Tacis

Caspian Environment Programme, Phase 2

Operational Storm Surge Warning Centre

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Chapter 1. Introduction

This report describes the work on storm surge modelling done by the Caspian Centre for Water Level Fluctuations (CCWLF) within the Caspian Environment Programme.

The objectives of the study have been to:

- Establish an operational storm surge forecast centre.
- Investigate the possible future changes in storm surges due to changes in background water level of the Caspian Sea.
- Set up specifications for running an operational storm surge forecast centre.

In this report, the established storm surge model is briefly described together with a description of the work done within each of the listed objectives.

Three additional investigations applying the surge model have also been undertaken. The results from these are described in the separate reports:

- Studies Relating to the Updating Extension of the KazNIIMOSK Surge Model, Tacis report Nr. CEP1/WLF 7L.
- Non-periodical Fluctuations' Studies of Sea Level (wind effected phenomena), Tacis report Nr. CEP1/WLF 19L.
- Research on Influence of Sea Rising and Surges on Economic Complex of North-Eastern Caspian Region, Tacis report Nr. CEP2/WLF 054.

Chapter 2. The Storm Surge Model

A 2-dimensional hydrodynamic model of the Caspian Sea has been established. The model is based on the DHI model, MIKE 21 HD, which solves the full time-dependent non-linear equations of continuity and conservation of momentum in a finite difference grid. See http://www.dhisoftware.com for more information.

The hydrodynamic model has been established for the whole Caspian Sea as well as for the northern shallow part of the Caspian Sea. The model areas are shown in Figures 2.1 and 2.2.

Figure 2.1 Caspian Sea Bathymetry, 10-km Grid Resolution

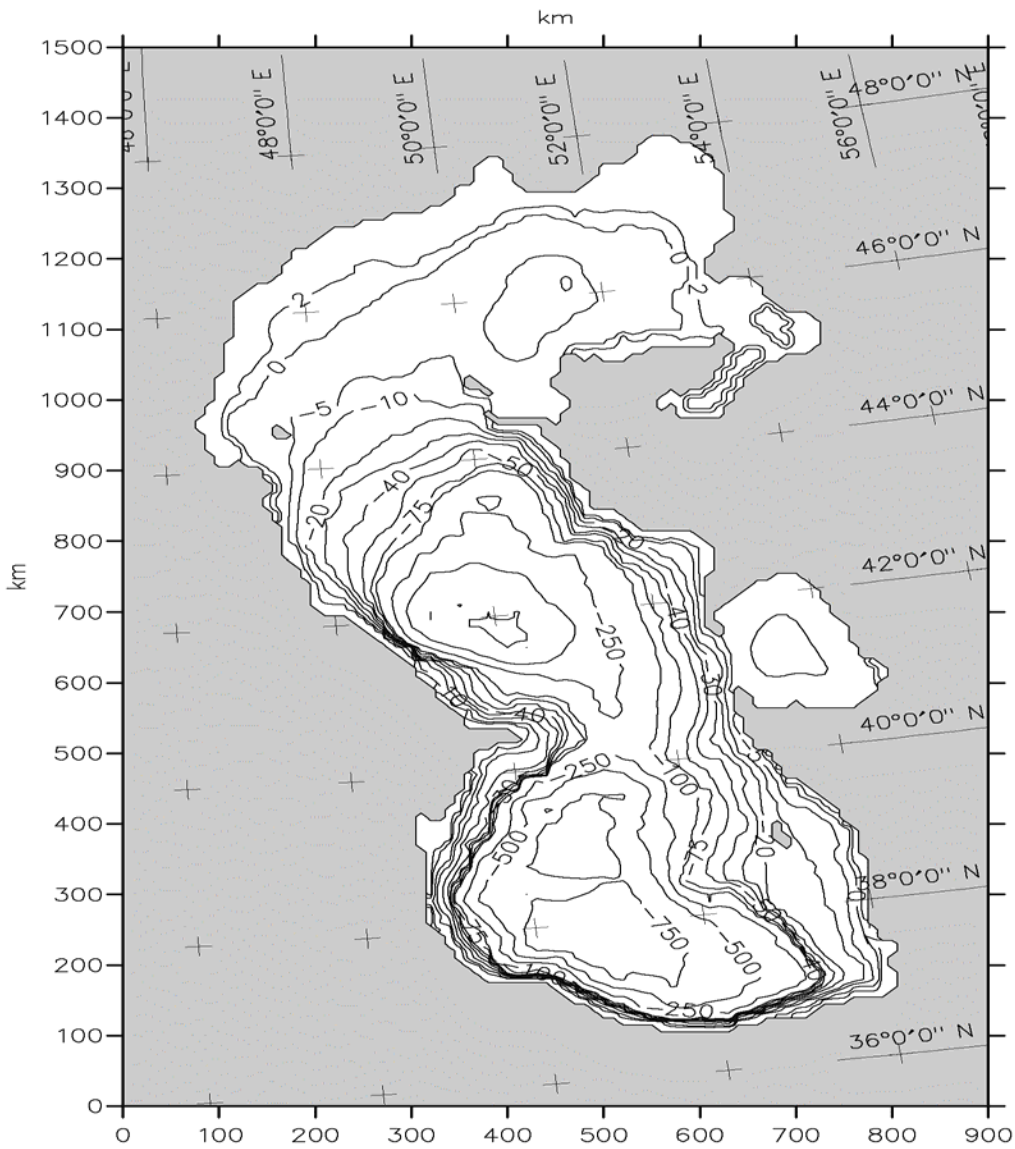
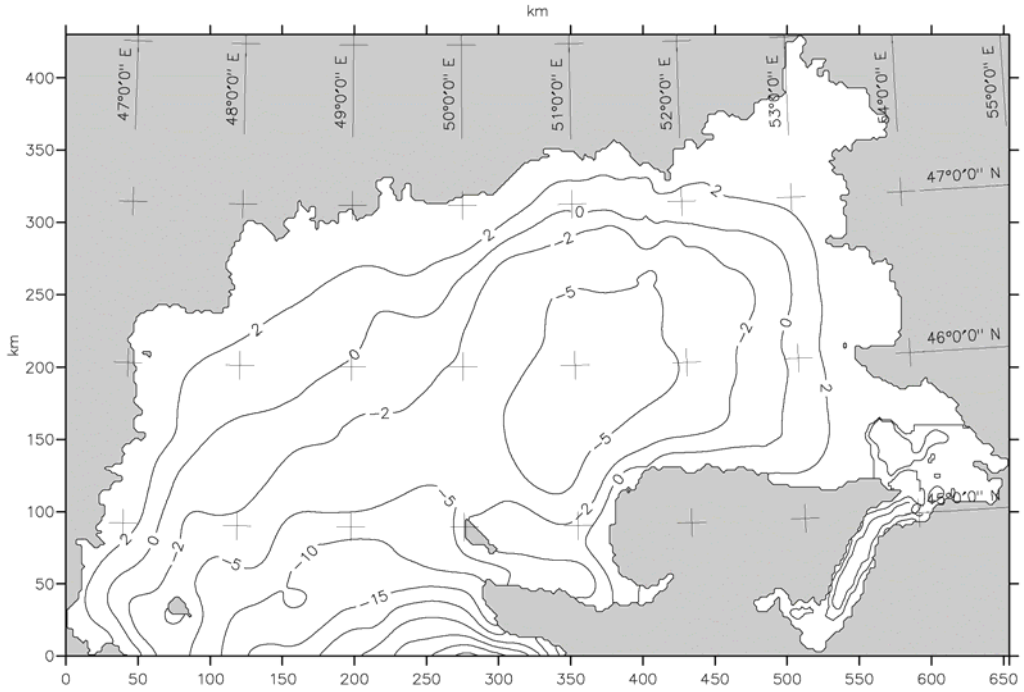


Figure 2.2 Northern Caspian Sea Bathymetry, 2-km Grid Resolution.



