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RBW DRAFT WORKING NOTES

PART I. SEA SURFACE TEMPERATURES AND EVAPORATION

1.1. INTRODUCTION

Establishment of actual evaporation from the Caspian Sea is currently difficult as limited information exists on climatic conditions over the sea itself. Evaporation estimates generally have been made using climatic data collected at shore based stations. Evaporation may also be implied from considerations of the water balance of the sea. The current version of the water balance model indicates an annual average evaporation of from the sea of the order of 1020 mm. This may of course incorporate systematic errors in a number of the inputs to the model and it is desirable to try and confirm sea evaporation by more direct measurement.

In some past studies use has been made of the Smirnova equation which relates sea evaporation to average sea surface temperatures in the preceding month. It is unclear on what basis the equation was developed, but it does give results that are similar to those produced by the water balance model. Figure 1.1 presents implied evaporation calculated from the water balance model, compared with evaporation calculated from the Smirnova equation.

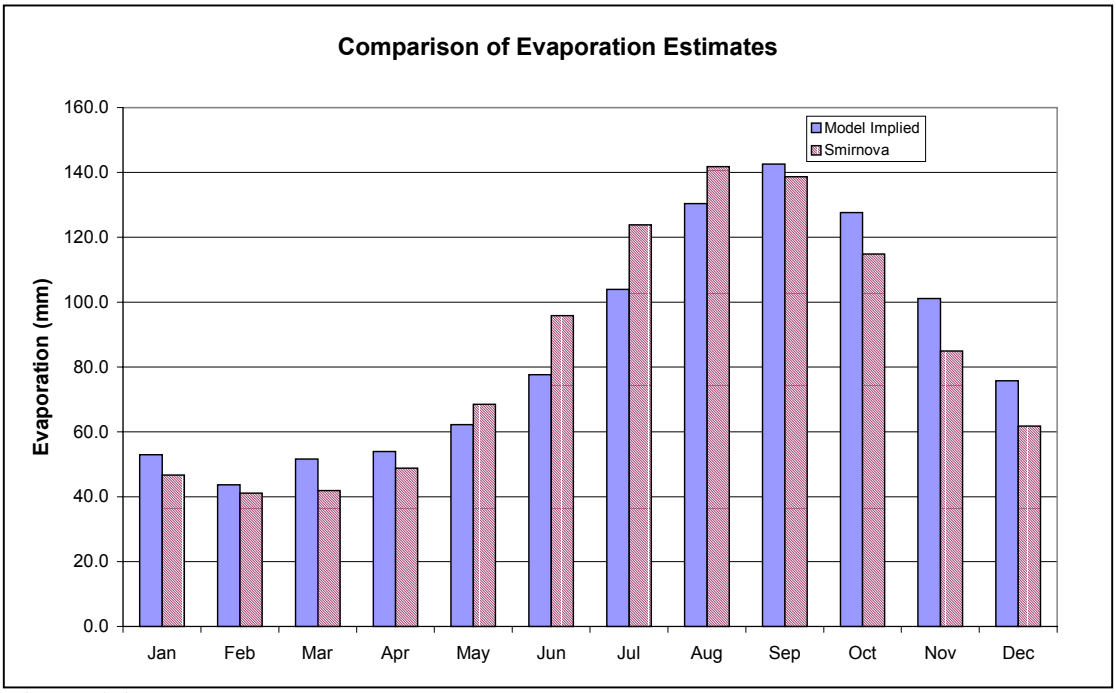


Figure 1.1. Comparison of water balance model evaporation and Smirnova estimate

The comparison between the two is remarkable. On an annual basis the model gives a mean evaporation of 1020 mm, and the Smirnova equation an average of 1010 mm. The equation may well have been developed from water balance considerations, and this would be something worth following up.

Temperature data and sea surface temperatures may give a reasonable basis for estimating Caspian sea evaporation. Some analysis has been carried out of variations in sea and air temperatures in order to help evaluate the possibility of using sea temperatures as a basis for sea evaporation estimation.

1.2. SEA SURFACE TEMPERATURE DATA AVAILABILITY

Sea surface temperatures are understood to be observed at each of the main sea level recording stations on the sea – Baku, Makhachala, Shevchenko and Krasnovodsk. The mean monthly sea surface temperatures averaged over these three stations are available in the project data base, and have been obtained from Roshydromet. These data are available from 1925.

Sea temperature data were given in a brief note by Abuzyarov explaining the manner in which monthly sea level forecasts are made. These data were available for some 11 stations around the sea. Also included were sea levels at some of these stations for 1998 and 1999.

Sea Surface temperatures may be estimated by satellite imagery. Interpretations of satellite data were provided by the Kazakhstan Space Research Laboratory for 1997 and 1999. For each month, two sets of data are available: for beginning and the middle of each month.

1.3. VARIATIONS IN SEA SURFACE AND AIR TEMPERATURES

The sea surface temperature data and air temperature data available in the note by Abuzyarov have been plotted and are shown in Figures 1.2 and 1.3. Sea surface and air temperatures follow almost identical patterns at all stations, and there is very little difference between them. Figure 1.4 presents the difference between air temperatures and sea temperatures in 1999. With a few exceptions the difference is seldom more than ± two degrees.

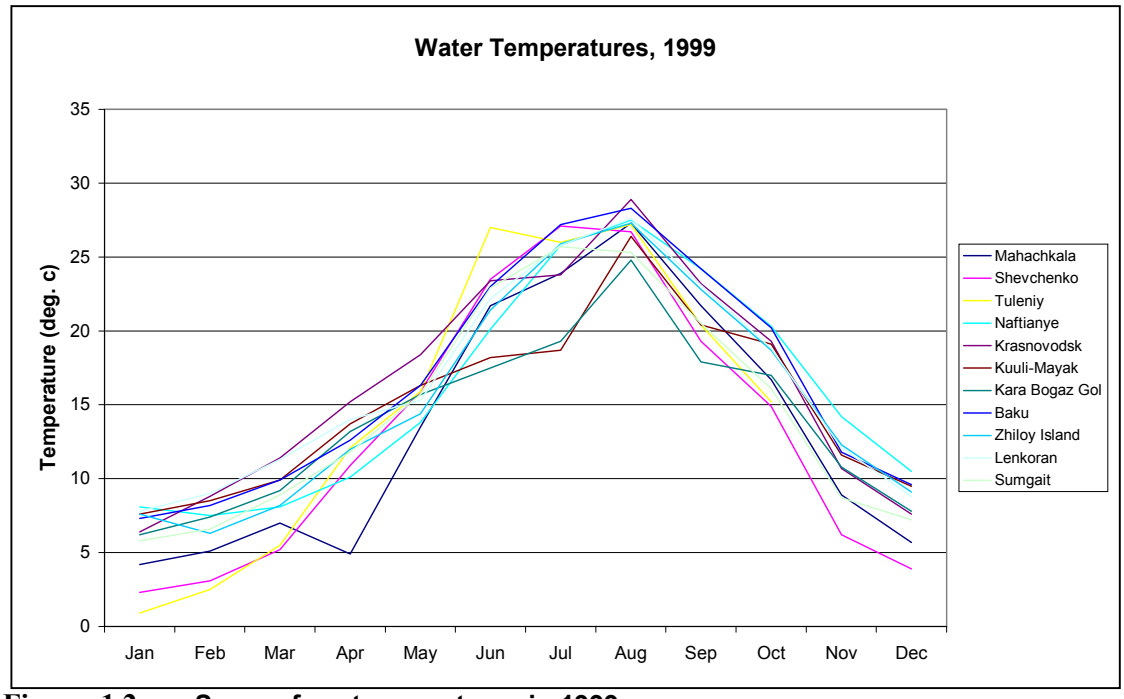


Figure 1.2. Sea surface temperatures in 1999

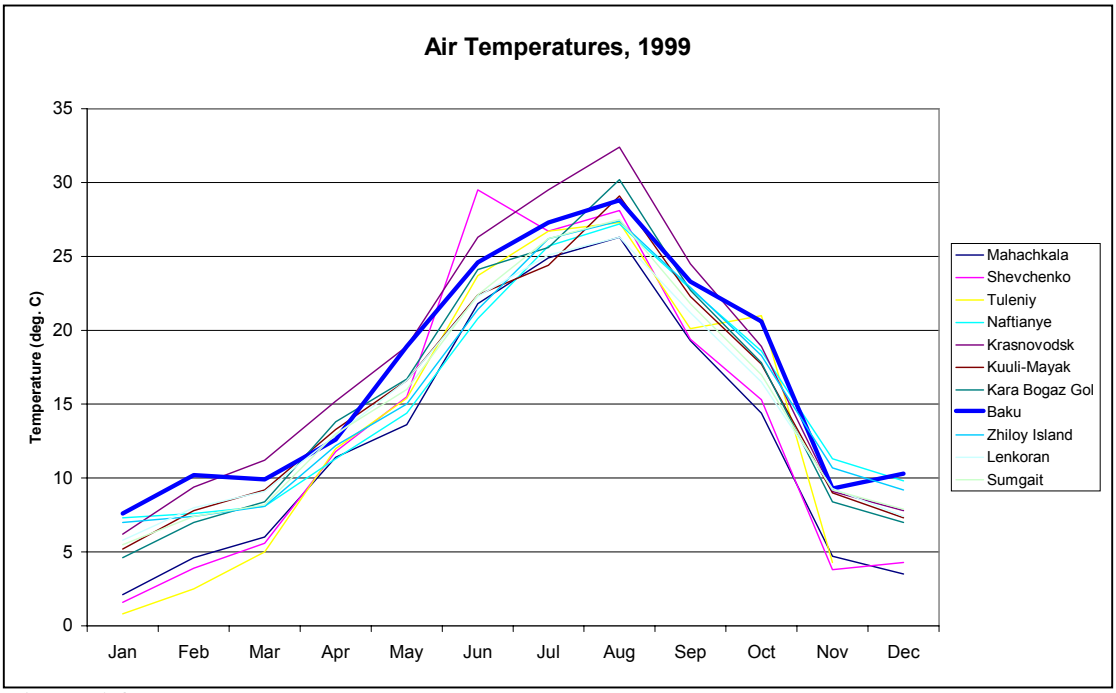


Figure 1.3 **Air temperatures in 1999**

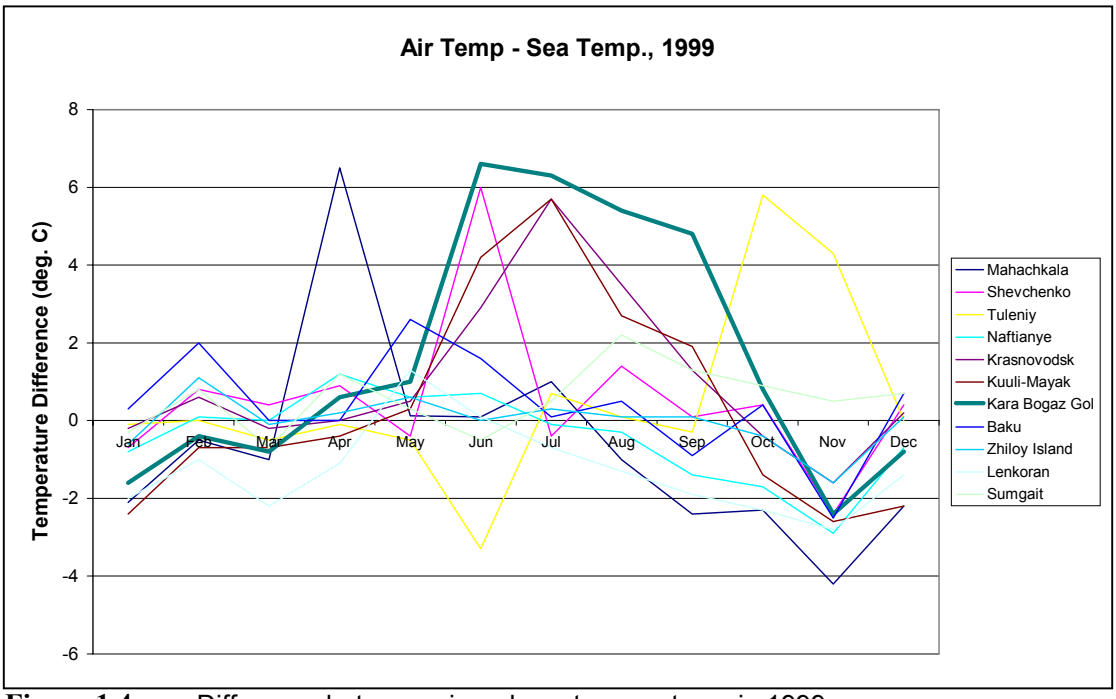


Figure 1.4 Difference between air and sea temperatures in 1999

The indications are that for many shore areas, sea surface and air temperatures will often be very similar.

