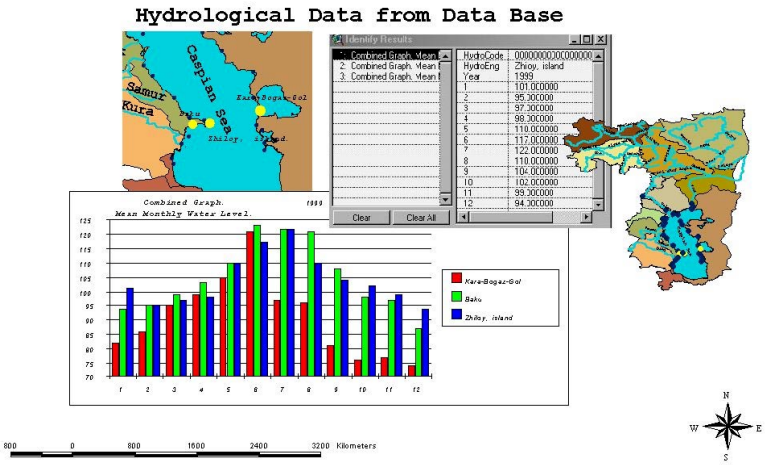


Figure 3.44 Combined graph. Mean monthly water level.

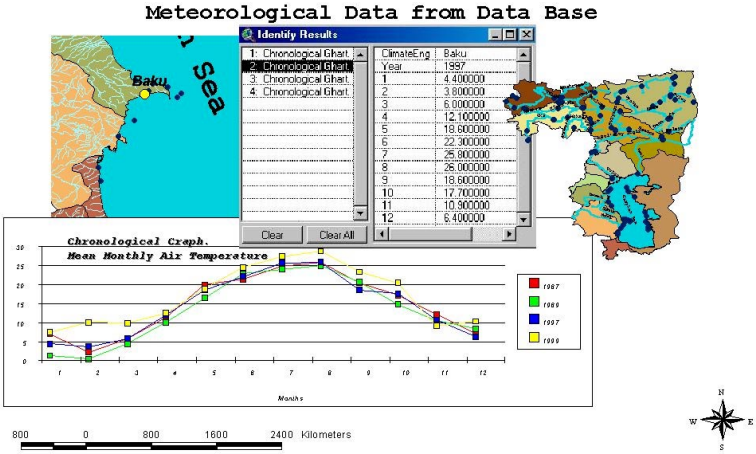


Figure 3.45 Chronological graph. Mean monthly air temperature.

7. "User's Manual of the CCWLF Update Hydrometeorological Data Base" and "User's Manual of the CCWLF Data Base with ArcView GIS System" have been prepared (Appendices A and B).

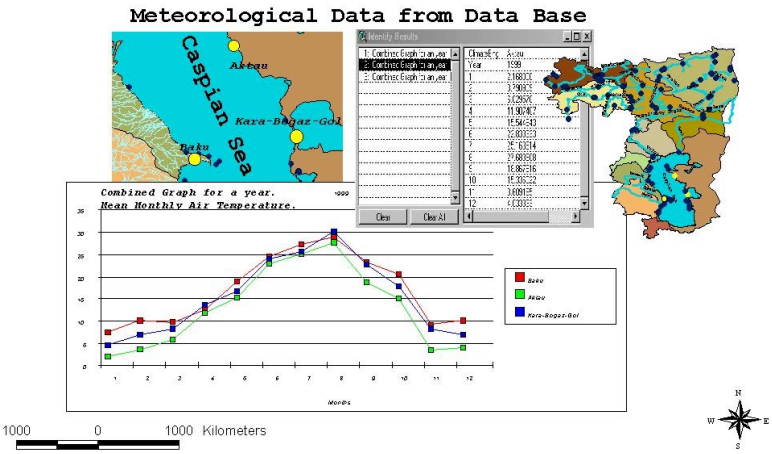


Figure 3.46 Combined graph. Mean monthly air temperature.

Basically, these improvements assume that more available historical data will be entered into the database and data from the database will be accessible through clicking on the maps in ArcView.

In the future it is possible to make comfortable user interface for the work with the Data Base in ArcView.

3.7 Business Plan

The Coordinator of the Water Level Fluctuation Centre has prepared the following business plan for the continuation of the work at CCWLF. Two letters sent to the Ministry of Environmental Protection of Republic of Kazakhstan and to the CEP Coordination Office have been attached in Appendix A.