The bathymetries have been established based on all depth information available at KazHydroMet in Almaty, Kazakhstan. The bathymetry reference level is -28 m relative to the Baltic Sea Datum. To be able to simulate flooding during the most extreme storms, the bathymetry has been digitised up to level -22 m or approximately 5 meters above the present background level of the Sea.

The primary model calibration parameters are the bottom friction coefficients, the wind friction coefficient and the eddy viscosity. Besides, adjustments of the bathymetries in areas of, for example, narrow channels, which cannot be resolved in the applied resolution of 10 km or 2 km, have been made.

A description of the model and its calibration/validation is given in: Studies Relating to the Updating Extension of the KazNIIMOSK Surge Model, Tacis report Nr.CEP1/WLF 7L.

The Caspian Sea model can be used in two ways: By running the 10 km model alone (used for long CPU-demanding simulations) or by running the 10 km model first and then transferring model results as boundary conditions to the 2 km model (used for more detailed short simulations). The model uses a time step of 10 minutes.

As the Caspian Sea has no connection to the open sea, the only external input to the model is meteorological forcing, river inflows as well as evaporation/precipitation at the water surface. For storm surges, the meteorological part is of major importance. The in- and outflows to the Caspian Sea have been included to cover the total water balance and to include the seasonal and yearly variations in background water level.

The meteorological data consists of maps of 10-m wind speed and direction and surface air pressure.

In earlier studies performed at the CCWLF host institute, KazNIIMOSK, meteorological maps (2D data sets) were established by digitising synoptical weather charts drawn by hand by the meteorological duty forecaster.

For this project this very time consuming procedure could not be used, for the reasons described in the following sections.

Chapter 3. Operational Storm Surge Forecasts

As the activities in the Caspian Sea have increased, especially because of the oil industry, the need for information about the movements of the sea has become greater. Using the established hydrodynamic model, it is possible to obtain information about the past, the present and future currents and water levels all over the Sea. Here past and future are limited to the near past and future since no attempt has been made to couple the surge model to hydrological models and forecast the long-term changes in the background water level of the Caspian Sea.

An operational storm surge forecast centre has been established at KazHydroMet. The objective has been to establish a system for producing daily forecasts of water levels for a test period.

To produce storm surge forecasts that give an adequate warning period, digitally produced meteorological data is needed. Manually digitised maps of wind and air pressure are very time consuming and would be available too late to enable adequate forecasts to be made.

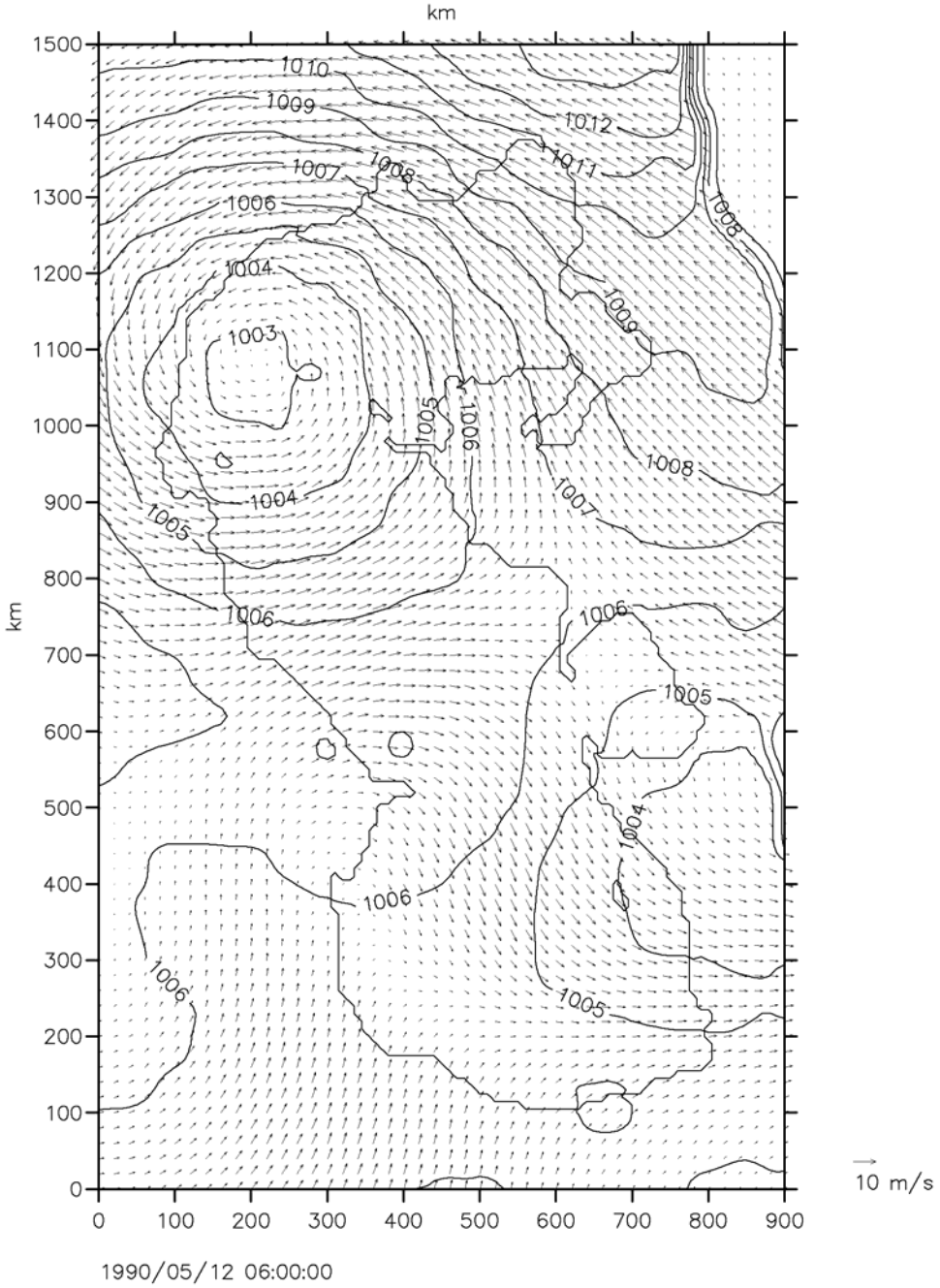
Accordingly, an agreement with the UK Met. Office was established at the beginning of 2001to receive daily meteorological forecasts for a period of one year. However, technical difficulties meant that the fully operational set-up of the data transfer from UK to CCWLF was not in place until the early summer 2001. Besides, due to poor Internet connections in Kazakhstan there have been a lot of errors in the transfer of data and accordingly gaps in producing daily forecasts. Much time has been wasted on handling these kinds of problems.