A presentation has been prepared of the sea surface temperature data obtained from the Kazakhstan Space Research Centre. These data were manipulated through a FORTRAN program and imported in ArcView for presentation purposes. Contour plots have been prepared for the first period of each month in 1997 (Figures 1.7). Time did not permit the plots for the second part of each month to be produced, or for the data for 1999 to be analysed. The plots are attached and demonstrate clearly the manner in which temperature variations shift throughout the year, with three distinct zones always preserved in the sea. In winter there is a distinct temperature gradient from north to south. In the summer, the coolest

part of the sea is in the middle, with hot zones south and north. Of particular note is the formation of cold spots north of the Kara Bogaz Gol in August, and the west-east gradient in temperatures in the central part of the sea in September, with a cold region on the eastern coast.

It should be noted that in some months and in some areas there has been cloud cover, and the computer program has interpolated through that. Time has not permitted identification of these periods in which data were missing. Note also that land areas have not been masked off when producing plots.

Using the sea surface temperatures from atellite, it should be possible to determine how representative the four gauges (Baku, Makhachala, Shevchenko and Krasnovodsk) used by Roshydromet are of aveage sea surface temperature.

1.4. VARIATIONS IN SEA LEVELS

Included in the note on sea level forecasting by Abuzyarov were sea levels for seven locations around the Caspian Sea for 1998 and 1999. Plots of these levels are shown in Figures 1.5 and 1.6. The four main stations used by Roshydromet are highlighted.

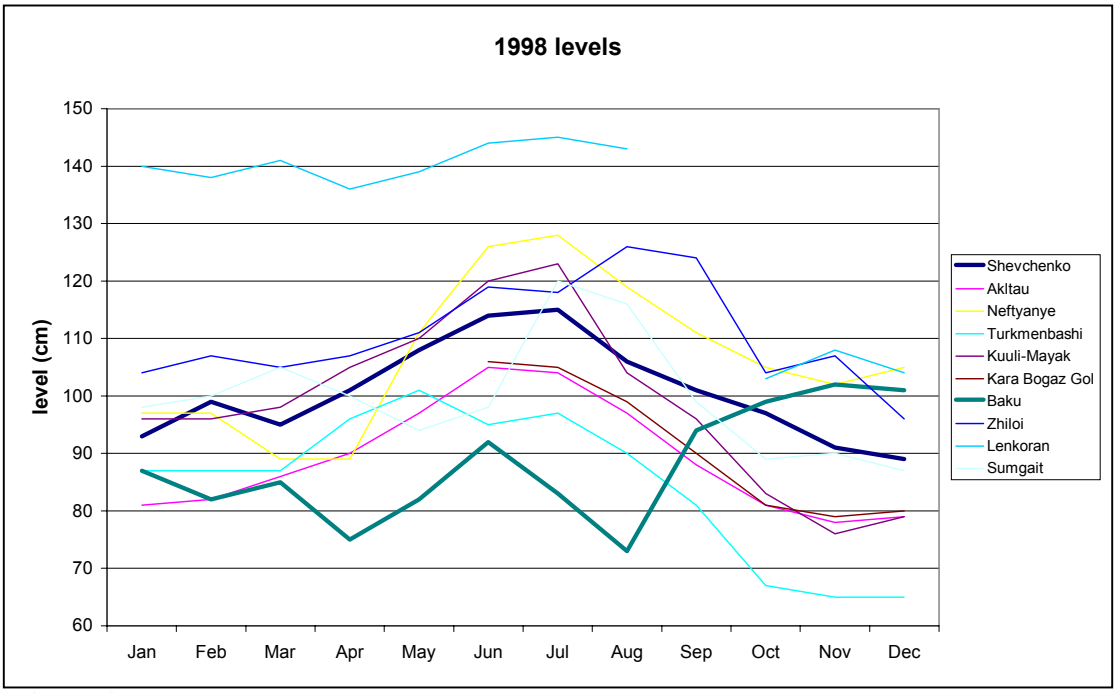


Figure 1.5. Sea levels in 1998

The levels for Baku are a bit unusual for 1998, and one would have to question the gauge records for Baku in 1998. It is also of interest to note the spread of records following broadly parallel tracks, indicating that gauge datumn are not consistent.

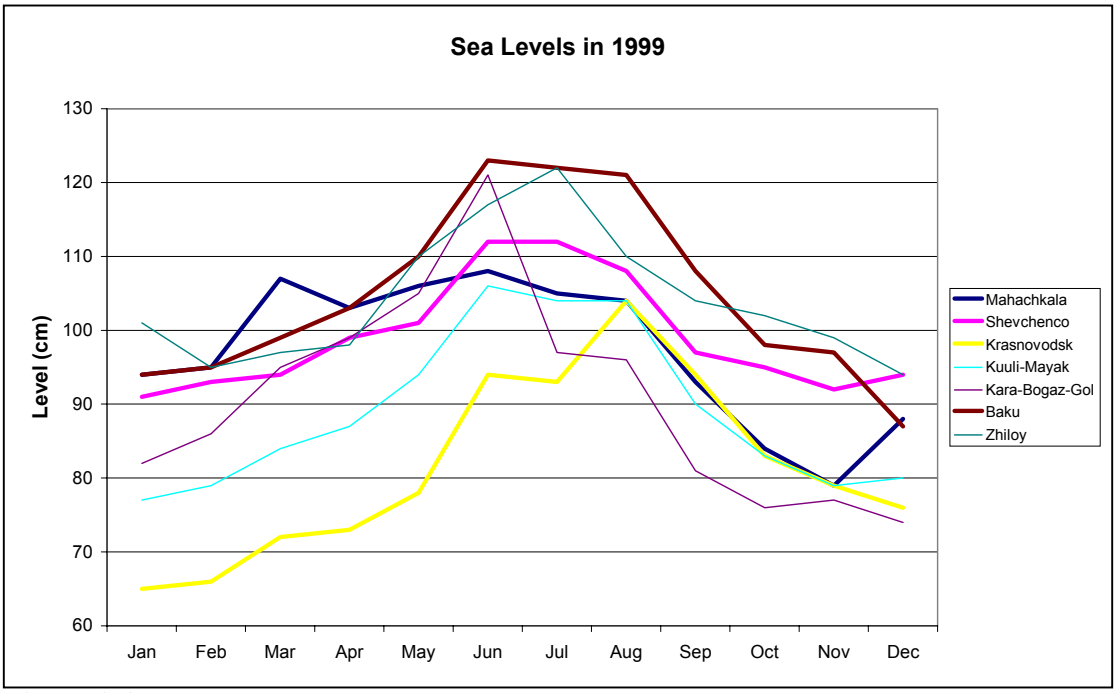
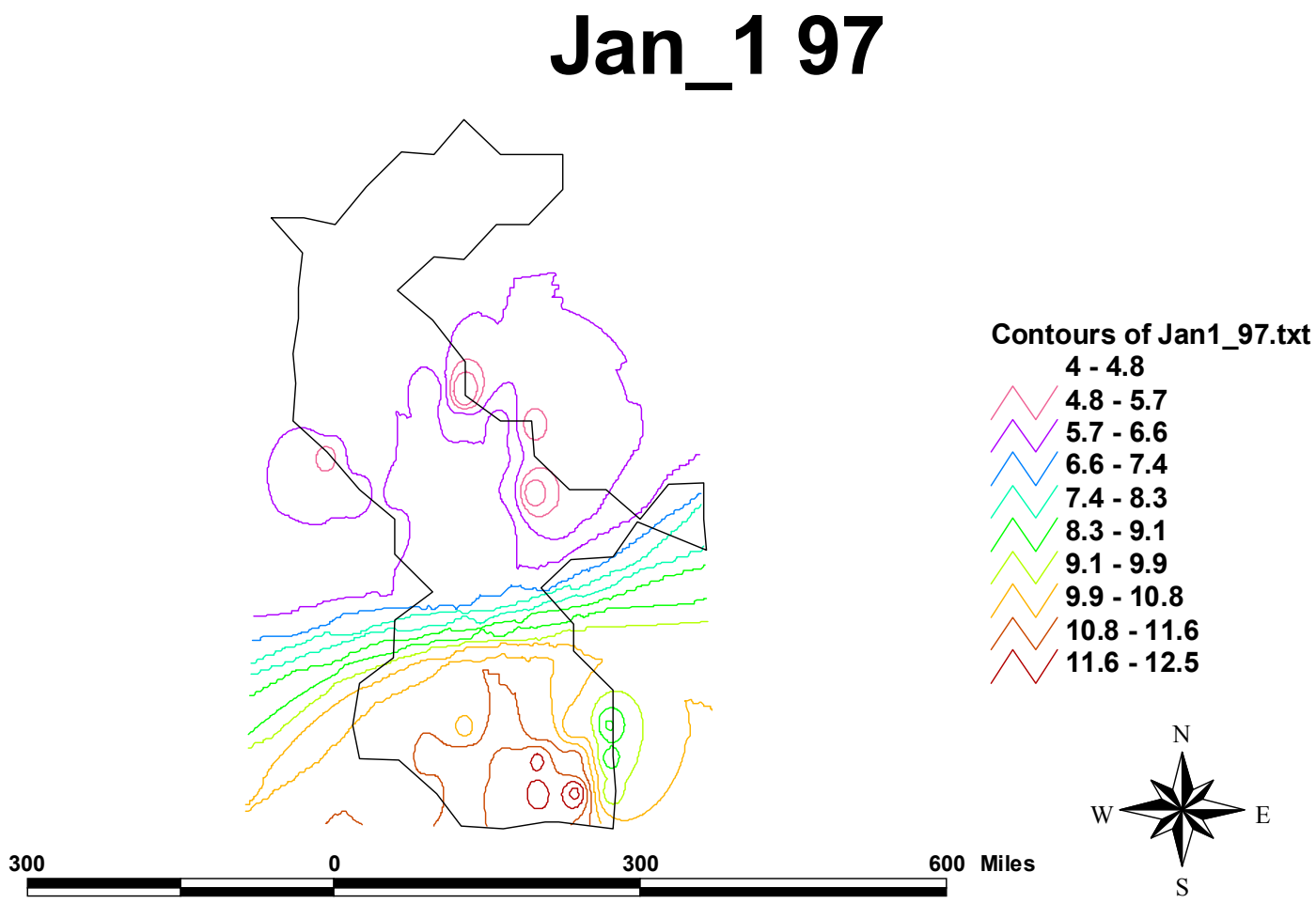


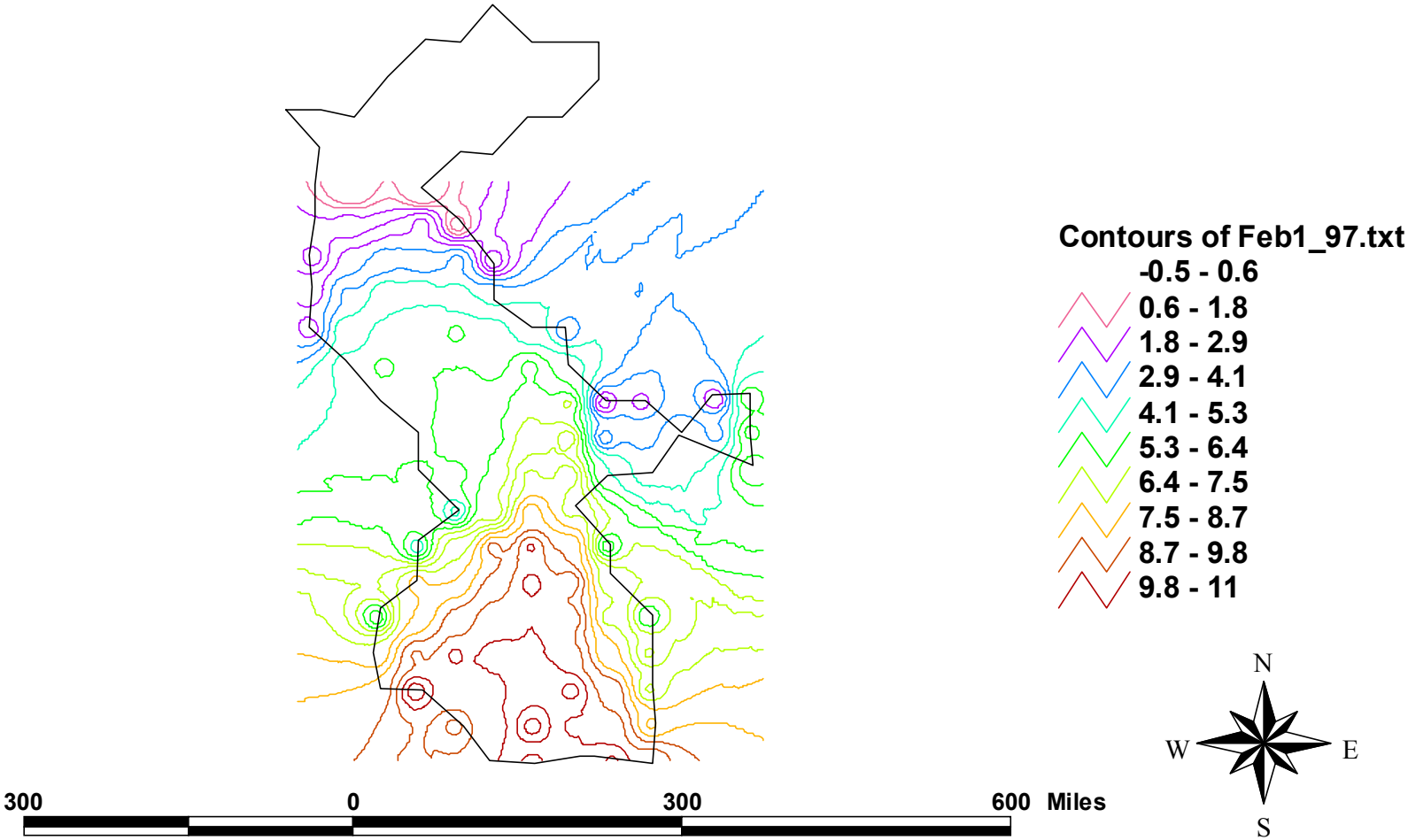
Figure 1.6. Sea Levels in 1999

The records for Krasnovodsk in 1999 look particularly suspect, and this is of some concern as this is one of the stations used in calculating a mean sea level. It would be of value for someone to visit the four main stations and to report on how measurements are made and when the gauge datumns were last checked.