The list of contents is:

1. Name and address of project applicant;
2. Brief information about the Water Level Fluctuation Centre;
3. Business plan purpose and centre tasks;
4. Economical situation, which applies to the project;
5. Prognosis of service provided for the potential consumers;
6. Project financing;
7. Analysis of service market capacity, competition status;
8. Main advantages of the proposed project;
9. Main barriers for project implementation;
10. Strategy and project promotion program submitted feasibility study implementation;
11. Preventive documents for business-plan promotion

Name and Address of Project Applicant
Water Level Fluctuation Centre at Caspian Environmental Program
Kazakhstan, Almaty, Seifullin Av., 597.

Brief information about the Water Level Fluctuation Centre
The Sea Level Fluctuation Centre was created in November 1998 under the financial support of the TACIS program. The Centre performed work on issues of Caspy level fluctuation (in short-term, seasonal and long-term period). Development according to the Caspian Environmental Program tasks include, in particular, the following issues:

- Analyses of the causes of current sea level rise;
- The development of methods calculation for 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 modeling of storm surges/retreats;
- The establishment of a sectional model for the Caspian Sea basin "Grid –model".

Business Plan Purpose and Centre tasks

The current phase of the Caspian Sea level rise resulted in the watering of extended lands and provided serious environmental problems for the five Pre-Caspian states. These problems dictate the necessity to develop and perform the strategy of Caspian region sustainable development plan. Sustainable development of the 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 present 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 and 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 optimization 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 background sea level. All of this requires several research projects for scientific sea level prognosis development.

The periodical rise and fall of water level under the wind impact, so-called storm surges/retreats are typical for the Caspian Sea. They have significant impact on the coastal infrastructure of all Pre-Caspian states. In particular this is the case with Kazakhstan and Russia, located within area of Pre-Caspian lowland, which most of all are liable to the flooding by seawater (up to 30 km) during storm surges/retreats. Thus, the results of Storm Surge Centre 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 Pre-Caspian states with reliable prognoses of coastal flooding or the nearest and long-term outlook;
- The developing of steps to protect nature through sustainable development of the coastal area using Caspian Sea Geographic Information System and submitting to the Pre-Caspian state governments.

For these purposes 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 Caspian Sea basin;

2. Improvement of the database with hydrometeorological information system 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 surges modeling in order to:
   - Assess the Northern Caspiy coast flood through various scenarios;
   - Estimate the probable features of surges for various coastal areas;
   - Prepare map of coast flooding and drying during surges/retreats;
   - Propose the system of flood prevention.

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

Economical Situation, which Applies to 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 only in two coastal areas – Atyrau and Mangistau – has increased more than fourfold and reached about 30 million tons by 2002. Potentional hydrocarbon reserves in Kazakhstan's sector of the Caspian Sea will allow production of oil in the future on a level of 150-200 million tons 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 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 area, 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 of the Caspian Sea Kazakhstan's 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 Centre and its activities are greatly required.

Prognosis of Service Provided for the 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-, construction-, transportation- 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 project 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, 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 services of the Centre is a long-term prognosis 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 Centre are important for use in the Caspian Environmental Program for coastal zone management. In addition to this, the Centre 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, Centre outputs are distributed by the following directions:

- Oil-gas and other economic sector enterprises and companies;
- Government agencies;
- Regional authorities;
- International organizations.

Project Financing

During the feasibility study preparation the Water Level Fluctuation Centre-Storm Surge Centre is not a commercial organization. It is a structural thematic department of the Caspian Environmental Program. Centre activity is conducted under the sponsor financial support.

For self-financing providing the source should be payment of the services for prognosis information about water level change during surges/retreats at a time earlier than 120 hours or 5 days for each point ordered by client.

Currently, market cost of one prognosis is $50.

In the Centre activity the profit of this work will be the main part of obtained benefit.

At the same time the Centre will sell the prognoses of background sea level for long-term periods of 3 and 5 years – In conformity with each client's wish.

Centre plans to take part in Caspian Environmental Program projects in coastal zone management block.

Some profit is going to be obtained owing to the professional training for specialists in the area of coastal zone management and university students in the area of hydrology and water basins.

The next income item can be the expertise of oil, gas and other sectors' projects for the purpose of sea level change registration during economic activity in the coastal area over the period of 20-30 years and development of nature protective arrangements against the flood of industrial and social objects.