The meteorological data received operationally from UK consists of surface air pressure and 10 m elevation wind speed and direction, produced by the ECMWF global meteorological model. The horizontal resolution of the data sets has varied from 0.5 to 1.5 degrees (approximately 50-150 km). The time resolution is 6 hours and the forecast length is 5 days. Software has been developed for converting the meteorological data from a geographical grid and GRIB-format to the UTM-projection and binary format used by MIKE 21. An example of the wind and pressure fields applied in the surge modelling is shown in Figure 3.1. Data is only used over the water surface so the difficult north-eastern corner, which is outside the coverage of the meteorological model, is not used.

Because of the late access to operational meteorological data, the test period was reduced to a period of 4 months, from 15 June to 15 October 2001.

During this semi-operational test period, a daily forecast has been produced.

Figure 3.1 Example from May 1990 of Wind and Pressure Field Used as Forcing in the Surge Model

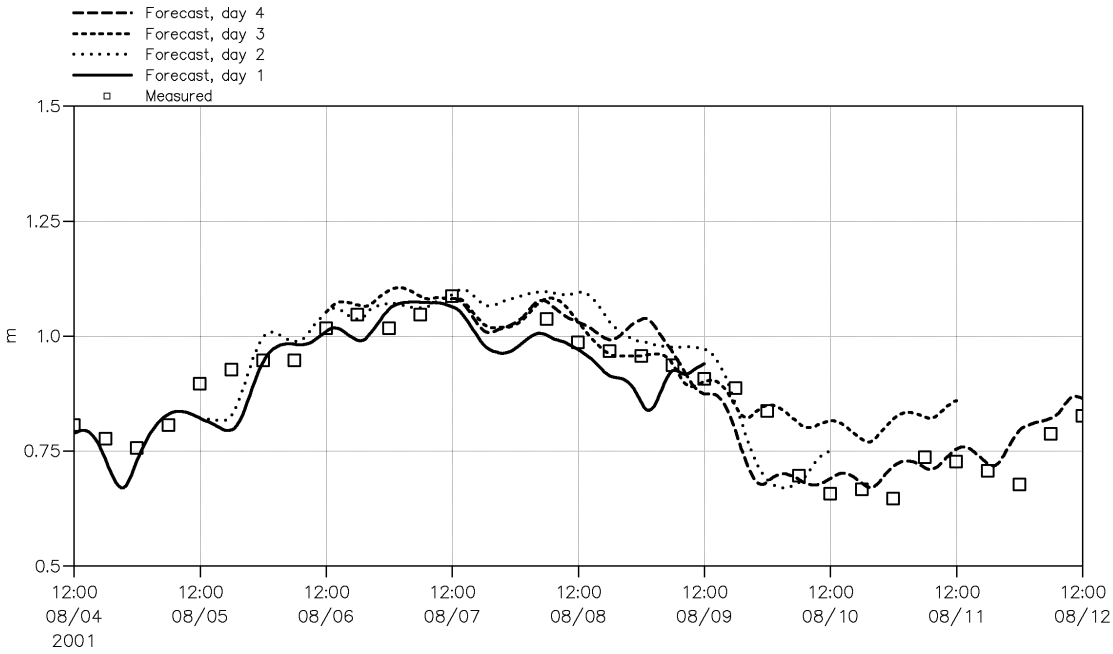


Based on the available meteorological data a 24-hour hindcast (based on meteorological analyses) and a 120-hour forecast (based on meteorological forecasts) have been produced daily. The hindcast has been used to update the state of the Caspian Sea from the previous day to the time of the forecast.

To get the highest quality of forecast, both the 10-km and the 2-km models have been used for the simulations.

Daily, time-series of water levels at selected locations have been extracted from the model simulations and compared to measured water levels at a few Kazakh stations. Observations from stations from other Caspian countries were not available. An example of 4 successive forecasts is compared to measurements in Figure 3.2.

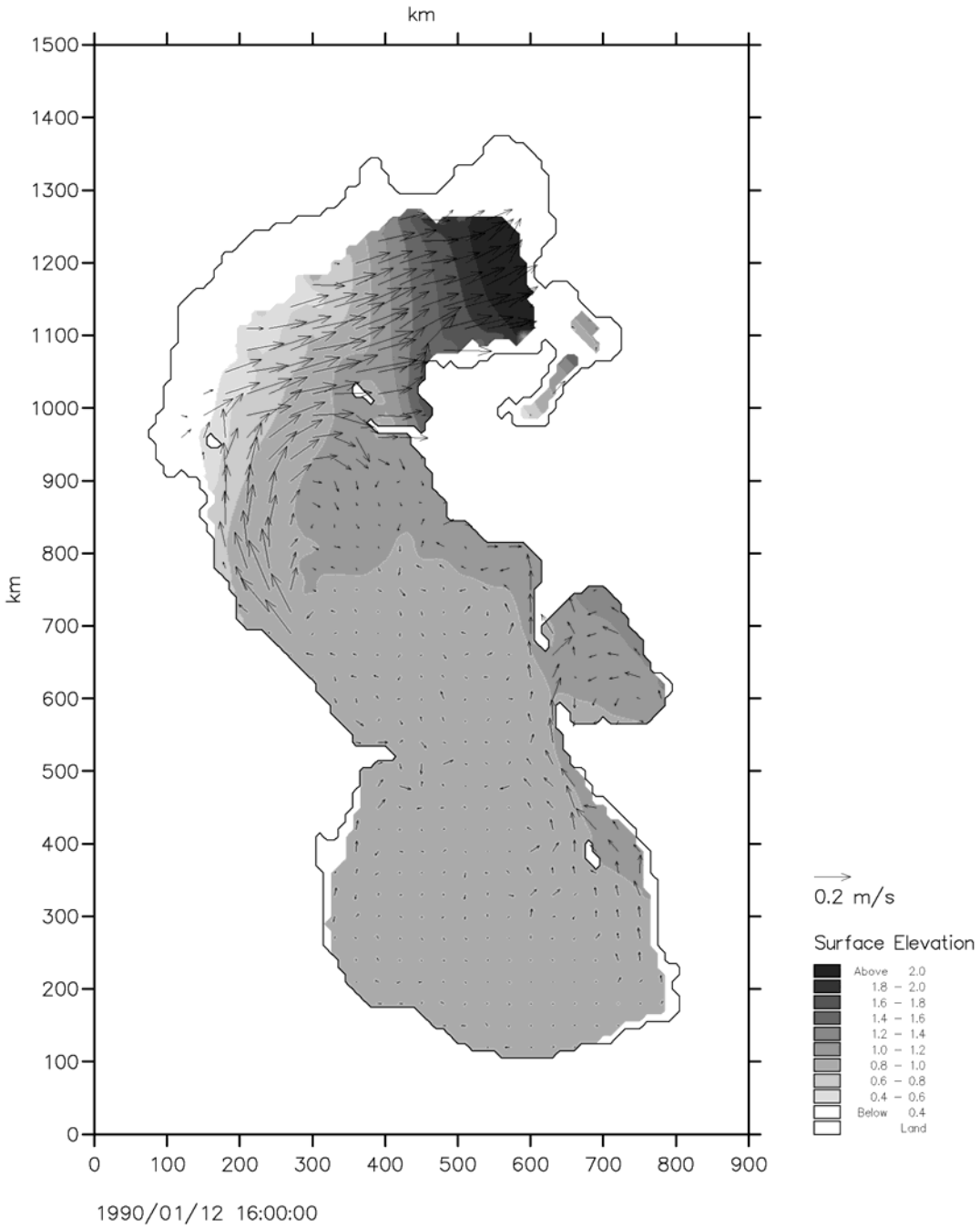
Figure 3.2 Example of Water Level Forecasts at Peshnoy.