Figures 1.7 Contour plots for the first period of each month in 1977



Feb_1 97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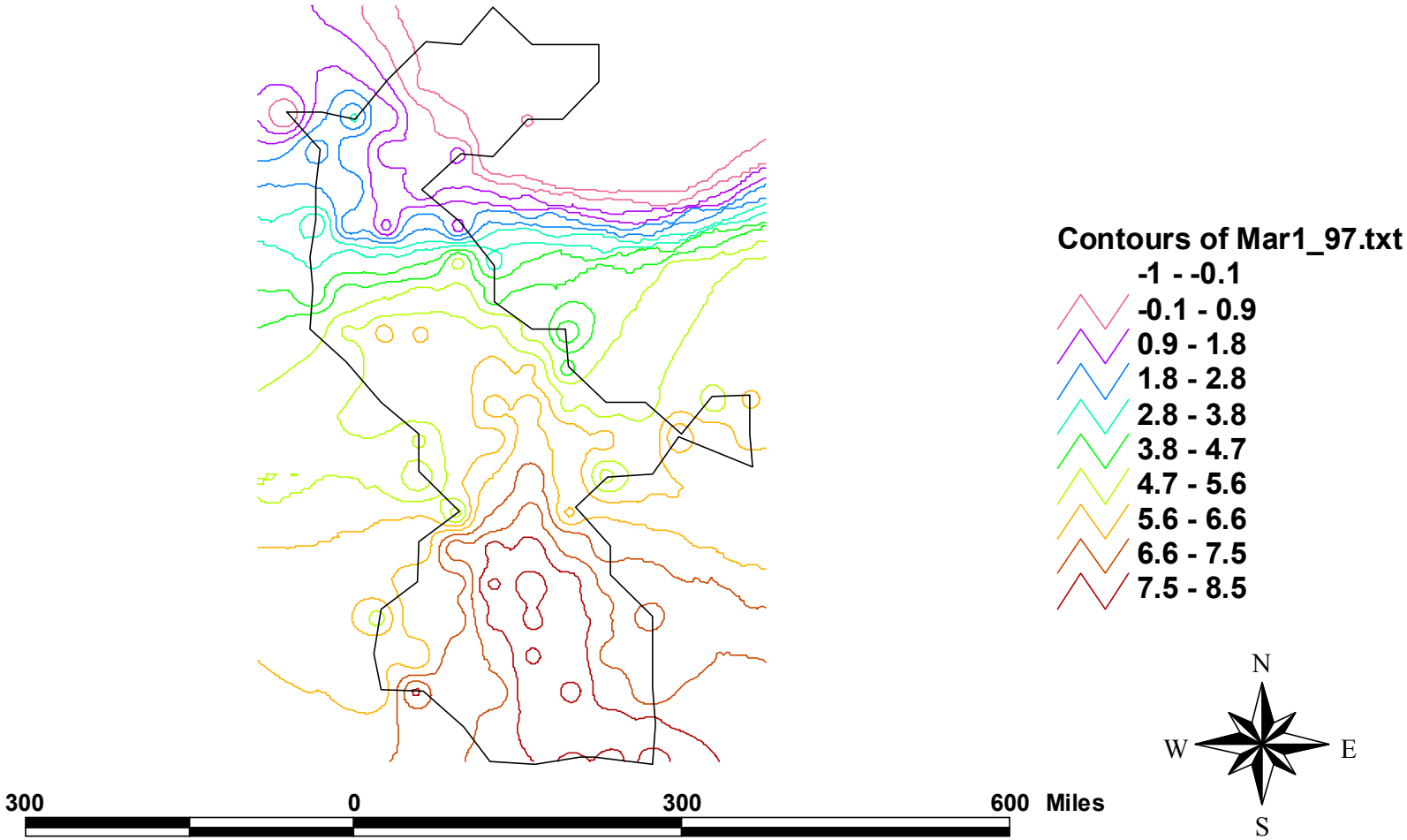
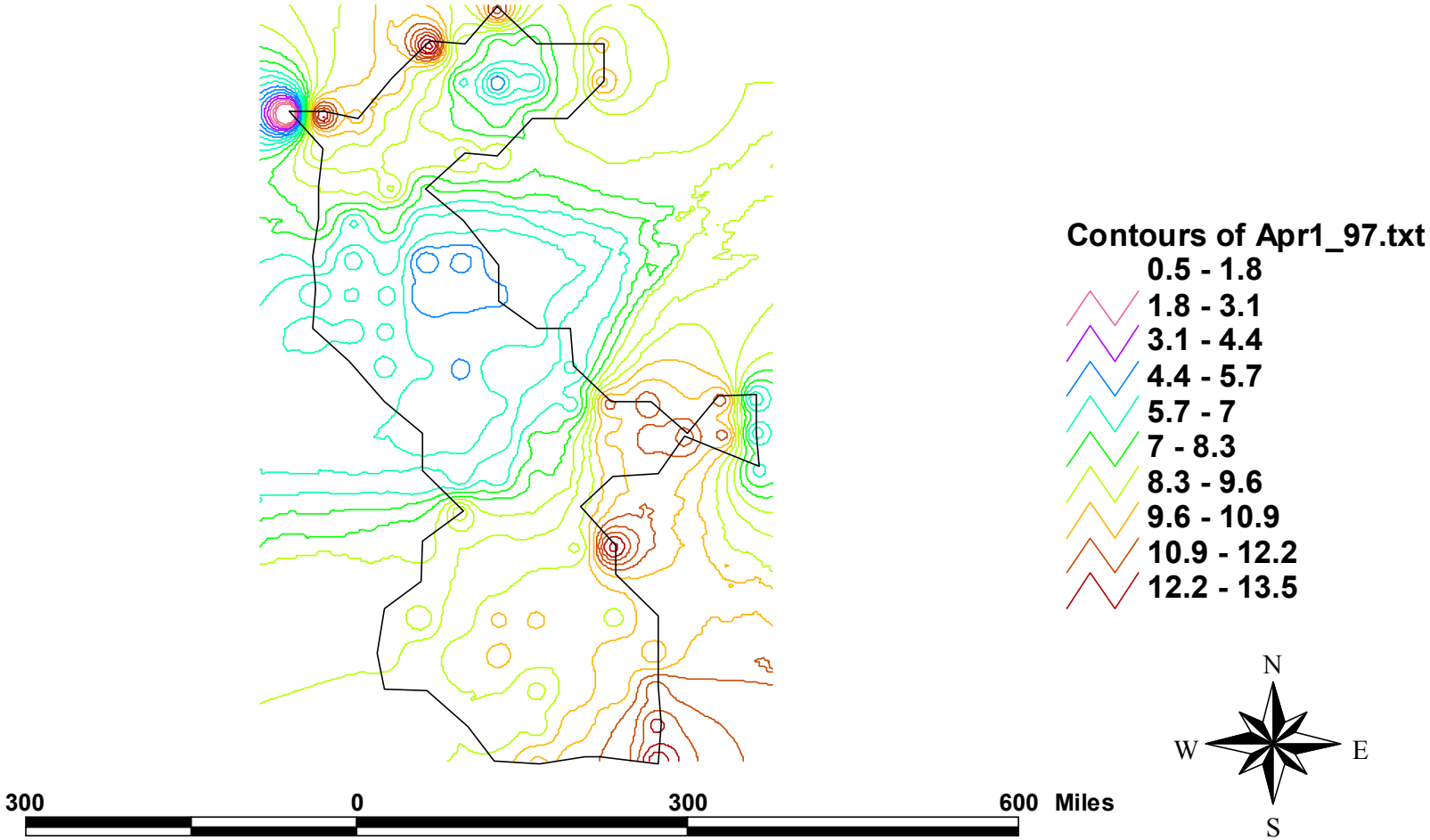
-0.5 - 0.6
0.6 - 1.8
1.8 - 2.9
2.9 - 4.1
4.1 - 5.3
5.3 - 6.4
6.4 - 7.5
7.5 - 8.7
8.7 - 9.8
9.8 - 11
N
W
E
S
300
0
300
600 Miles

Mar_1 97


Contours of Mar1_97.txt
-1 - -0.1
-0.1 - 0.9
0.9 - 1.8
1.8 - 2.8
2.8 - 3.8
3.8 - 4.7
4.7 - 5.6
5.6 - 6.6
6.6 - 7.5
7.5 - 8.5
N
W
E
S
300
0
300
600 Miles