Thus, the annual volume of service cost by all types is the following at maximum cost of service unit and maximum number of services:

All services	Cost of one prognosis	Number of prognosis targets	Annual prognosis number	Total service cost
Prognosis of water level with lead time of 5 days	$50	25	1,825	$ 91,250
Long-term prognosis of sea level fluctuation over 5 years	$15,000	1	1	$15,000
Training for specialists and students	$100 payment for one trainee	50 people per year		$5,000
Preparation of flood and desertification maps for nature users	$2,000	5		$10,000
Seminars, conferences	-			$5,000
Project expertise	3,000	3 projects		$ 9,000
Total	17,150			$ 135,250

Cost for production and proposal of services in the market

Costs connected with the preparation of product, (service) are formed from the following costs:

Expense items	Annual sum $
Preparation of meteorological information from European Meteorological Centre, KazGydroMet and others	20,000
Equipment procurement	8,000
Premise rent	7,000
Public utilities	3,000
Communication	2,000
Transportation cost	1,500
Spare parts, service parts	4,500
PR and advertising	3,000
Marketing	1,000
Centre personnel salary	56,400
TOTAL	86,400

Budget payment:
VAT—16% - $21,640
Social funds – 32% from salary volume - $18,058
Total sum of expenses and budget payment is $126,098

Total income
Total income is difference between the service cost, expenses and budget payment. This income is as follows:

135,250- 86,400 –21,640-18,058 = $ 9,152

Taxes
According to Kazakhstani legislation tax payments from the total income is 30%. Thus, the annual budget payments for full program performance will be the following:
$ 2,745.6

Profit
Annual profit is $ 6,406.4

All financial calculations were made for the period of maximum service volume per year.

It is assumed that 2 years of gradual service volume and cost increase will be required to achieve this level under conditions of newly created enterprise and market peculiarity, related to Caspian Sea Kazakhstan sector oil and gas production expansion as well as western and local oil companies and construction and service companies attraction into the region. Results will have been achieved only by the third year.

Financial indices (USD)
Under the assumption of an annual increase services cost and other expenses for 30% in average, financial indices will be as follows:

Item	First year	Second year	Third year
Service volume	45,083.3	90,167	135,250
Expenses	43,152	86,204	126,098
Net income	1,931	3,861	9,152
Profit	1,351	2,703	6,406

Annual budget at the cost for one prognosis $40, $45 and $50

Service volume	117,000	126,125	135,250
Expenses and budget payments	123,178	125,300	126,098
Net income	Negative balance	825	9152
Profit	Loss	578	6406

The table shows that commercial activity is the most profitable if the cost of one prognosis is $50. Profitability will depend on the market demand and consumer amount.

Dynamics of service volume changes if prognosis consumer amount is changed (for only storm surges/retreats):

Consumer amount	Annual prognosis amount	Annual service cost if one service cost is $50
10	720	36,000
15	1,080	48,600
25	1,825	91,250

Dynamics of profit change for various consumer amounts

Consumer amount	Prognosis amount	Annual profit
10	720	-46,098 loss
15	1,080	-23,498 loss
25	1,825	6,406

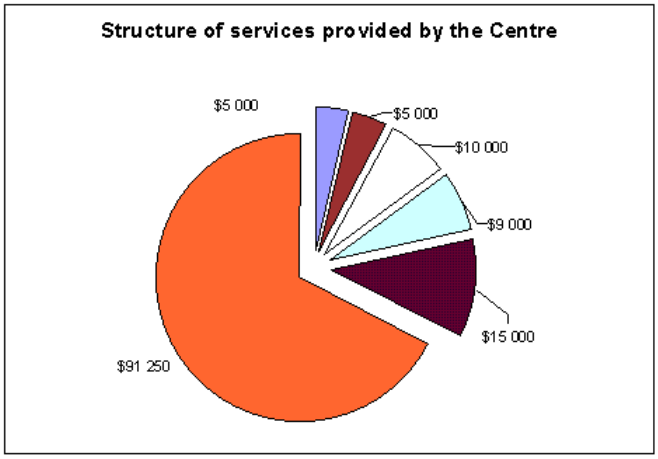
Thus, the profit, which can provide the financial self-sufficiency of the Centre, with minimum expenses and with minimum staff members will be achieved if consumer amount is 25 and more, so 1,825 prognoses, should be made. These indices can be achieved at a large-scale in the beginning of oil production (2007-2009) on the shelf of Caspian Sea Kazakhstan part and the attraction of private western and local companies.

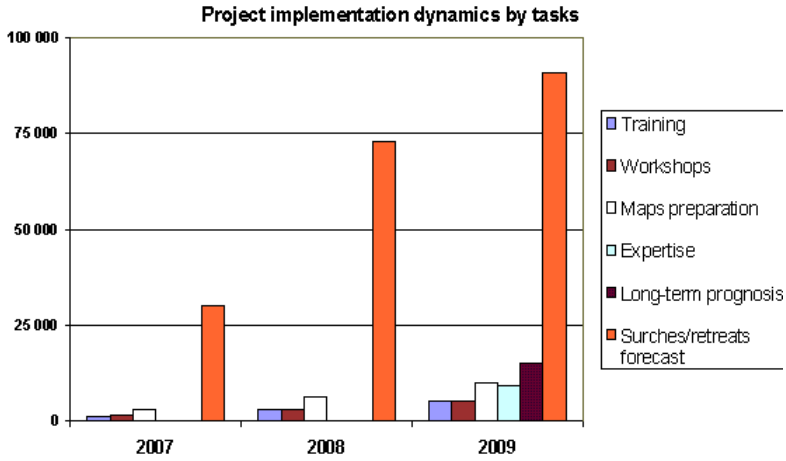
Before this period the Centre should develop normative, methodical and technical aspects of its activity, conduct modeling and model calibration on the basis of financing from national budgets and grants.