The four forecasts are from the days 4-7 August 2001, 12:00 UTC. In comparison with measured water levels (small squares) it is noticed, as expected, that the best quality is obtained for short-term forecasts.

An example of a calculated flow field is shown in Figure 3.3. The figure shows a high water situation at the Kazakh coast in January 1990. The white part of the Caspian Sea is the area that could be flooded in the model.

Figure 3.3 Example of Calculated Currents and Water Levels



To reduce the man-hours necessary to operate the model, automatic procedures (Windows programs and scripts) have been developed to handle most of the data flow.

As part of the northern Caspian Sea is frequently covered by ice, the effect of ice (the reduced transfer of momentum from the air to the sea) has been implemented in the model using a simple approach whereby the wind stress, τ_w is reduced by a factor in the case where ice is present :

$$\tau_w = \text{factor} \cdot \tau_w$$

In the case of ice, the factor is 0. For open water the factor is 1. In practice, a set of typical ice cover situations has been identified and maps of related wind drag reduction factors prepared, from which the duty forecaster should daily select the most appropriate as input for the forecast simulations.

The seasonal effect on water levels from river inflows, evaporation and precipitation is not included in the forecast model, as this information is not available in real-time. Some climatological values could have been applied, but the duty forecaster needs to make necessary adjustments in the initial model background level anyway. Accordingly, these in- and outflows have been ignored in the operational forecast system.

From the approximately 120 individual forecasts produced during the 4 months test period, an assessment of the forecast quality has been made. The results are shown in Table 3.1 and in Figure 3.4.

From each forecast, the forecast water levels at 00 hours, +24 hours, +48 hours, +72 hours, +96 hours and at +120 hours have been extracted and compared to measurements at station Peshnoy. In Table 3.1 the statistical measures Mean Absolute Error (MAE), Root Mean Square Error (RMSE) and Correlation coefficient (R) for each lead-time are shown. It is noticed that all forecasts have been prepared from a previous hindcast (-24 hours to 00 hours (= time of forecast)) and no adjustments of the initial level of the model or the starting level of the individual forecasts have been made. Possible phase errors in the forecasts have also been disregarded. This means that a perfect forecast of an extreme event but with a small phase error will not be assumed perfect and will introduce an error in the analysis, even though phase errors of several hours often are accepted in practise.

An increase in the error as function of an increased lead-time, as expected, is seen from the table. This is partly due to uncertainty (errors) in the meteorological forecasts. It is also noticed that the initial error is rather large, which indicates that the initial conditions at 00 hours are not optimal. The obtained error could be further reduced by specifying a correct initial level (background level) to the model at simulation start and/or by adjusting the forecast time series according to the latest available water level observation.

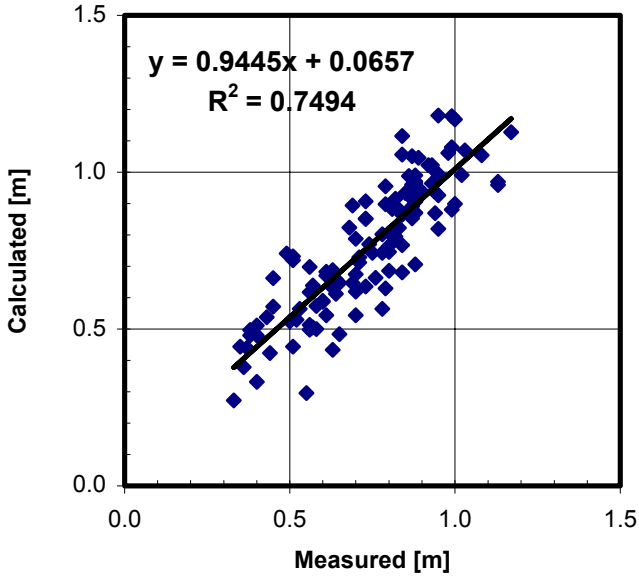
Table 3.1 Calculated Statistics on Surge Forecast Quality (Mean Absolute Error (MAE), Root Mean Square Error (RMSE) and Correlation Coefficient (R)).

Lead-time hours	MAE cm	RMSE cm	R
00	9	12	0.87
24	9	11	0.87
48	11	14	0.80
72	13	16	0.70
96	13	17	0.69
120	15	19	0.62

To improve the starting conditions is not straightforward, but an improved hindcast based on more frequent meteorological analyses than the present 12 -hour intervals is possible. Also, introduction of water level data assimilation in MIKE 21 is a possibility, but here on-line data is necessary. The most obvious and easiest way to improve the forecast is accordingly to adjust the predicted time series to the latest available water level observations.

A visualisation of the error at +24 hours is given in Figure 3.4. This figure shows all the 24-hour forecasted water levels compared to the actual observations. A perfect forecast should be a straight line at 45 degrees, which corresponds to a slope of one. The linear regression line shown has a slope of almost one (0.94).

Figure 3.4 Comparison of Measured and Forecasted (+24 hours) Water Levels at Peshnoy



To be able to produce and issue storm surge forecasts after the end of the present Tacis project only digital meteorological forecasts are needed. As the agreement with the UK met. office has been limited to the period of the Tacis project, a new agreement of getting access to such data should be negotiated. Unfortunately, such data are not yet available within Kazakhstan and need to be provided by meteorological offices in Russia, UK or USA.