Apr_1 97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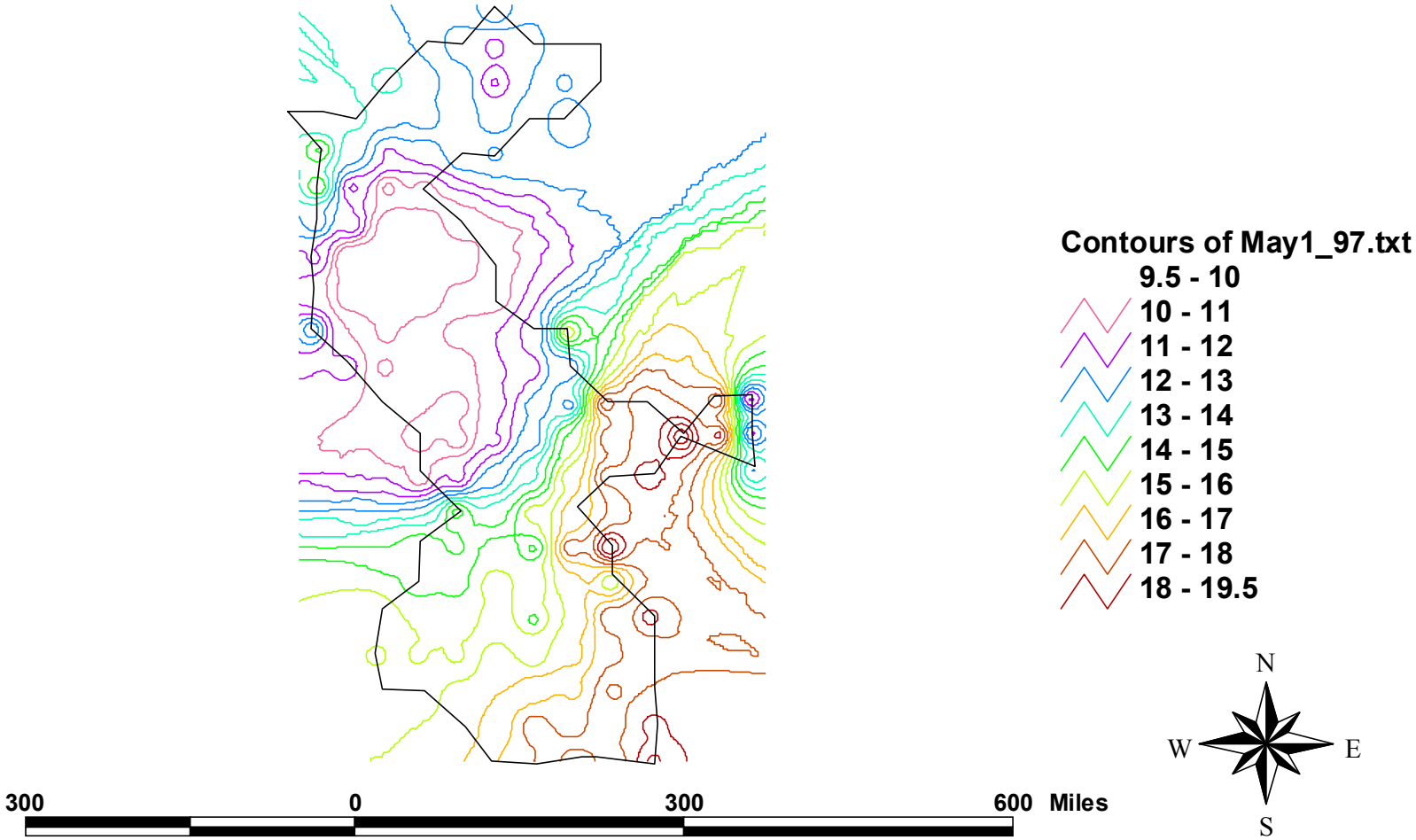
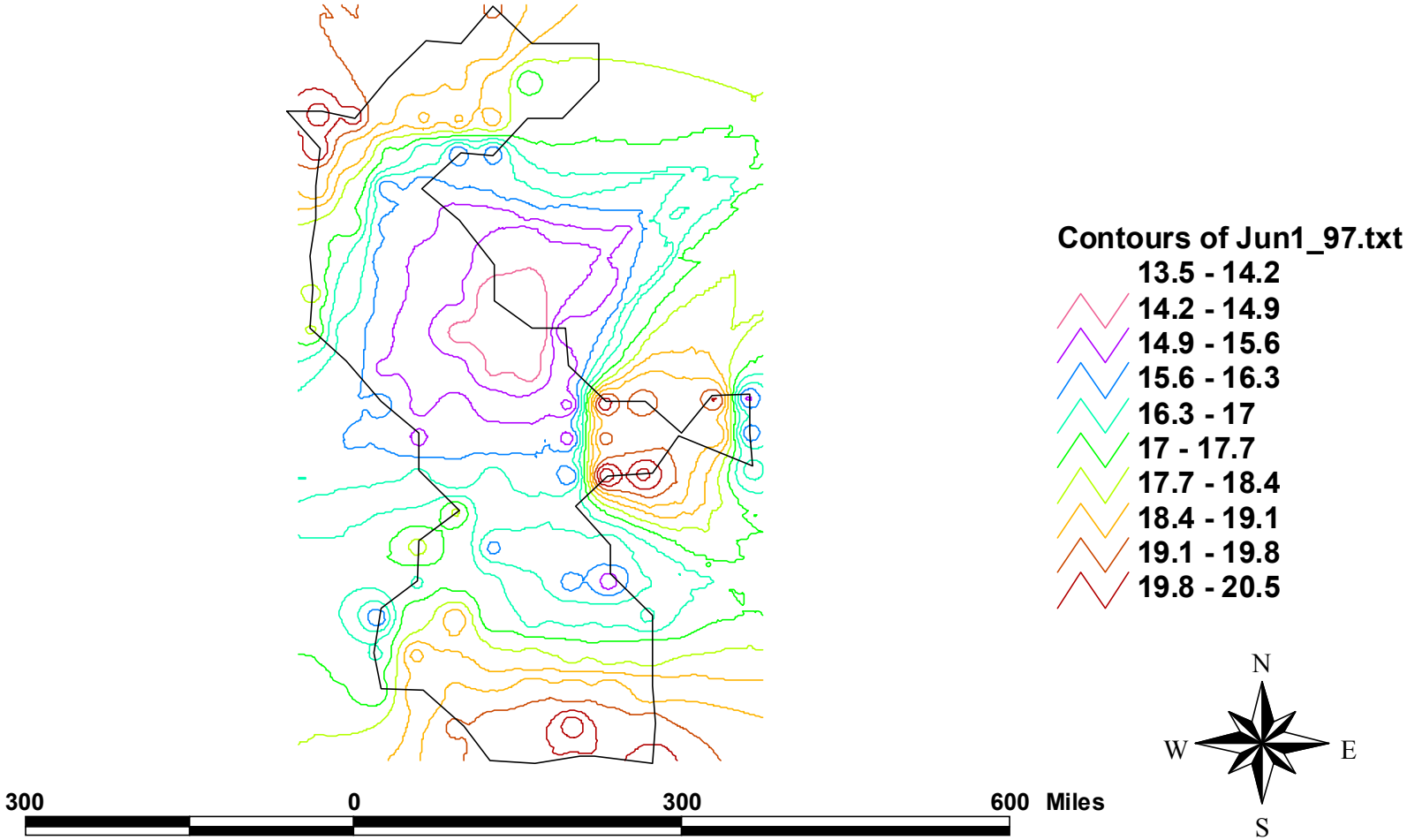
0.5 - 1.8
1.8 - 3.1
3.1 - 4.4
4.4 - 5.7
5.7 - 7
7 - 8.3
8.3 - 9.6
9.6 - 10.9
10.9 - 12.2
12.2 - 13.5
N
W
E
S
300
0
300
600 Miles

May_1 97


Contours of May1_97.txt
9.5 - 10
10 - 11
11 - 12
12 - 13
13 - 14
14 - 15
15 - 16
16 - 17
17 - 18
18 - 19.5
N
W
E
S
300
0
300
600 Miles

Jun_1 97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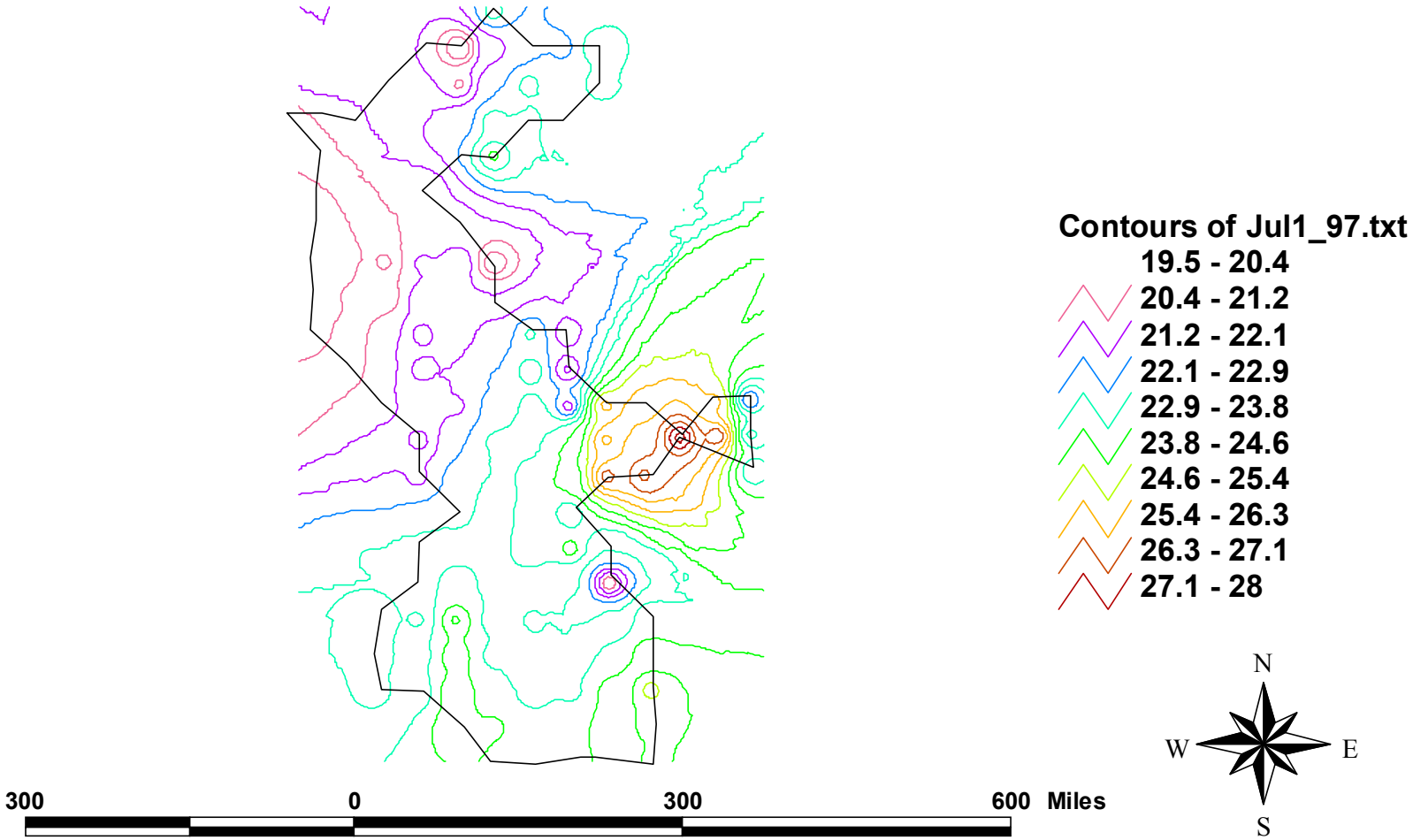
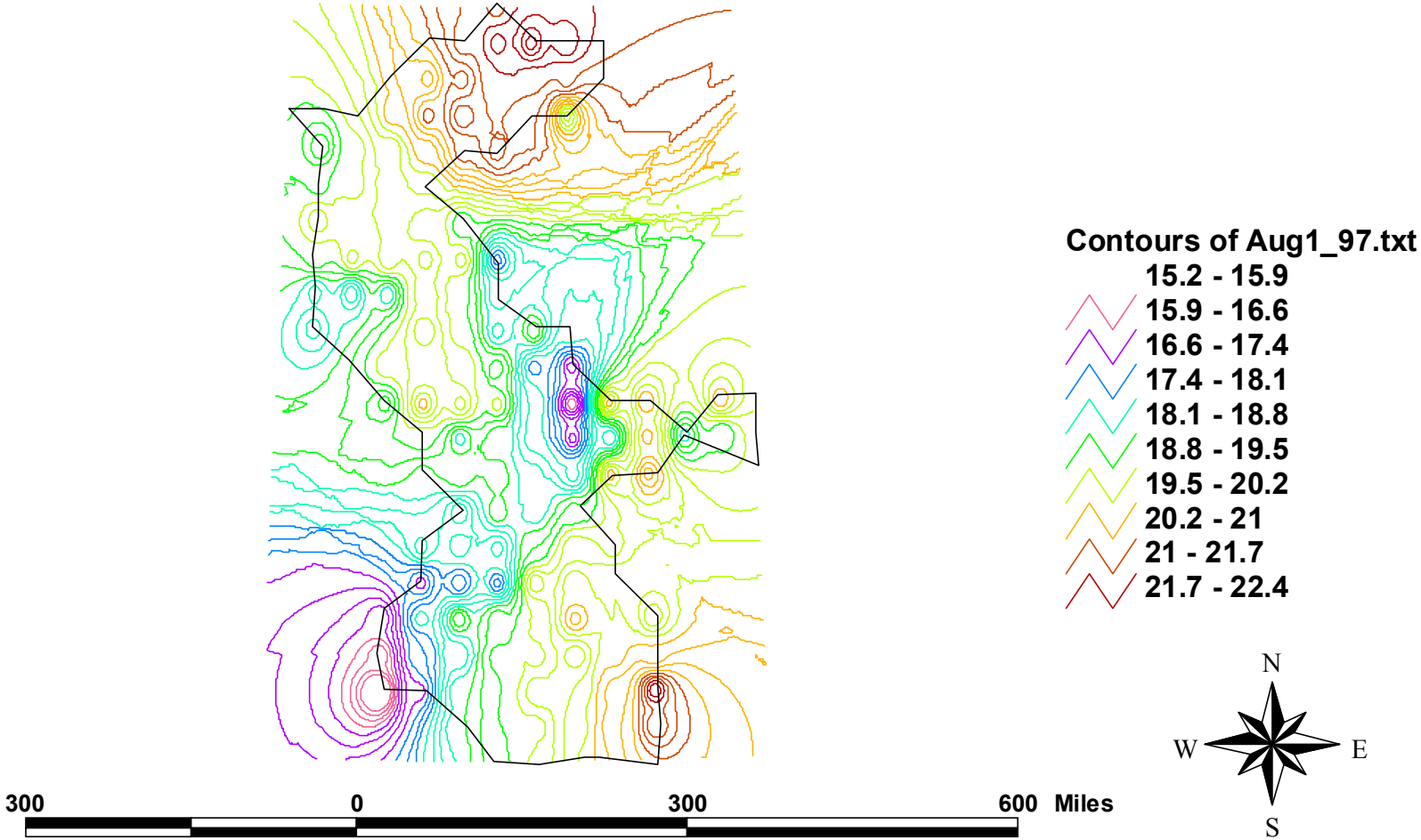
14.2 - 14.9
14.9 - 15.6
15.6 - 16.3
16.3 - 17
17 - 17.7
17.7 - 18.4
18.4 - 19.1
19.1 - 19.8
19.8 - 20.5
N
W
E
S
300
0
300
600 Miles