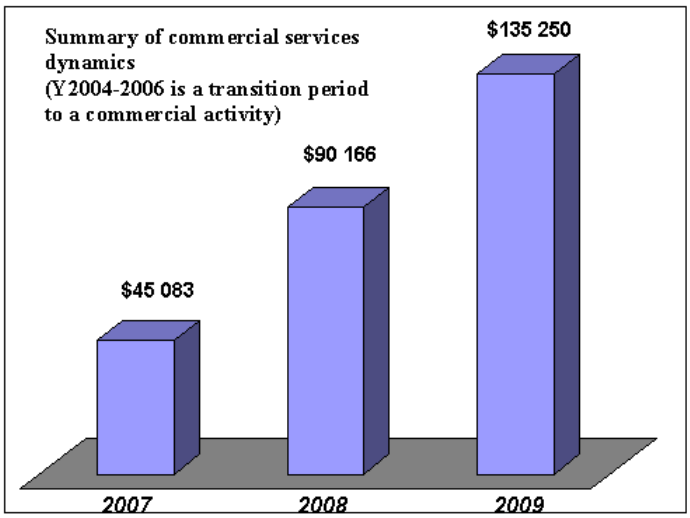
In the period prior to the self-sufficiency period losses can be avoided and stable work of the Centre can be provided due to the expense minimization at the mentioned consumer dynamics.

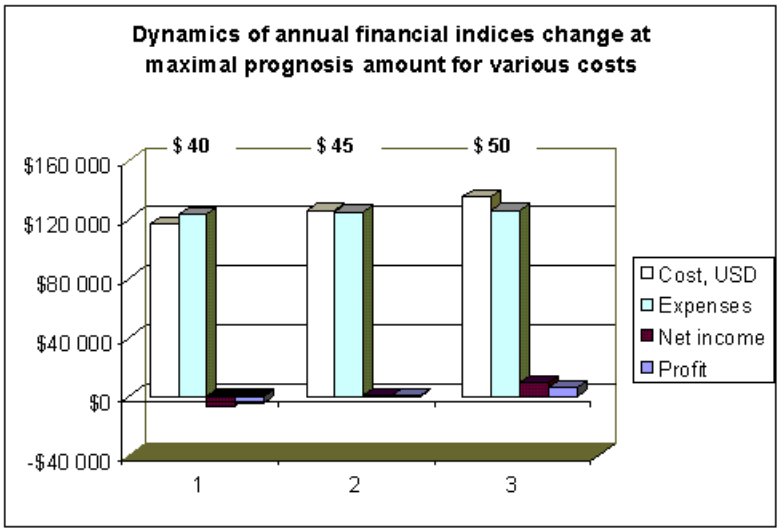
For example, if expenses and budget payments will be reduced by the years by 35%, 25%, 10%, the financial indices at various consumer amount during three years will be the following:

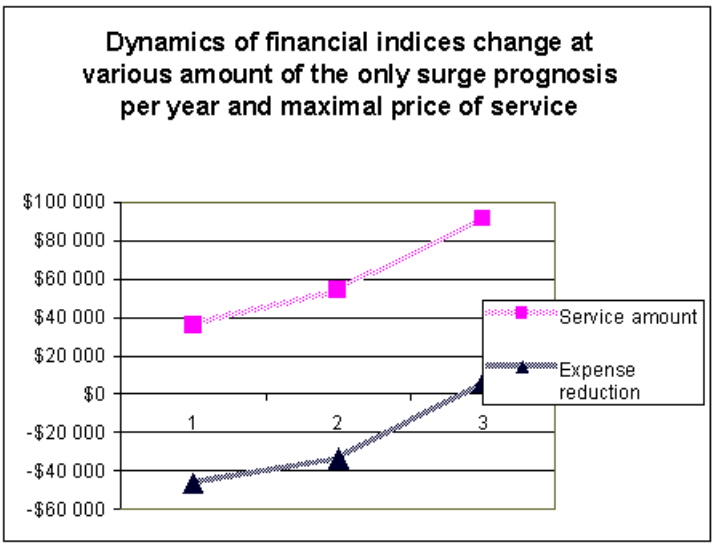
Period	Consumer amount	Service cost	Net income	Profit
2007	10 / 720	80,000	0	0
2008	15 /1,080	98,000	3,426	2,399
2009	25/1,825	135,250	21,250	14,875