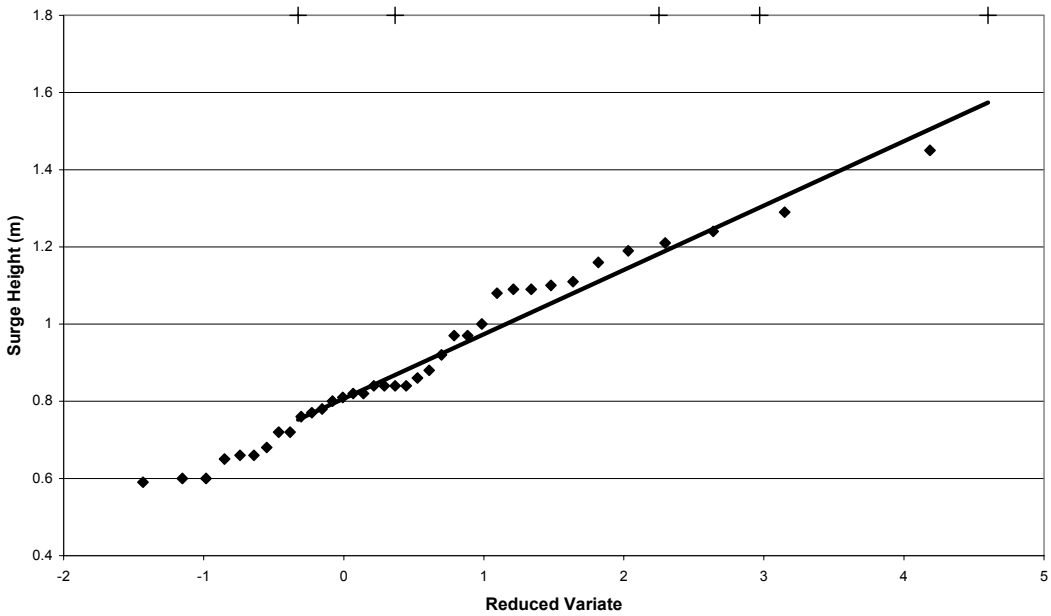
In Section 5, a possible storm surge-forecasting centre at KazHydroMet is described in more detail.

There are good possibilities to find public and private customers willing to establish commercial contracts for receiving operational forecasts. The need for storm surge forecasts in the Caspian Sea has increased with the increased background water level. Flooding of cities (eg. Atyrau) and pollution due to flooded oil wells happens regularly. Besides, the oil companies need good forecasts for planning off-shore operations.

Chapter 4. Sensitivity of Surges to Caspian Sea Background Level

The magnitude of extreme storm surges in the Caspian Sea can be estimated from long time-series of water level observations. Unfortunately, only few locations exist where such long time-series exist. One of them is Peshnoy, Kazakhstan. In Figure 4.1 a statistical distribution (Gumbel) of the measured extreme water levels at Peshnoy is shown together with the yearly measured maximum water levels within the period 1961-1997 (37 years). By application of a simple extreme value analysis, a 100-year storm surge event, for example, can be estimated to be 1.57 m.

Figure 4.1 Surge Probability at Peshnoy Based on Historical Data 1961-1997



But what is the effect of an increase or a decrease in the general background water level on these extreme surges ?.

In the above estimate the surges are not treated consistently with respect to background water level as this has been varying over the 37 year period due to the non-linearity of the storm surges. For a given wind condition, the surge at a given location is a function of the background water level. The greater the water depth at the location, the smaller wind set-up is generated.

To analyse the sensitivity of the storm surges to long term changes in the Caspian Sea background level, some long-period simulations have been made. Unfortunately, due to lack of manpower near the end of the project, only one location, Peshnoy, and only two background levels have been considered in the analysis. It was originally the intention to include several different locations and a greater variety of background levels in the analysis.

The long historical period from 1 January 1979 to 1 January 1997 (in total 18 years) has been simulated with the established surge model (10-km grid only).

To be able to simulate the historical period, digital meteorological forcing of wind and pressure is necessary. The UK met. office has supported the Tacis project by providing access to historical ECMWF analyses from this period. A very large amount of 6 hourly 2D data sets was collected and processed at Edinburgh University, at DHI and finally at CCWLF.

The 18-year period has been simulated using two different background levels: -26 m and –28 m relative to the Baltic Sea Datum. Today, the approximate background level is -27 m, so the analysis is based on background levels approximately one meter respectively above and below the present background level.

To avoid the effect of changed background level through the 18-year simulation period, but to keep the effect of seasonal variations in the background level, average in- and outflow to the Caspian Sea has been applied.

Monthly averaged values over the 18-year period of total inflow were distributed to the largest five rivers as indicated below.

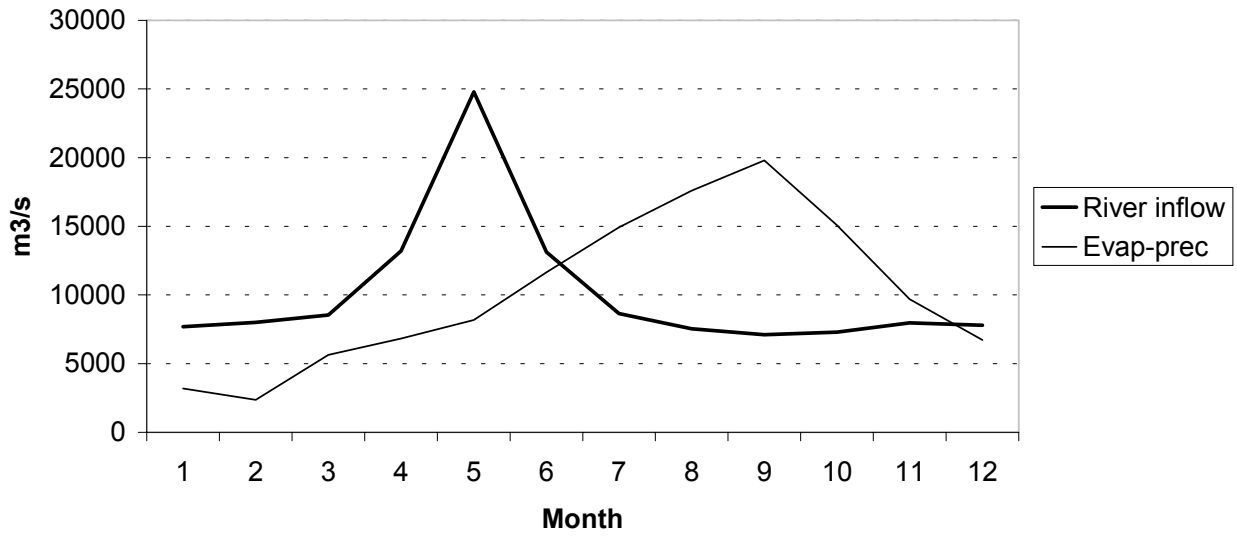
Table 4.1 Average Monthly Inflow from Rivers

The applied relative distribution is: Volga: 85 %, Kura: 6 %, Terek: 4 %, Ural: 3 % and Sulak: 2 % of the total inflow

month	Sulak	Terek	Ural	Volga	Kura	sum
	m^3/s	m^3/s	m^3/s	m^3/s	m^3/s	m^3/s
Jan	154	308	231	6,536	461	7,689
Feb	160	320	240	6,804	480	8,005
Mar	171	342	256	7,262	513	8,544
Apr	264	528	396	11,224	792	13,205
May	496	992	744	21,071	1,487	24,789
Jun	262	525	394	11,152	787	13,119
Jul	173	346	259	7,343	518	8,639
Aug	151	301	226	6,403	452	7,534
Sep	142	284	213	6,041	426	7,107
Oct	146	292	219	6,197	437	7,291
Nov	160	319	239	6,783	479	7,980
Dec	156	312	234	6,626	468	7,795
Sum	**2,434**	**4,868**	**3,651**	**103,442**	**7,302**	**121,697**

Similar average outflow (evaporation minus precipitation) were also established and finally corrected by a factor to balance the inflow. By doing so, the yearly net inflow is identical to zero.