Jul_1 97


Contours of Jul1_97.txt
19.5 - 20.4
20.4 - 21.2
21.2 - 22.1
22.1 - 22.9
22.9 - 23.8
23.8 - 24.6
24.6 - 25.4
25.4 - 26.3
26.3 - 27.1
27.1 - 28
300
0
300
600 Miles
N
W
E
S

Aug_1 97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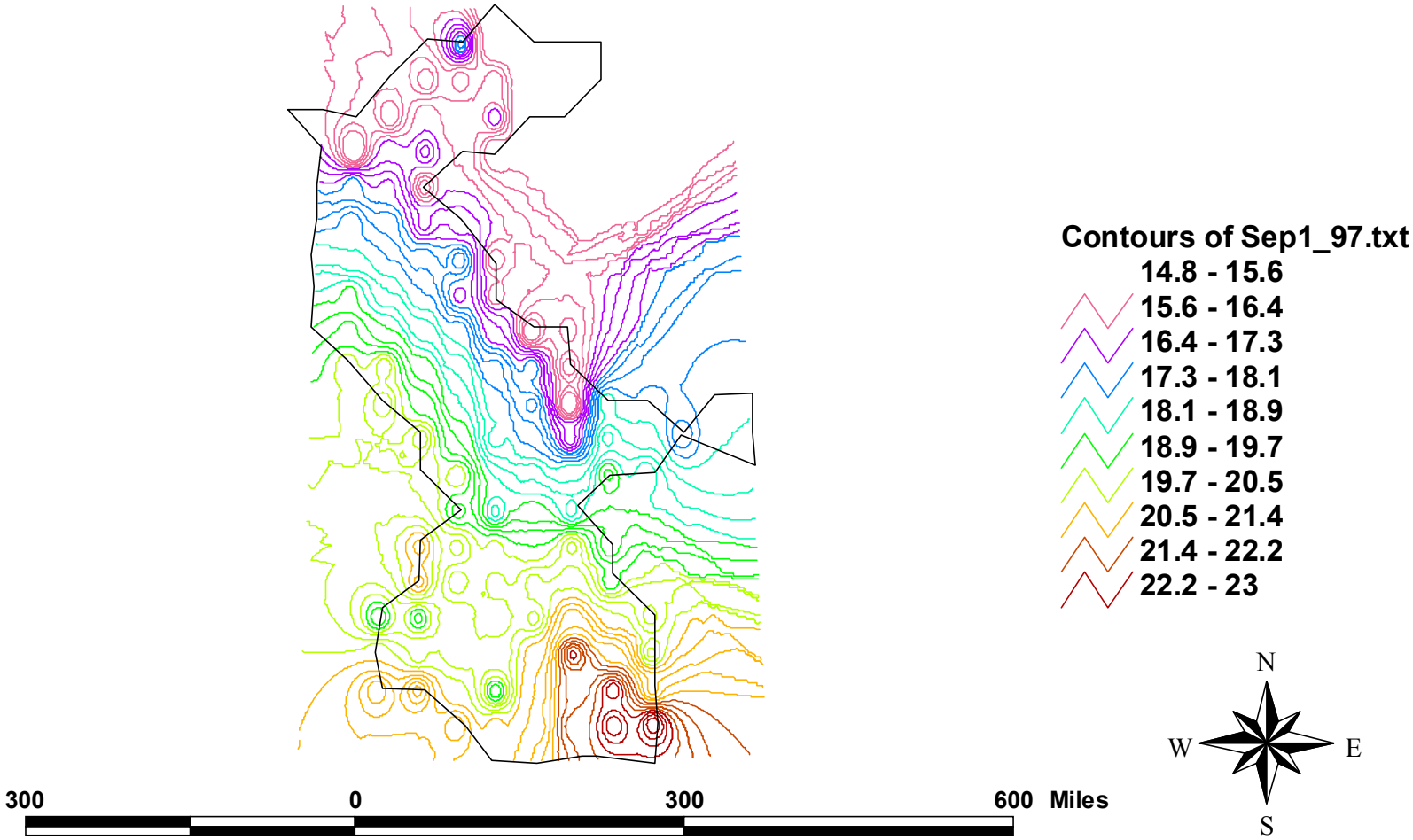
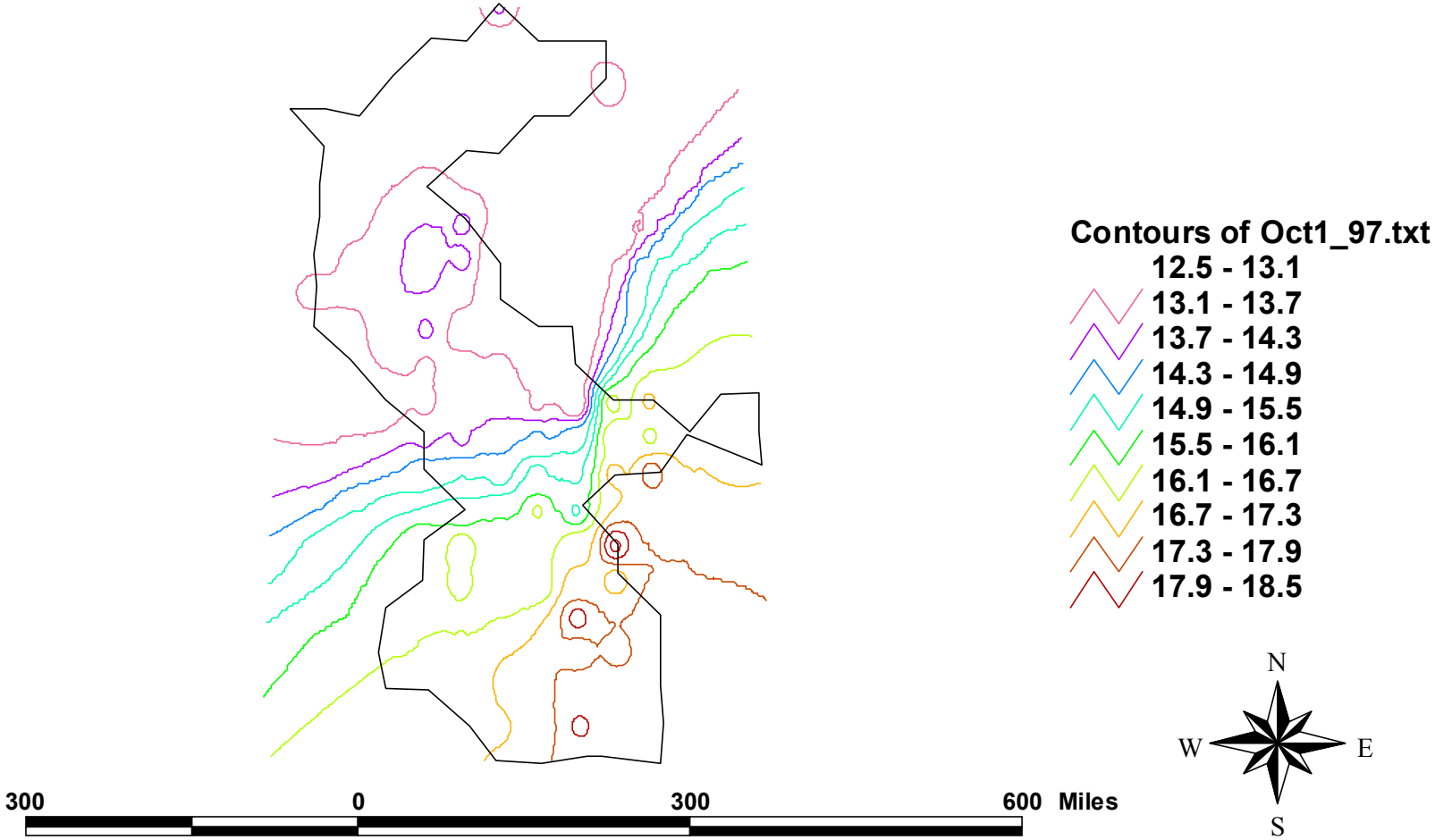
15.2 - 15.9
15.9 - 16.6
16.6 - 17.4
17.4 - 18.1
18.1 - 18.8
18.8 - 19.5
19.5 - 20.2
20.2 - 21
21 - 21.7
21.7 - 22.4
N
W
E
S
300
0
300
600 Miles

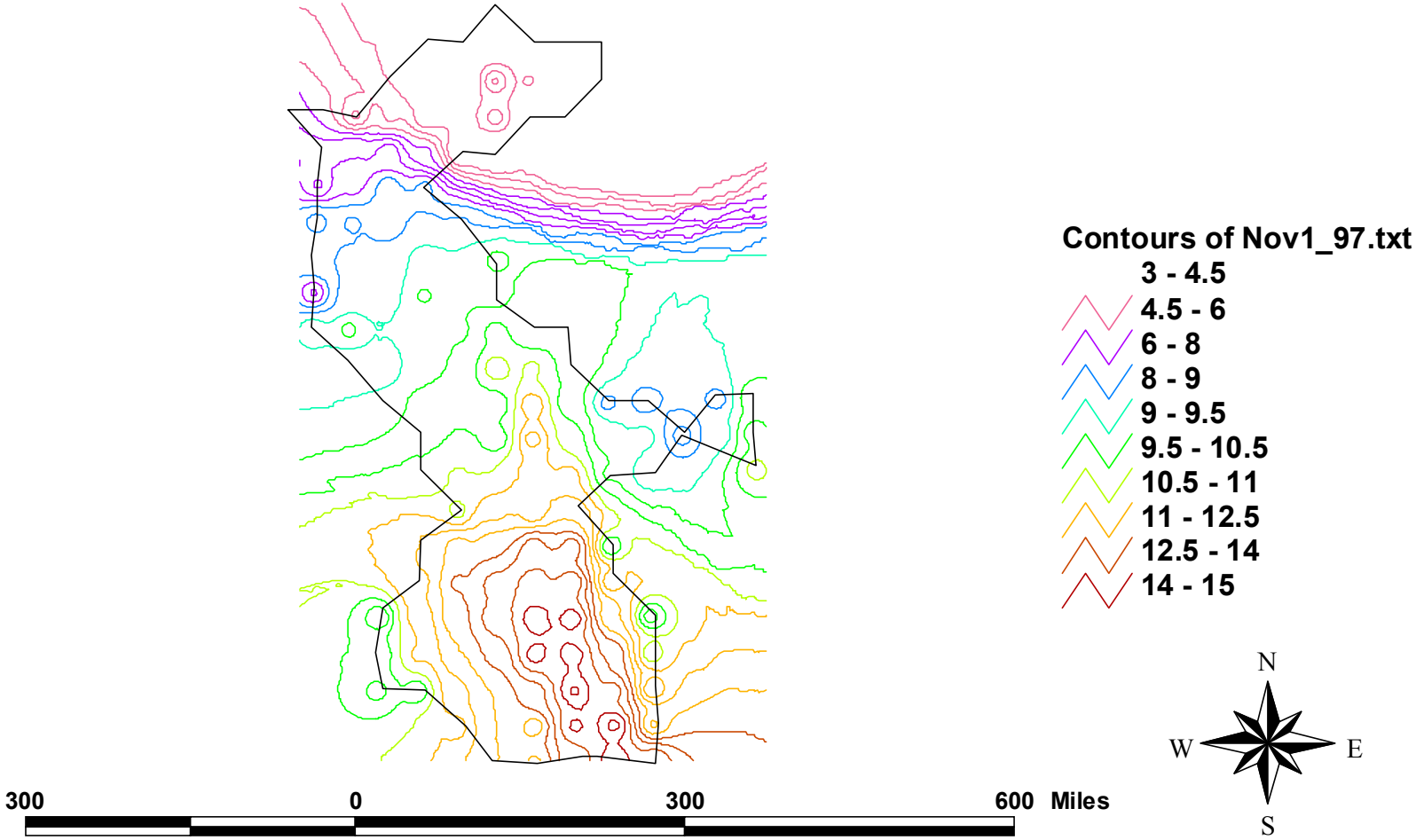
Sep_1 97


Contours of Sep1_97.txt
14.8 - 15.6
15.6 - 16.4
16.4 - 17.3
17.3 - 18.1
18.1 - 18.9
18.9 - 19.7
19.7 - 20.5
20.5 - 21.4
21.4 - 22.2
22.2 - 23
N
W
E
S
300
0
300
600 Miles