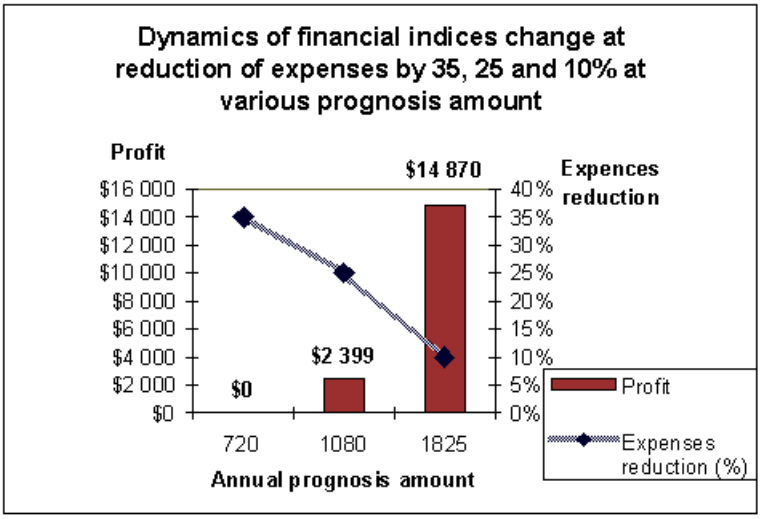

Structure of services provided by the Centre
$5 000
$5 000
$10 000
$9 000
$15 000
$91 250


Project implementation dynamics by tasks
100 000
75 000
50 000
25 000
0
2007
2008
2009
Training
Workshops
Maps preparation
Expertise
Long-term prognosis
Surches/retreats forecast


Summary of commercial services dynamics
(Y2004-2006 is a transition period to a commercial activity)
$45 083
$90 166
$135 250
2007
2008
2009


Dynamics of annual financial indices change at maximal prognosis amount for various costs
$ 40
$ 45
$ 50
$160 000
$120 000
$80 000
$40 000
$0
-$40 000
1
2
3
Cost, USD
Expenses
Net income
Profit


Dynamics of financial indices change at various amount of the only surge prognosis per year and maximal price of service
$100 000
$80 000
$60 000
$40 000
$20 000
$0
-$20 000
-$40 000
-$60 000
1
2
3
Service amount
Expense reduction


Dynamics of financial indices change at reduction of expenses by 35, 25 and 10% at various prognosis amount
Profit
Expences reduction
$16 000
$14 000
$12 000
$10 000
$8 000
$6 000
$4 000
$2 000
$0
40%
35%
30%
25%
20%
15%
10%
5%
0%
$14 870
$2 399
$0
720
1080
1825
Annual prognosis amount
Profit
Expenses reduction (%)

Initial Financial Support

Financial support was provided by TACIS during the activity of Water Level Fluctuation Centre under the Caspian Environmental Program and was completed in 2001. To perform this business-plan and achieve self-sufficient financing planned by this project, some time is required to enter the service market and perform the plan, program and strategy of business-plan promotion. Preparation and transition period is assumed to be 3 years (2004-2006), taking into account the actual situation and problematic specific character on the Kazakhstan part.

Under these conditions and on the basis of estimations and Centre experience, the necessary financial expenses for the Centre maintenance should be $19,000 per year.

This sum should be issued from the budget of Ministry of Environmental Protection in relation to the financing of KazGydroMet, which always contributed according to the Caspian Environmental Program in the form of premise providing, payment for communication and public utilities.

The concept of budget expenses is following:

Expense item	Sum in USD
Obtaining hydrometeorological information from European Meteorological Centre	4,500
Premise rent	4,000
Public utilities and others	2,000
Equipment and material procurement	1,500
Salary	7,000

In preliminary and transition periods the Centre will cooperate closely with KazGydroMet's Department of Caspian Sea Issues and KazNIIMOSK institute, processing organizational, scientific, methodical and standard aspects of the Centre entrance into the market forms of services and providing with regional international cooperation in the area of seal level fluctuation long-term research and prognosis on the basis of net model (Grid-model), which records climatic changes and circulation processes in the air.