Figure 4.2 Applied Inflow and Outflow for the 18-year Historic Simulations.

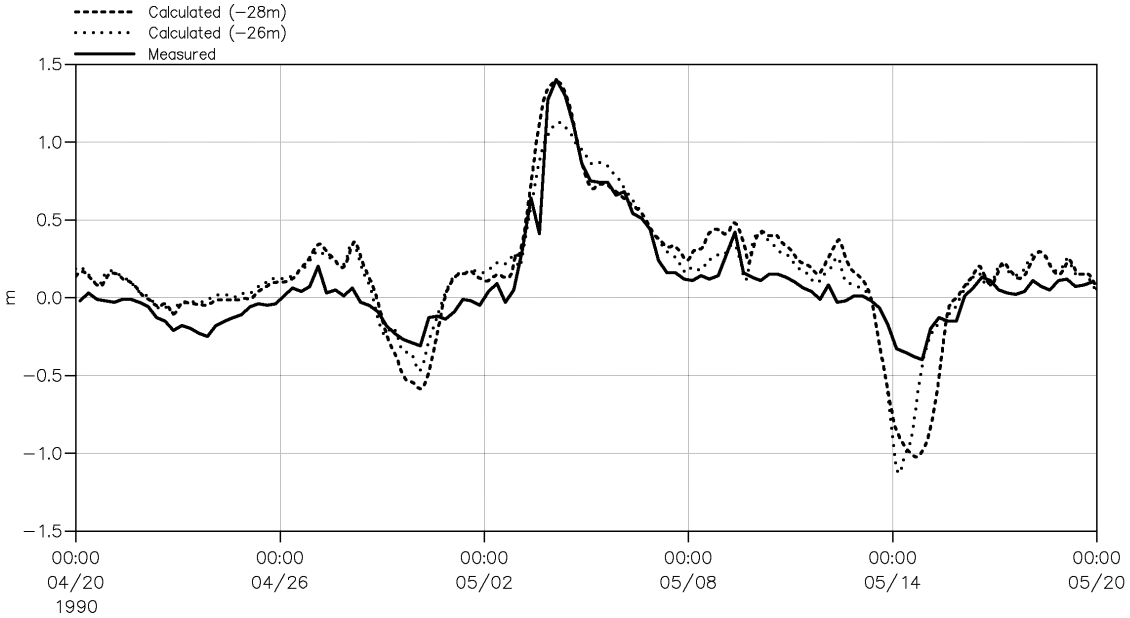


River flows, evaporation and precipitation data have been obtained from the database developed at CCWLF and partly from work reported in Caspian sea Water Balance Modelling, Tacis Report Nr. WLF 8E.

To compare the storm surges from the two simulations, the background level has been subtracted from the calculated water level time series. An example is shown in Figure 4.3 together with the actual measured water level. During the short period shown there was a severe storm surge at Peshnoy. In the figure the effect of the background level is clear. The extreme surge is much higher (and better replicated) in the simulation with a background level of -28 metres. The difference between the two peaks of about 25cm is due to the change in background level of 2 m.

Figure 4.3 Example at Peshnoy from April-May 1990 of Calculated Surges with Background Level at -26 m and -28 m

The full line is the actual measured water level (at approximate background level -27.6 m)



To estimate the effect on the extreme surges, an extreme value analysis has been made. The applied method is the Annual Maximum Series, where the maximum calculated water level within each calendar year has been extracted and a curve fitted (Gumbel). The yearly extreme levels are shown in Figure 4.4. It is noticed that the extremes are in general higher for the simulation with the background level at -28 m compared to the level -26 m simulation. The measured extremes vary more due to varying background levels. The related statistical distributions are shown in Figure 4.5 and in Table 4.2 the estimated surges at different return periods are summarised.

For comparison purposes, the measured extremes and related statistics are also shown, although they should not be compared directly because of the varying observed background level of the Caspian Sea.

Figure 4.4 Calculated and Measured Yearly Maximum Levels

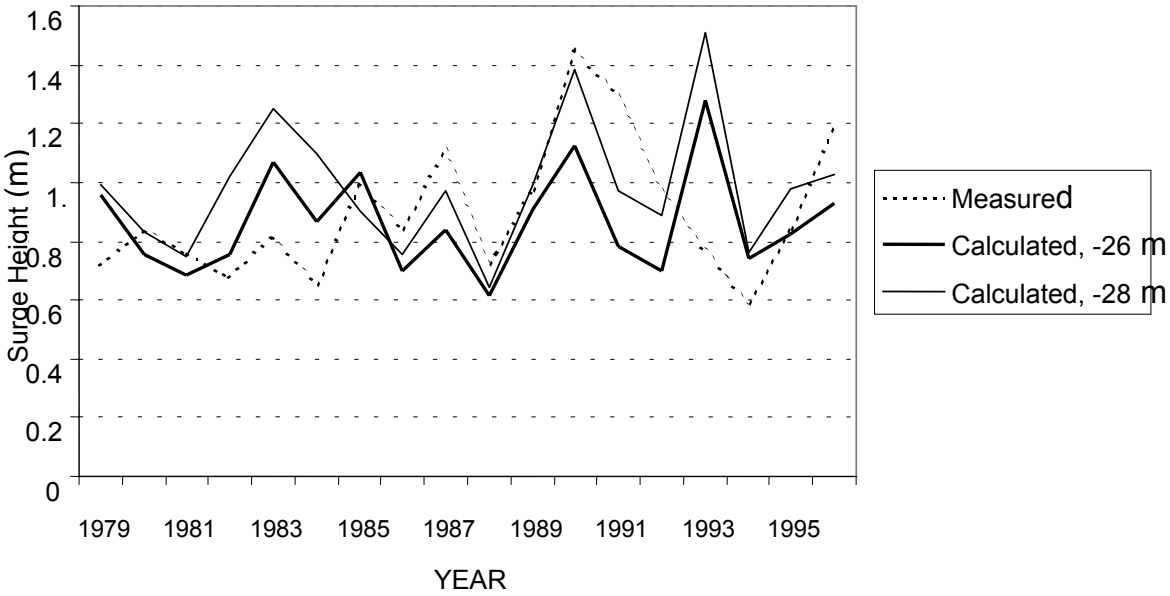
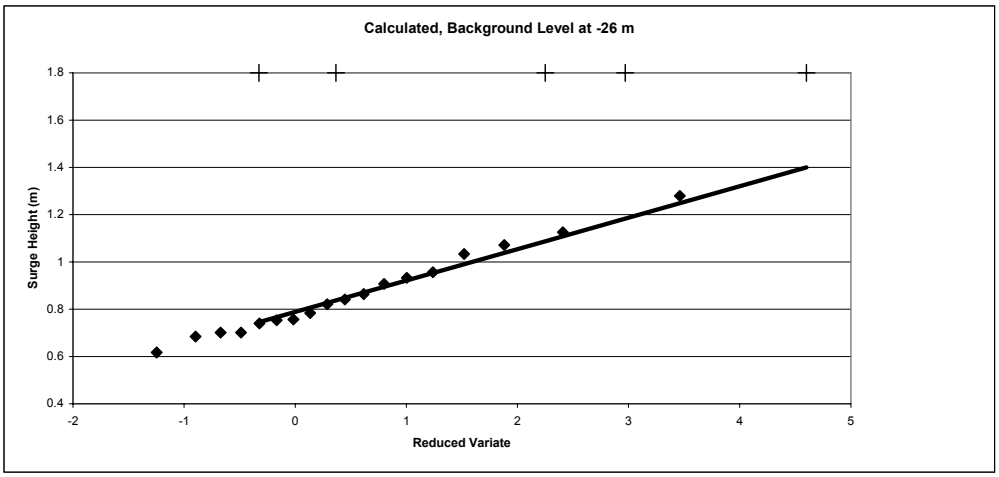
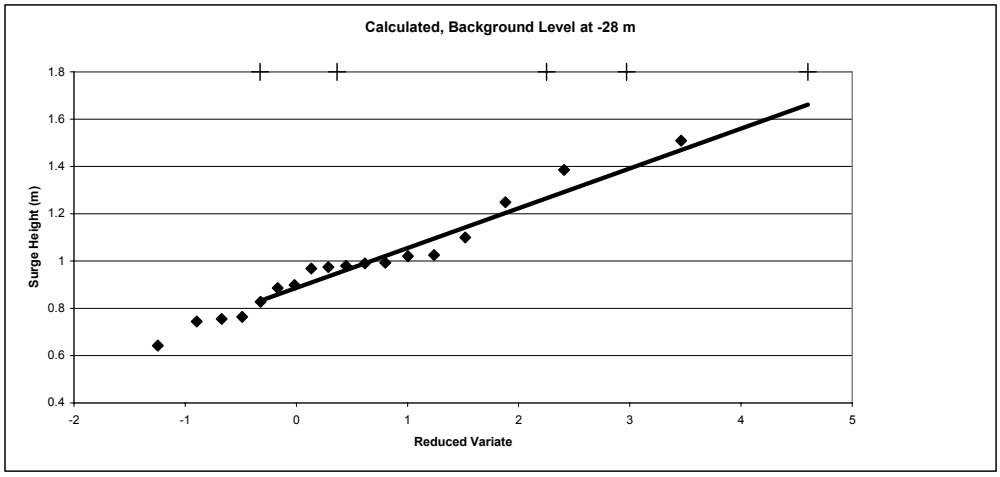