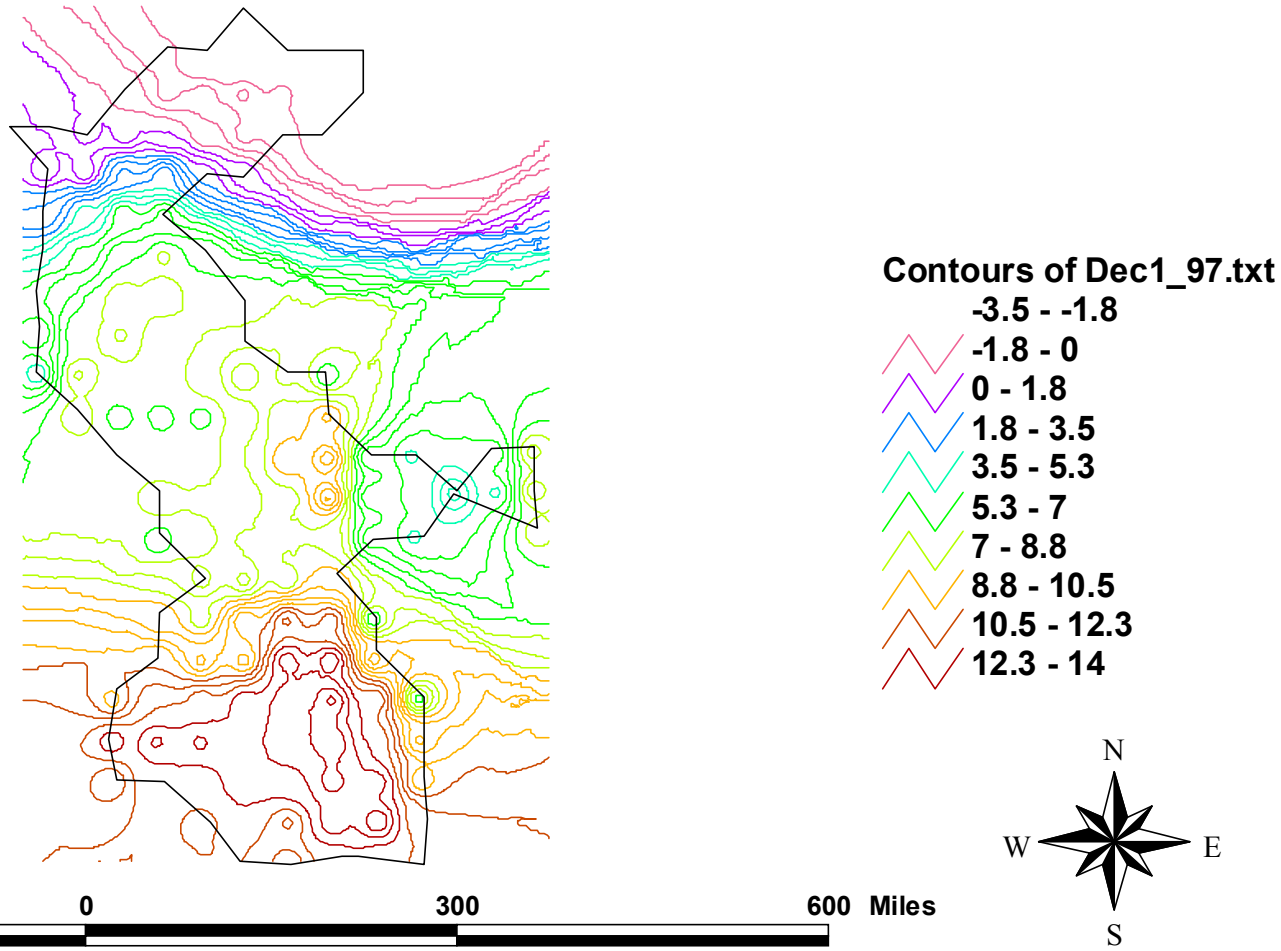
Oct_1 97


Contours of Oct1_97.txt
12.5 - 13.1
13.1 - 13.7
13.7 - 14.3
14.3 - 14.9
14.9 - 15.5
15.5 - 16.1
16.1 - 16.7
16.7 - 17.3
17.3 - 17.9
17.9 - 18.5
300
0
300
600 Miles
N
W
E
S

Nov_1 97


Contours of Nov1_97.txt
3 - 4.5
4.5 - 6
6 - 8
8 - 9
9 - 9.5
9.5 - 10.5
10.5 - 11
11 - 12.5
12.5 - 14
14 - 15
N
W
E
S
300
0
300
600 Miles

Dec_1 97


Contours of Dec1_97.txt
-3.5 - -1.8
-1.8 - 0
0 - 1.8
1.8 - 3.5
3.5 - 5.3
5.3 - 7
7 - 8.8
8.8 - 10.5
10.5 - 12.3
12.3 - 14
N
W
E
S
0
300
600 Miles

RBW DRAFT WORKING NOTE

Part 2. WATER BALANCE REPORT UPDATE

2.1. INTRODUCTION

The Caspian Sea Water Balance Studies reported by Wardlaw (1999), indicated a number of potential inconsistencies in the data sets on which the water balance was based. The water balance model developed had a monthly time step, and the most significant inconsistencies identified were that:

i) a very high and unrealistic sea evaporation was required in May to close the water balance;
ii) the peak of implied evaporation was in September and October, when air temperature and solar radiation are declining;
iii) implied evaporation in December, January and February was significantly higher than that in March and April, when air temperatures and solar radiation are increasing.

Figure 2.1 presents the implied evaporation distribution from the 1999 report. Clearly the discrepancies in the implied evaporation are the result of errors in the water balance inputs, or the result of failure to represent significant processes influencing the input data. This note presents the results of investigations aimed at addressing the discrepancies identified above.

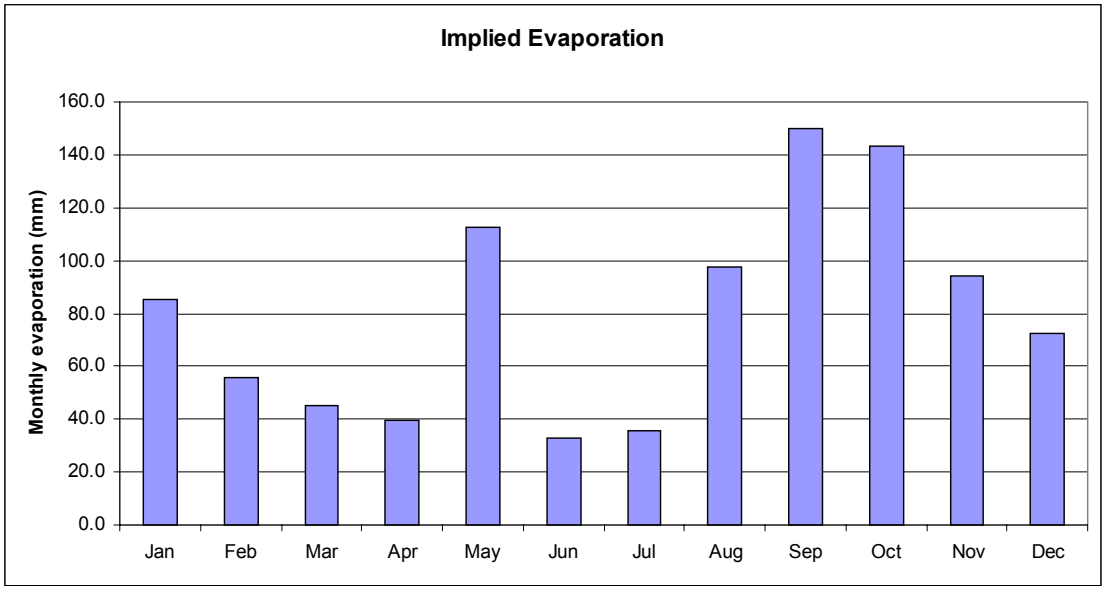


Figure 2.1. Implied evaporation estimates presented in 1999 report (Wardlaw, 1999)

2.2. FEEDBACK FROM DR GEORGIYEVSKY

Valuable feedback on the 1999 report has been received from Dr Georgiyevsky of the Russian State Institute of Hydrology in St Petersburg. He has made a number of important observations:

i) mean sea level may be determined from the level data at four posts (Baku, Makhachala, Shevchenko and Krasnovodsk) for use in annual water balance studies, but for studies at a monthly time interval it is preferable to use a greater number of stations in order to account for hydrodynamic variablility resulting from seasonal wind and density differences;
ii) estimation of precipitation on the sea solely from land based stations may result in under-estimation;
iii) in some years there may be some error in flow estimation in the lower Volga, but failure to model floodplain storage in the Volga Delta is identified as the principal reason for the very high implied evaporation in this month.

The above observations are addressed in model revisions which are outlined in the following sections.

2.3 REVISION OF MODEL DATA SETS

The primary data sets used in the water balance model are:

- historic sea levels
- historic rainfall on the sea
- historic evaporation from the sea
- historic inflows to the Kara Bogaz Gol
- historic inflows to the sea

2.3.1 Historic Sea Levels

In the 1999 report, sea level data were taken from a report by Bortnik. These were understood to be end of month data for Baku. It has now been possible to review mean monthly sea level data obtained from Roshydromet, and Dr Golubtsov. The Roshydromet data are averaged levels for Baku, Makhachala, Shevchenko and Krasnovodsk. These data are very similar to what had previously been assumed to be end of month data at Baku, but several anomalies have been noted that indicated that the data require more detailed quality control. Differences in sea levels of up to 0.8 m were noted in some months, which is clearly not possible. Such discrepancies were not noted to the same extent in the data previously obtained from Bortnik, and for the present purposes of improving the basic model structure, the Bortnik data has been retained, but used as mean monthly data rather than as end of month data in the model. The data obtained from Roshydromet and Dr Golubtsov must now be more carefully quality controlled, and following this should be used in the water balance model.

2.3.2 Historic Rainfall on the Sea

For the 1999 report, rainfall data on the sea was estimated by extrapolating from the gridded rainfall data set produced by the Climatic Research Unit at the University of East Anglia. A dataset of rainfall on the Caspian Sea has been prepared by Roshydromet, and this has now been incorporated directly in the model. A comparison of mean monthly rainfall data from Roshydromet and that interpolated from the UEA data is presented in Figure 2.2.

In terms of mean annual precipitation, the UEA data give a value of 240 mm. The Roshydromet data give an annual mean of 222 mm. The differences are not large, although the lower figures from Roshydromet in October, November and December will reduce implied evaporation in these months. Quality control checking of the Roshydromet data should be carried out, and the basis of it's determination documented.

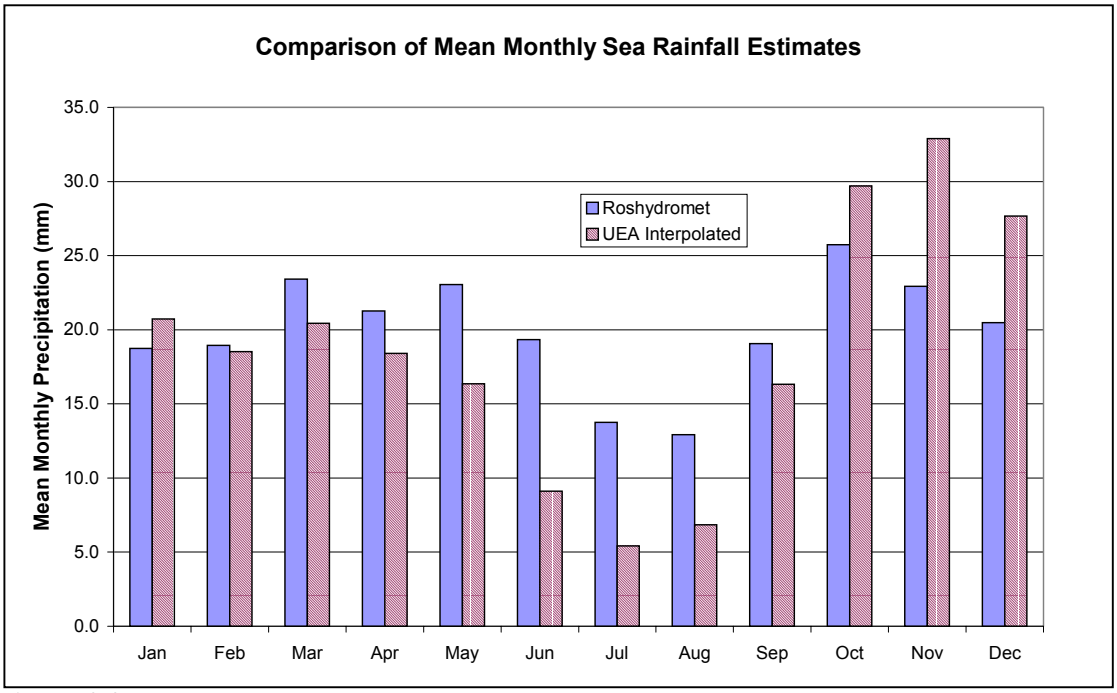


Figure 2.2 Comparison of sea rainfall estimates

2.3.3 Historic Evaporation From the Sea

For the 1999 report, evaporation data was implied initially from the water balance, and no direct estimates of evaporation were input to the model, although these were being computed by parallel investigations. A data set of historical sea evaporation has now been obtained by Kasnimosk from Roshydromet. This data set has been compiled using the Smirnova method, applied to sea surface temperatures for Baku, Makhachala, Shevchenko and Krasnovodsk. The data may be used directly by the model, or it is possible to run the model with implied evaporation.