In this period the significant component of Caspian Environmental Program idea realization outlook is cooperation of Pre-Caspian countries for Caspian ecosystem protection, especially in the aspects of trans-boundary problems, such as maintaining cooperation in the area of Caspian Sea level fluctuation research at the international level. This meets the objectives of international environmental policy and plans donor support by Global Environmental Foundation, European Union and other international environmental organizations.

In these conditions the second phase of Caspian Environmental Program in the block of coastal zone management can actively use the Water Level Fluctuation CENTRE as an important component of effective preventive tool of nature protective arrangements. The Centre has all reasons to take part in these projects and rely on the grant from $5,000 to 10,000 per year.

Available Resources of the Centre

The Centre is located in the building, which belongs to KazGydroMet, and it occupies three rooms with a total area of 70m^2. The Centre is provided with computer and office equipment and a telephone line.

Over the past period the Centre worked, attracting the contract local specialists and scientists from various areas of the problems connected with sea level fluctuation, according to the CEP Terms of Reference. Total number of attracted experts is 10 people from Kazakhstan. Educational level corresponds to the requirements of TACIS Program; there were PhDs and specialists with large experience in this area.

Centre Status

Centre status should provide the significance for successful performance of business-plan, in particular what role the Centre will play in the market of storm surges/retreats prognosis and other works, concerning sea level fluctuation aspects.

The most optimal option is the creation of independent production unit on the basis of Kazakhstan legislation with authorities of a legal entity. Moreover, the Founder can be not only a state organization, but also private consulting companies and private people working in this Centre.

The most effective founder is a Republican State Enterprise "KazHydroMet» and Kazakh Research Institute for Environment Monitoring and Climate (KazNIIMOSK), which will have both commercial interest for the Centre activity results and administrative possibility to manage and coordinate work under the KASPAS Program and Republic National Plan for Caspy.

Taking into account that the Sea Level Fluctuation Centre has been created by Caspian Environmental Program Centre for perspective and long-term projects and that many tasks, specified to the perspective, have international and trans-boundary nature, it is important to keep the regional status of the Centre. Such position will help the Centre while performing future CEP phases to coordinate and cooperate with experts and specialists of Pre-Caspian countries in the area of sea level fluctuation study, to develop and propose the jointly developed method of long-term Caspian Sea level prognosis on the basis of a net model (Grid-model), taking into consideration climatic changes in the future. International status provided the Centre plan with some grants from sponsor organizations.

Analysis of Service Market Capacity, Competition Status

During the planned economy, before Kazakhstan got its independence, the service proposal, dealing with prognosis, for example of storm surges/retreats hadn't any market nature. All available information was delivered to the local government bodies by hydrometeorological organizations according to the Regulation for their activity. During the initial period of market economy need of such information was limited by the decrease in the industrial sector activity and poor financial possibilities due to the absence of legislative standards and collapse of old state management system.

The period of necessity to obtain the environmental and hydrometeorological information to perform the activity according to the environmental legislation of the Republic of Kazakhstan began only with the emergence of western capital into the oil sector of the PreCaspian region, initiation of large oil companies operation and creation of joint ventures with such organizations as Chevron, Mobile, British Petroleum, British Gas,

Total, Shell and others, and the increase in petroleum production. Regarding the information about sea level fluctuation and of storm surges/retreats real-time prognosis, it is obvious to say that Kazakhstani companies couldn't compete in these service markets due to the absence of hardware and software models. This niche has been occupied by western consulting companies, which have up-to-date prognosis methods. As a result, this market was monopolized. Currently, none of the western companies use the storm surges/retreats prognosis services, which can be proposed by, for example, KazGydro-Met.

Main Advantages of Proposed Project

In condition of Kazakhstan independence and economical self-dependency policy, performed in practice, import displacement principle in the main lines of production activity, the tasks of this project fully correspond to the aims of the Republic economic policy. This situation favors obtaining the support from Ministry of Environmental Protection and regional state bodies in the area of the Surges/Retreats Centre financial self-sufficiency promotion, market entrance.

Over the period of the first phase of CEP Water Level Fluctuation Centre has demonstrated the efficient work fulfilling the regional international program and coordination of PreCaspian states' experts and scientist activity in this area. It obtained the positive mark from appropriate structures of the European Union expressed in a temporary financial support, while financing of all other Centres of Caspian Environmental Program has been cancelled.

The Centre activity under CEP let Kazakhstan occupies the leading position in the study of enigmatical problems of sea level fluctuation, which will facilitate creating scientific school in future and bring up our own scientists and specialists in this area. To continue this activity and search the financing source, the performance of this business-plan will allow the Centre to perform future cooperation, research exchange among PreCaspian countries. All that meets the aims of the Caspian Environmental Program and Kazakhstan obligations of participation in its task implementation.