Figure 4.5 Surge Probability at Peshnoy Based on Simulations with Background Level at -26 m and -28 m Together with Probability Based on Measured Data (1979-1997)





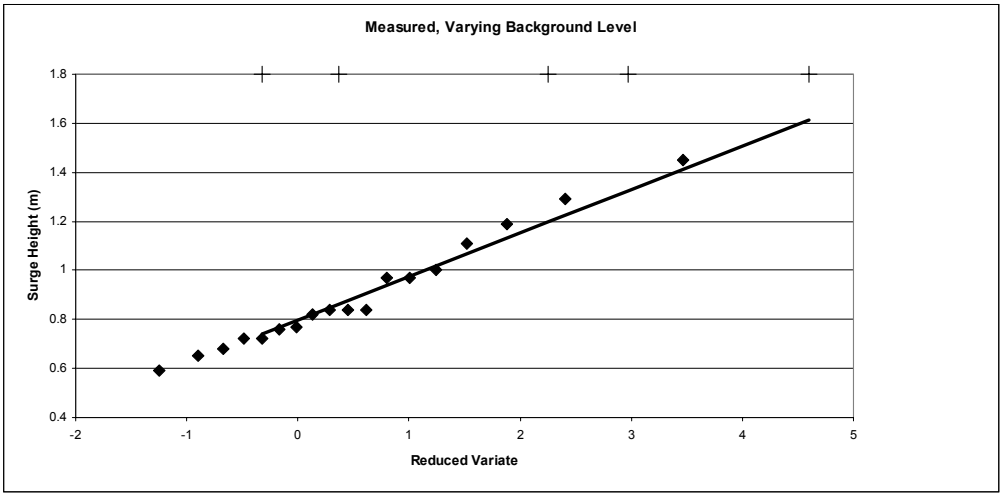


Table 4.2 Estimated Surge Heights at Peshnoy at Given Return Periods for the Two Different Background Levels

Measured (18 years) results are shown for comparison

T [years]	Calculated, -28 m [m]	Calculated, -26 m [m]	Measured [m]
1.33	0.83	0.75	0.74
2	0.95	0.84	0.86
10	1.27	1.09	1.20
20	1.39	1.18	1.32
100	1.66	1.40	1.61

From Table 4.2 it is noticed, as expected, that the extreme surges are higher at background level -28 m compared to background level -26 m. The 100 year surge event is 26 cm higher. The observed background level during the years 1979 to 1996 has been varying between -28.6 m and -26.6 m.

Additional tables like Table 4.2 for station Peshnoy can easily (although CPU-time consuming) be made at any location in the Caspian Sea and at any background level, by using the established model and the already processed long historical period of analysed meteorological data. Additional analyses were planned to be completed during the current project, but unfortunately could not be finished before the end of the project.

The conclusion of the analysis is that the magnitude of the storm surges increases as the background level decreases because the surge magnitude is a function of the water depth. At large depth there will be almost no effect whereas in shallow water the effect is significant.

This sensitivity analysis is based on two artificial simulations where the background level has been kept constant over an 18-year period. Accordingly, the result can only be used relatively to explain how big the effect on surge height would be if the future background level would increase or decrease.

The effect of possible ice cover during winter seasons has not been considered in the modelling. It has been assumed that all calculated yearly extremes could be used in the extreme value analysis for a relative comparison.

Chapter 5. Operational Surge Forecasting Centre at KazHydroMet

As a continuation of the CEP, Phase 2 project it is recommended to established an operational storm surge forecast centre at KazHydroMet in Almaty. Trained staff and the necessary tools for producing storm surge forecasts are available. Only digital meteorological forecast data is needed.

The centre should be financed by the Kazakh government, but in an initial phase alternative funding is needed to get a continuous transition from the Tacis project to full governmental funding. Additional funding could be found through commercial contracts with the private industry.

The surge forecast centre should be operated by a small group of hydraulic engineers currently on the staff of KazNIMOSK. A duty forecaster should be responsible each day for running the forecast model, checking the water level forecast results and issuing the forecast to the system users.

The users should typically be public authorities and private companies operating in coastal and off-shore areas of the Caspian Sea.

Criteria for extreme surges and related contingency plans should be established in co-operation with the appropriate authorities.

Presently, access to water level measurements and especially on-line measurements is limited. To improve the forecast quality (cf. Section 3) and to avoid issuing misleading warnings, it is important to have access to at least two on-line water level recorders along the Kazakhstan coast.

To be able to produce surge forecasts, access to operational meteorological forecasts is essential. Meteorological data from the UK have been applied during the operational test period but this data flow ends with the Phase 2 of the CEP project. It is therefore necessary to establish an agreement with an operational meteorological centre of getting access to operationally produced digital meteorological forecasts.

It will be obvious that the group of engineers and technicians attached to the operational forecast centre should also perform supplementary analyses within the centre on surges and flooding problems of the Caspian Sea.