2.3.4 Historic Inflows to the Kara Bogaz Gol

The historic inflows to the Kara Bogaz Gol used in the 1999 report were obtained from Brodynk. A data set has now been obtained by Kasnimosk from Roshydromet. The data from both sources are almost identical, and Roshydromet data set has now been incorporated in the model.

2.3.5 Historic Inflows to the Sea

The historic inflows to the Caspian Sea used for the 1999 report were from Bortnik, and represented the combined inflows from all rivers, net of delta losses. An almost identical data set has now been obtained by Kaznimosk from Roshydromet. Figure 2.3 shows a comparison of mean monthly inflows from both data sets. There are no significant differences in mean monthly discharges. The data obtained from Roshydromet have been incorporated in the model.

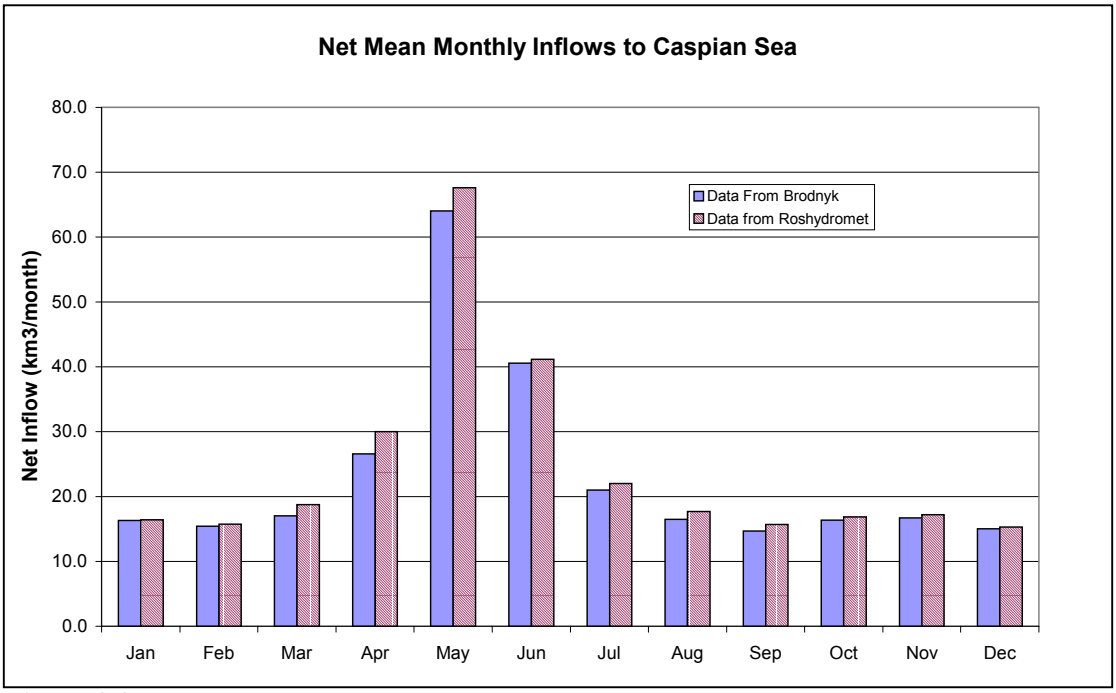


Figure 2 3 Comparison of mean monthly inflow estimates

There is clearly a need to carefully quality control the Roshydromet data.

2.3.6 Influence of Revised Data Sets on Model Results

The revised data sets obtained from Roshydromet are for the period 1925 – 1997. In the 1999 report, a standard data period of 1936 – 1996 had been adopted. Because of a requirement to further quality control the Roshydromet sea level data, and continued use of the Bortnik sea level data, the 1936 – 1996 period has been retained at present.

Figure 2.4 shows the comparison of implied evaporation estimates made in 1999 with those made from the revised data and including a correction in the model to deal with mean monthly sea levels rather than end of month levels. It is apparent that the revised data results in higher estimates of implied evaporation in June, July and August. This is partly as a result of increased precipitation on the sea in these months in the revised data sets, but mostly to the shift introduced by classifying the sea level data as mean monthly rather than end of month data. Figure 2.5 shows a comparison between the implied evaporation estimates using the revised data and (as in Figure 2.4) the 1999 data modified to include water level data as mean monthly levels rather than end of month values. There is no significant difference between the plots. The most significant impact comes from correcting the sea level data. There is clearly still a problem with the implied evaporation for the month of May, and this must be resolved through the introduction of floodplain storage.

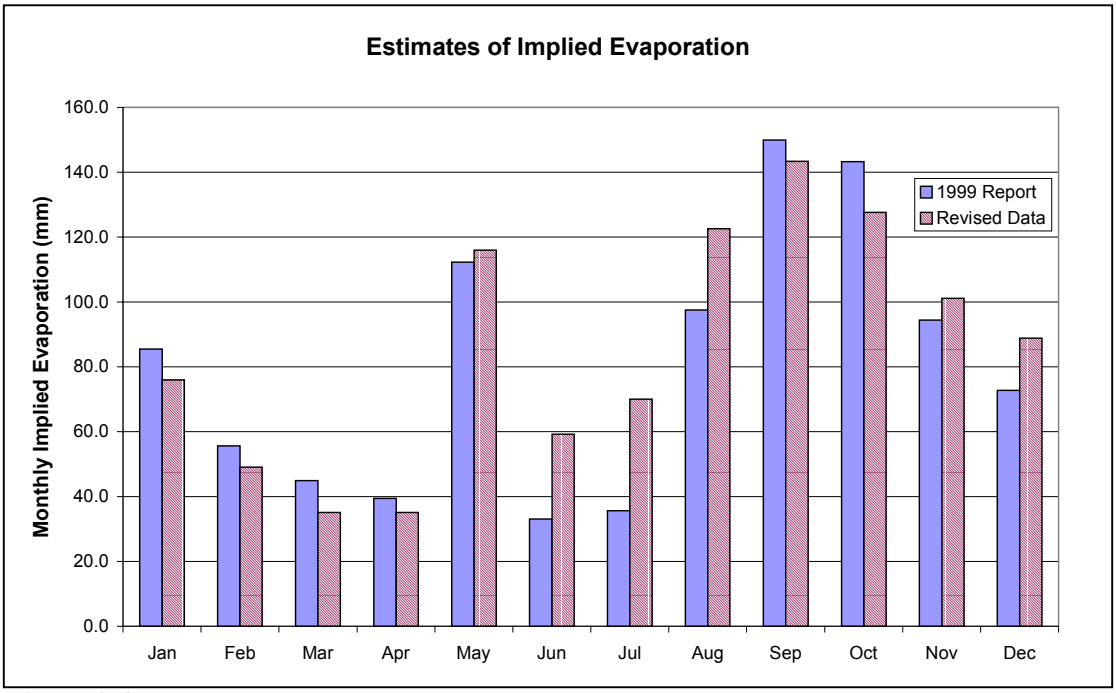


Figure 2.4 Impact of revised data on implied evaporation estimates

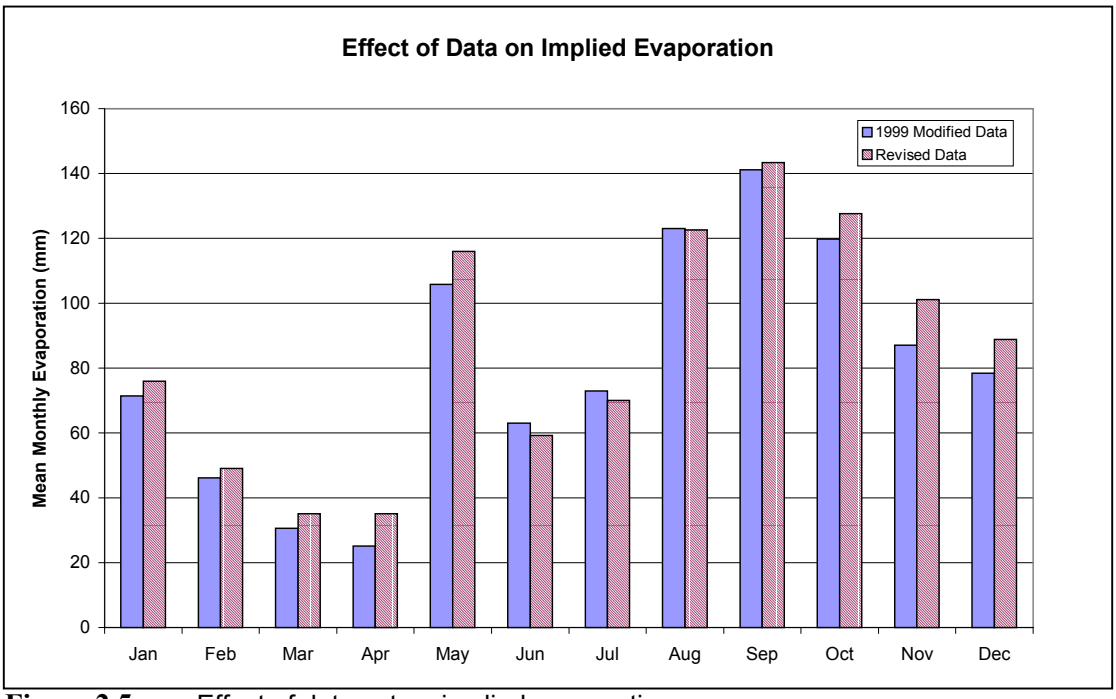


Figure 2.5 Effect of data set on implied evaporation

2.4 INTRODUCTION OF A DELTA STORAGE TERM

In the work carried out in 1999, it had been assumed that the monthly net inflows to the Caspian Sea had incorporated floodplain losses. An interpretation of Figure 2.4 is that they clearly do not, and that the inflows in May should be attenuated and lagged into June and July. A very simple storage function has been included in the model. A threshold discharge is set for the delta, and at discharges above this, flow goes into storage. A maximum of 30% of storage will be released in a month in which the storage and inflow exceed the threshold. All storage is released when the sum of storage and inflows is less than the threshold. This normally has the effect of storage influencing delta outflows in May, June and July. The only parameter that needs to be set is the threshold monthly inflow above which floodplain storage becomes active.

Figure 2.6 shows the effect of the function in terms of attenuation of inflows to the sea. Figure 2.7 shows the impact of the function on implied evaporation from the sea with a threshold flow of 50 km^3/month. The previous peak of implied evaporation in May has been removed, and distributed into June and July. When compared with the mean monthly evaporation estimates made from the Smirnova method, it is clear that the model is now approaching a better realisation of what is likely to be happening.