Under CEP in the second phase of its realization in the block of coastal zone management in the National Program of Caspian Sea Northern Part Environmental Monitoring – the existence of Surges/Retreats Centre, its prognosis data can and should be used in the system of early emergency prevention and arrangement of coastal zone protection against floods and shelf contamination.

In the atmosphere of paying services rendering to projects of oil and gas industry, concerning the creation of oil-production systems and attendant infrastructure the Centre activity is especially significant regarding the expertise of environmental project aspects, taking into account the sea level change in a long-term perspective and surges/retreats. The Centre can also develop nature-protective arrangements for each project connected with the protection against floods. Currently, such expertise is not performed professionally, taking into consideration sea level fluctuation, and real-time operation mode.

One of the important advantages of the project is a competitive ability of the future Centre due to the absence of similar structures in a national niche of such services.

Appreciable plus of the project can be quite a competitive price of the services in comparison with western consulting companies due to decreasing prime costs and low salary of the staff members.

The project implementation meets the state economic policy, in particular the tax intake and population employment increase.

Thus, the project advantages are supported by the following circumstances:

- Political and economic;
- Environmental and methodical;
- Research;
- International and regional;
- National and protectionist.

Main Barriers for the Project Implementation

Implementation of any project cannot avoid overcoming various barriers, which occur by impartial and subjective reasons. From this point of view this business-plan can have the barriers related to subjective tendencies, because its promotion will strike against the realities and established procedures of paying services rendering, in particular prognosis of surges/retreats.

Insistent and laborious work, negotiations with appropriate bodies in order to convince them of the necessity to support the project, enactment of required legislative standards at the level of Ministry of Environmental Protection lie ahead.

Another obstacle is to overcome existing positions in this aspect of foreign oil production companies, operating in the Caspian region of Kazakhstan, which orientates to the western consulting companies.

A constricting factor can be the transfer and delay to the later terms of Caspian Sea shelf oil production and start up of equipment for hydrocarbon transportation to the western market to a later period of installation. This will restrict the speed of increase in potential surges/retreats prognosis consumers in respect of oil companies and other business units, which did not begin the production and transportation of petroleum hydrocarbons and will not have the financial capabilities.

At the same time, all above-mentioned barriers are surmountable while performing well-considered program and strategy of this business-plan promotion and actual support from Kazakhstan government agencies and Caspian Environmental Program.

Strategy and Project Promotion Program, Submitted Feasibility Study Implementation

Barriers	Necessary actions	Terms
The Centre of water level fluctuations is not included in the second phase of the Caspian Ecological Program (2004-2006)	Keep the Centre as a regional structure of Caspian Environmental Program, in coastal zone management block. Apply to the CEP Steering Committee, Ministry of Environmental Protection, TACIS	2004
Search for the Centre financing source for the period of its commercial self-financing preparation	Put a question to the Ministry of Environmental Protection about budget financing since 2004	2003
Registration of the Centre as a legal entity	Make a proposal to the Ministry of Environmental Protection, Kazhidromet and private companies regarding to the foundation	2004
Issues of structural scheme of the Centre interaction in Kazhidromet system	Discussion with appropriate bodies concerning the grant of authority in the area of prognosis services for surge/retreats and other activity. Issue necessary standard documents for Centre authority regulation	2004-2005
Performance of organized campaign for the Centre image creation in order to penetrate into the service market of increasing oil sector	- Advertising - PR - Centre presentation in seminars and conferences - Apply to the regional authorities	2005-2006

Preventative Documents for Business-plan Promotion

Performance of this project, assigned to provide the future Surges/Retreats Centre financial independence and keeping within the Caspian Environmental Program to solve the trans-boundary problems, which should be solved with cooperation of all five Pre-Caspian countries, and it- proposes to conduct the appropriate presentation work with relevant authorities of Kazakhstan and international organizations, which deal with environmental problems of Caspy, for the purpose of a proposed business-plan support. For this purpose the appropriate letters to Ministry of Environmental Protection of Republic of Kazakhstan, CEP Coordination Office and information material, which will be sent to regional departments of the Caspian Region and oil companies have been prepared.

Coordinator of Water Level Fluctuation Centre, CEP
M. Kireyev

A P P E N D I C E S

A P P E N D I X A

Letters prepared in relation to the business plan

To: Ministry of Environmental Protection of Republic of Kazakhstan
Mrs. A.B. Samakova

Issues of Water Level Fluctuation Centre support during the second phase of Caspian Environmental Program

Caspian Environmental Thematic Centre of Water Level Fluctuation Study (KRTC KUV), created in 1998 under the Caspian Environmental Program (CEP), has performed assigned tasks over the period of the first phase of CEP and obtained the positive appraisal of its activity, expressed in additional financing by TACIS in transition period, while other Centres financial support was terminated. The most important and practically significant work is development of future Caspian Sea level change prognosis method for short-term, long-term and seasonal periods on the basis of water balance model adaptation, air circulation recording, surge-retreats prognosis modeling.