A collaboration with the other Caspian countries on water level modelling could be established. For example, the surge model could be installed and run operationally within each country and representatives from each country could have annual meetings where developments are discussed. A common regional model (running at all centres) could be the basis for local models operated by the individual countries. In this way each country would be responsible for developing their own local fine scale models as required.

A note on establishing an operational surge forecast centre at KazHydroMet has been prepared by local experts. This note is included in Appendix A.

ANNEX A: Suggestions to Set up a Storm Surge Operational Forecast Centre

Wind set-up of sea water is a natural hydrometeorological phenomenon in the Caspian Sea that can be dangerous.

For example, a storm surge of more than 0,8 m above current sea level (minus 27.00 m abs) can last three days or more and would be especially dangerous for the low-lying lands bordering the northern coast. Populated areas, coastal constructions and other constructions are flooded, emergency situations are created at oil-fields. The storm surges bring big losses to Kazakhstan's economy of hundreds of millions of Tenge.

Wind set up of a sea water causes considerable changes in hydrology-morphological, hydrochemistry and ecological processes in the coastal zone. On average, each year, there are 3 – 10 cases of sea water wind set up observed. Therefore the Northern Caspian seashore is instable and it changes position during the year (80-85% of time). Length of a flooded land may amount to 20-30 km when the sea water wind set up under extreme wind conditions.

It is necessary a forecast of sea level changes in every hour for 3-5 days ahead in order to stave off or reduce storm surge after-effects. If forecasted sea level exceeds critical heights, it is need give storm warnings.

Existing system of operation warning of the storm surges is unreliable because of lack of good methods to forecasting this phenomena.

A technology to the storm surge forecasting made by Center of Caspian Water Level Fluctuations (CCWLF) is founded on a hydrodynamic module. It has been prepared to issue the operation forecasts. In Caspian countries the operation forecasts are produced by Hydromet-Centers of national hydromet services. These forecasts are founded on methods had been tested by independent material (as it was made by CCWLF in 2001).

The Caspian problems Department was set up by order of Director of KazHydromet with the object to pass this technology in operation regime.

Housing

The Center have to access to MIKE 21, meteorological forecasts and measured sea levels. Building of KazNIIMOSK's office is best place to the Center as it meet to above stated requirements and also the Caspian Problems Department which is a member of KazHydromet is placed here.

Personal

Operation forecasts of the storm surges will be made by specialists of the Caspian Problem Department. The Department has two specialists which had worked with MIKE

21 and have an experience in its verification. These specialists must train other personal to forecasting technology. At present six workers are a member of the Caspian Problems Department: manager of the Department, leader research worker, senior research worker, research worker, junior research worker, leader engineer. Leader research worker and senior research worker have been got ready for issue the operation forecasts. Research worker will be to master the technology of the forecasting. Senior research worker has access to measured sea levels. Leader engineer has a experience of a mapping.

Hydromet-Center has departments of short term and long term weather forecasts and department of hydrological forecasts, besides Caspian Problem Department. These departments could consult on weather forecast and hydrological forecast for Ural river, Ember river and eastern part of the Volga river delta, if it is need.

Equipment

KazHydromet is possessed of computers, printers, communications and other services ensuring the regular cycle of the operations forecasts.

The CCWLF's computer with installed storm surge forecasting technology should be given to possession of the Caspian Problems Department in order to expect unforeseen stoppages of the forecast issues as optimum variant. At the same time, other computer techniques and means of communications will be linked up to the Department at the expense of means of KazHydromet.

Access to on-line water level measuring stations

The Caspian Problems Department receives an information by e-mail from all hydrometeorological stations at the Kazakhstan part of the Caspian Sea every day. At present these data are forthcoming to the Department from following hydrometeorological stations: Peshnoy Island, Kulaly Island, Fort-Shevchenko, Aktau. In perspective KazHydromet has intends to set up some more two stations: one station will be at the area of Zaburunje settlement (between the Volga and Ural rivers) and another will be at the Terenyuzek oilfield (further south of the Amba river delta).

Besides that, Kazhydromet must receive daily information from stations placed on the Russian coast of the Caspian Sea in accordance with the agreements on interchange of the information with RosHydromet. Unfortunately, recorders to frequent sea level measurements are lack at the stations and sea level is measured four times in day (00,06,12,18 hours by Grinvich) at the hydrological pile stations by a pole.

Procedures for issuing of operation storm surge forecasts.

It is necessary to calculate hourly forecasted sea level to five days ahead at the following points on the Kazakhstan coast:

№	Point	Place
1	Ganyushkino settlement	Eastern part of the Volga delta
2	Zaburunje settlement	Country between the Volga and Ural rivers
3	Peshnoy island	Ural river coastal waters
4	Karaton settlement	Further south of the Emba river
5	Prorva oilfield	Further north of Komsomolets buy
6	Buriynshik	Northern coast of the Buzachy peninsula

The storm warning should be issues if sea level mounts on the following critical heights are took for the Kazakhstan lower coast:

Sea level heights above minus 28,00 m abs, sm	Description of a sea water wind set up
>140	Critical
>160	Danger
>210	Especially danger

If forecasted sea level exceeds the critical heights at a point it is necessary to prepare the storm warning for one, two or three days before start of the phenomenon. A text of the storm warning must indicate following information: name of a point, waiting height of the forested sea water wind set up, description of the phenomenon (critical, danger, particular danger), date and term of storm surge start, it duration. It might be as well to accompanied the storm warning by graphs of forecasted sea level change in the time of the storm surge and figures of area sea water spreading on area by the storm surge or co-ordinates of most probable sea water moving in land.

The storm warnings must be prepared in the Caspian Problem Department. After that, the warning should be communicated to oblast hydromet Centers (in Atyrau town, Aktau town) which then will inform local authorities and population.

The both storm warnings and meteorological forecasts being a component of the forecast technology must be state-paid. If some economy patterns will contracts to service by sea level forecasts and storm warnings (an oil company for an example) these forecasts should be paid under a contract.

The oblast Hydromet Centers must acknowledge the receipt of the forecast and it correctness, especially to the points without sea level measuring stations.

Other objects

1. The Center to the forecasting of storm surges in Kazakhstan can forecast a sea level for other Caspian coasts. With the object it is need make a test of MIKE 21 module for points having sea level measuring stations at present.
2. The Center can simulate a sea level surface and give an estimate on the Kazakhstan coast flooding by other scenarios of a background sea water stage and other wind conditions. This simulation will give a possibility to define geographical co-ordinates for most possible seashore line moving in land. Special software gives a possible to present results of the simulation in a form of maps.
3. It is necessary to district all Kazakhstan Caspian coast by sea water wind set up heights of 1% and 2% frequency in accordance with results of the simulation.
4. It is necessary to prepare a probabilistic forecast of flooded coast taking into account climate changes.
5. It is necessary to investigate the sea water wind set up moving in the Ural river delta and also the testing of MIKE 11 module is need.
6. It is necessary to make a simulation of the sea water driving away by wind affect that creates the damage to water transport and an estimation of a probabilistic forecast on coastal drain when sea level lowering by wind affect and mapping of most possible coast draining is needed.