It's necessary to underlie that the Centre has developed the surges/retreats prognosis method on the basis of Danish hydrodynamic model MIKE-21, which can be used, at first, in Kazakhstani sector of Caspian Sea. Centre has prepared a business-plan, which will provide chargeable sea level change prognosis services to the regional, municipal councils of coastal regions, emergency services, oil sector companies with lead time of 5 days in real-time using the International MeteoCentre network (Great Britain). Currently, these services are on offer of western consulting companies.

Another important part of the work performed by the Centre is adaptation of Grid-model for the whole basin of Caspian Sea, which lets model form water drainage and inflow, which makes the balance and determines the change of sea level in the long-term period. Continuation of this work requires the cooperation of scientists and experts of all PreCaspian countries, who deal with this problem.

I apply to you by the following reason. The Centre financing, performed by TACIS, has been stopped due to the completion of the first phase of CEP, and since 2004 there has been no clarity related to further Centre financing. In conjunction with this, as it was mentioned above, the Centre has developed the measure (business-plan) of independent financing on the basis of commercial activity, sale of surge/retreats prognosis services. In order to let Kazakhstan strengthen its leading position in Caspiy level fluctuation study the Centre also can perform trans-boundary works, occurring from CEP tasks at the expense of supposed profit, creating the scientific school and training own scientists and specialists in this area in future. The maintenance of the Centre status as a regional one, under CEP is the principal aspect in this context.

It takes some preliminary time and limited budget financing to perform the business-plan and it's necessary to implement several organizational and protective measures, normative and methodical arrangements for this purpose.

On the basis of stated I submit this business-plan project to you, the performance of it will provide the Centre operation with commercial basis, specified by CEP conception, with proper support of Ministry of Environmental Protection of Republic of Kazakhstan.

Coordinator of Water Level Fluctuation Centre, CEP
M. Kireyev

Coordinating office of Caspian Environmental Program

Issues of Water Level Fluctuation Centre support during the second phase of Caspian Environmental Program

Caspian Environmental Thematic Centre of Water Level Fluctuation Study (KRTC KUV), created in 1998 under the Caspian Environmental Program (CEP), has performed assigned tasks over the period of the first phase of CEP and obtained the positive appraisal of its activity, expressed in additional financing by TACIS in transition period, while other Centres financial support was terminated. The most important and practically significant work is development future Caspian Sea level change prognosis method for short-term, long-term and seasonal periods on the base of water balance model adaptation, air circulation recording, surge-retreats prognosis modeling.

It's necessary to highlight the fact that the Centre has developed the surges/retreats prognosis method on the base of Danish hydrodynamic model MIKE-21, which can be used, at first, in Kazakhstan sector of Caspian Sea. Centre has prepared a business-plan, which will provide chargeable sea level change prognosis services to the regional, municipal councils of coastal regions, emergency services, oil sector companies with lead time of 5 days in real-time using the International MeteoCentre network (Great Britain). Currently, these services are on offer of western consulting companies.

Another important part of the work performed by the Centre is adaptation of Grid-model for the whole basin of Caspian Sea, which lets model form of water drainage and inflow, which makes the balance and determines the change of sea level in the long-term period. Continuation of this work requires cooperation of scientists and experts of all PreCaspian countries, who deal with this problem.

My appeal is caused by the fact that the Centre financing, performed by TACIS, has been stopped due to the completion of the first phase of CEP, and since 2004 there has been no clarity about further Centre financing. In conjunction with this, as it was mentioned above, the Centre has developed the measure (business-plan) of independent financing on the basis of commercial activity, sale of surge/retreats prognosis services. In order to let Kazakhstan strengthen its leading position in Caspiy level fluctuation study the Centre can also perform trans-boundary works, occurring from CEP tasks at the expense of supposed profit, creating the scientific school and training own scientists and specialists in this area in future.

To perform the business-plan will require some time and limited financing from national budget and international grant support. In addition it's necessary to implement several organizational and protective measures, normative and methodical arrangements. Keeping the Centre status as a regional enterprise and including it into the coastal zone management block under the second phase of CEP is the principal aspect in this context.

Coordinator of Water Level Fluctuation Centre, CEP
M. Kireyev

A P P E N D I X B

User's Manual of the CCWLF Update Hydrometeorological Data Base

A P P E N D I X C

User's Manual of the CCWLF Data Base with ArcView GIS System