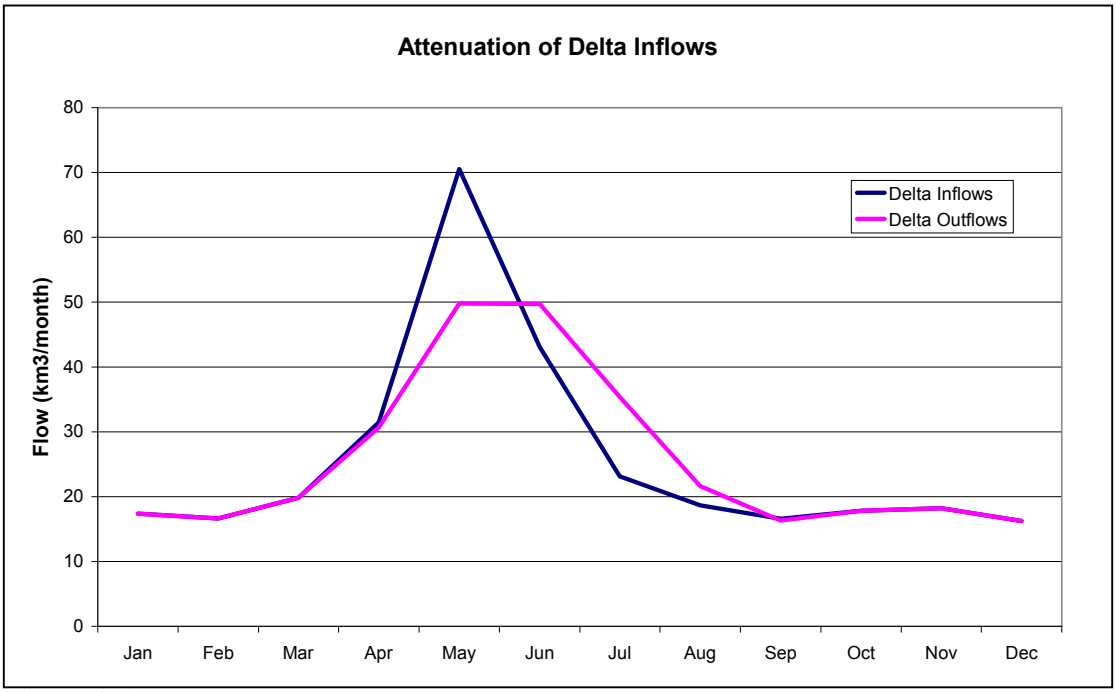


Figure 2.6 Attenuation of inflows to the Sea

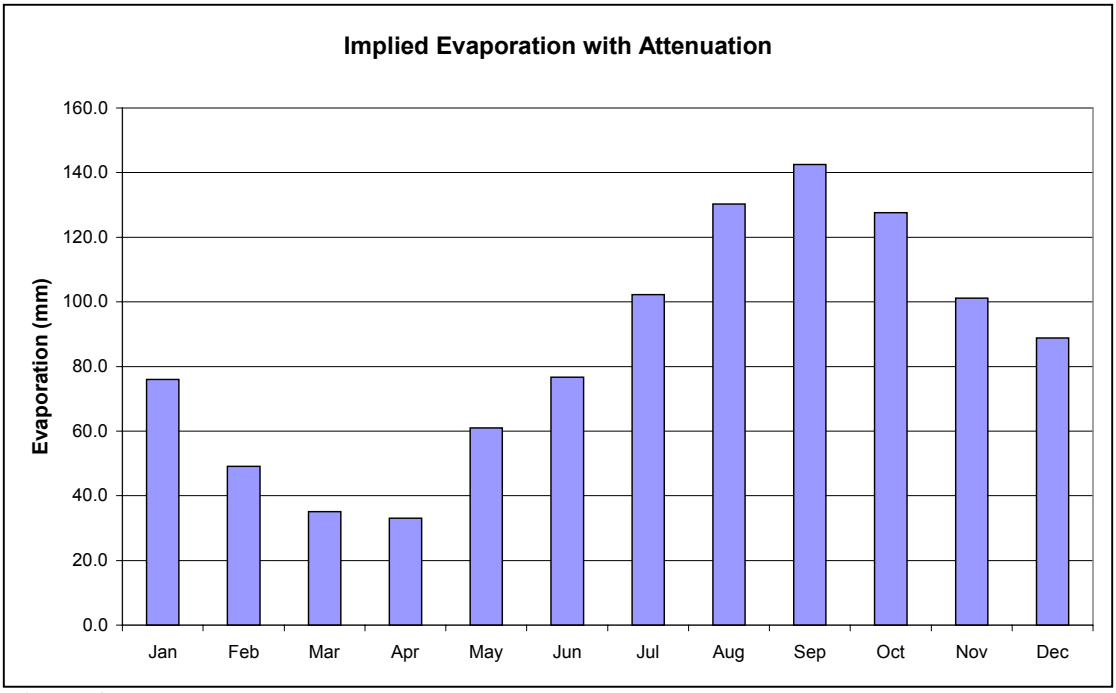


Figure 2.7 Influence of delta storage on implied evaporation

From Figure 2.7 it is apparent that there is still an over estimation of implied evaporation in the months of December, January and February. Sea surface temperatures are significantly lower in these months than in March and April, and it is inconceivable that evaporation could follow the pattern indicated. If it is assumed that on average the average monthly water level records are reliable, and that flow records upstream of the deltas are reliable, then a physical explanation must be sought for the implied evaporation results. It is considered that the only feasible physical explanation is the

accumulation of ice and restriction of outflows in the deltas of the Volga and Ural rivers taking water into storage in the months of December through February, thereby reducing inflows to the sea during these months. The accumulated ice storage would be released in March and April. An assessment of a simple approach to representation of ice storage is given below.

2.5 IMPACT OF ICE STORAGE

From a brief assessment of differences between the implied evaporation of Figure 2.7 and the evaporation calculated by the Smirnova method, it has been crudely estimated that on average, the required transfers of river water into ice storage are:

December	30% (5 km^3)
January	50% (8 km^3)
February	12% (2 km^3)

Representing a total storage of 15 km^3. It has been assumed that this would be released as follows:

March	40%
April	60%

The impact of introducing the above on average implied evaporation is shown in Figure 2.8. The resulting implied evaporation is now similar in distribution to mean monthly evaporation calculated by the Smirnova method, and to mean monthly sea surface temperatures. It would appear therefore that reasonable representations have been incorporated in the model to deal with floodplain storage and with ice storage. The representation used for ice storage is extremely crude, and it is desirable that a more objective and deterministic approach be developed in which ice build up is related to flow and temperature. Mean monthly air temperatures for Astrahan are shown in Figure 2.9, and support the distribution of storage adopted above. The representation of individual years in a realistic manner will require a temperature related function.

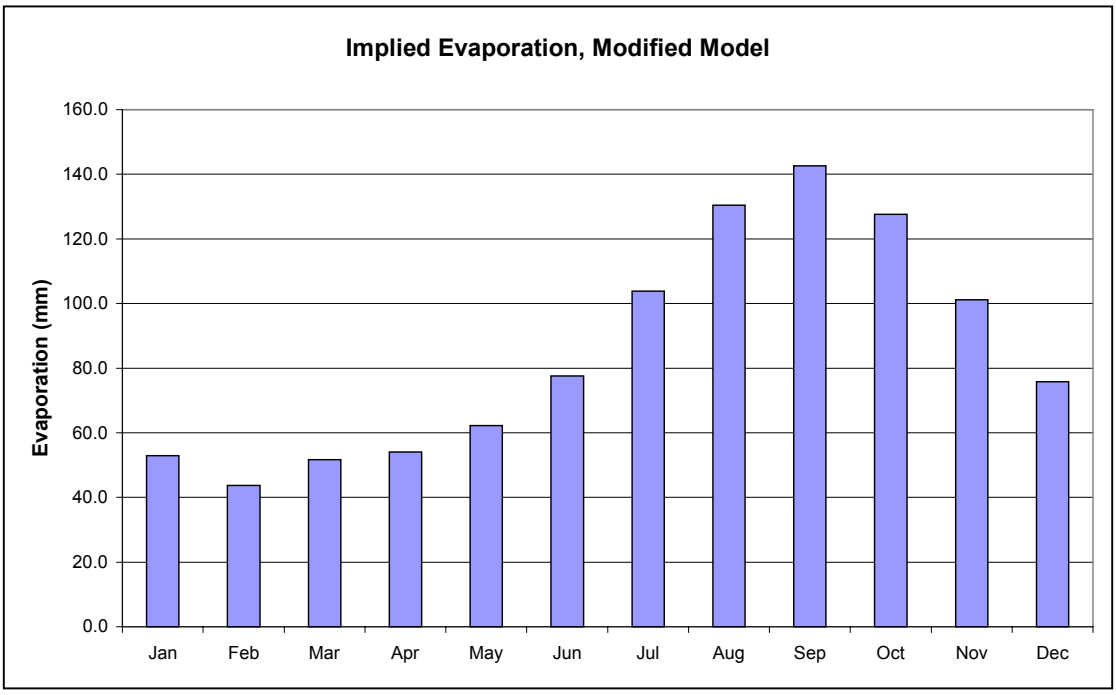


Figure 2.8 Implied evaporation with model incorporating ice and delta storages

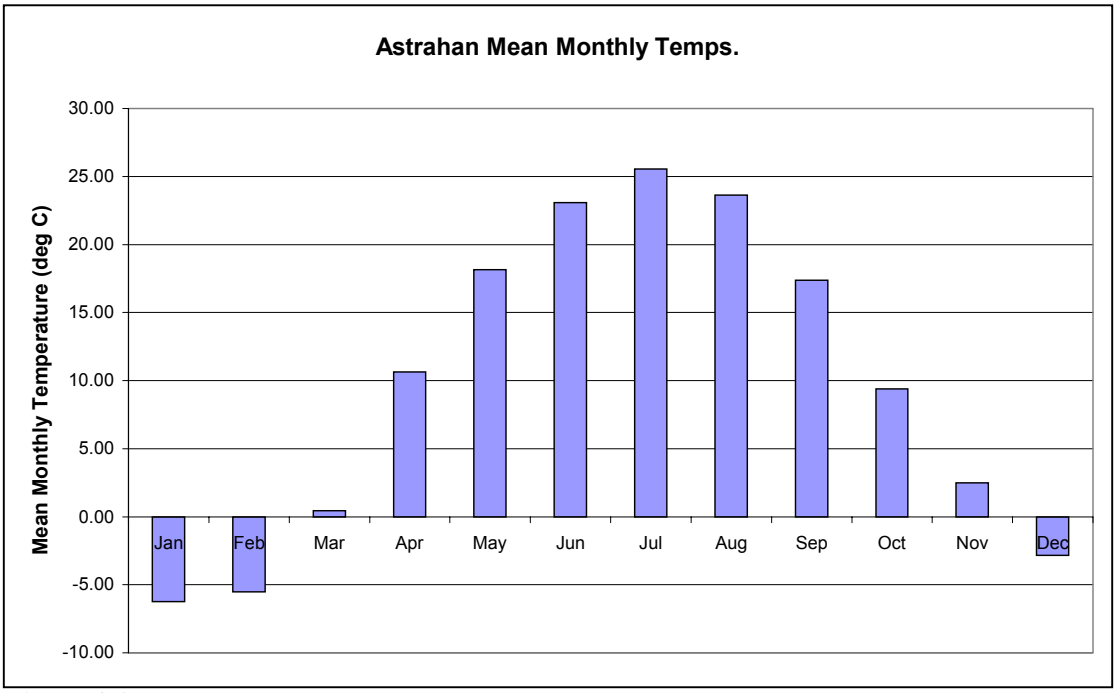


Figure 2.9 Mean monthly temperatures at Astrahan

2.6 REFINEMENTS REQUIRED TO MODEL AND DATA BASE

2.6.1 Inflow Data

The inflow data used in the model at present are net of delta losses, and equivalent gross inflow data are unavailable for the entire period of record. It is understood that the delta losses relate primarily to the Volga, and are calculated on the basis of a very simple formula:

$$Q_L = 0.034Q+0.22$$

where,

Q_L = the delta loss (km^3)

Q = volga flow downstream of Volgograd (km^3)

The basis of this equation is unknown, and clearly it does not account for floodplain losses or for the impacts of ice storage as discussed above. Given the approach that has been developed for floodplain storage and the need for an improved approach to ice storage, it is essential that the water balance model be driven by gross inflows to the delta regions, and that individual loss/attenuation and lag models be developed for the deltas of each of the major rivers. It is not sufficient to reverse engineer the existing net inflow records to obtain gross inflows. It is necessary to get back to original flow records at the head of each of the major deltas and to progress from there. It is recommended that this work be progressed now through Kasnimosk. It should incorporate data quality control also.

2.6.2 Rainfall Data

No assessment has been made of the Roshydromet rainfall data set for the Caspian Sea. The data should be quality controlled, and ideally a normal distribution fitted to each month of data to help spot any potentially anomalous values.

2.6.3 Potential Evaporation

It is believed that further work is required to be done on the assessment of potential evaporation from the sea. In effect both rainfall and evpotranspiration are difficult to quantify, although with the

introduction of new stations through HYCOS, estimates should improve. It is likely that the Smirnova equation applied with temperatures from four stations underestimates evaporation. A further review of potential evaporation estimation is required, and could utilise sea surface temperatures from satellite more fully. A separate review of evaporation is under preparation. For scenario modelling it is at present most appropriate to run the model with implied evaporation estimates.

2.6.4 Water Level Data

There is a requirement to quality control the Roshydromet sea water level data. Average water level changes in any month are not expected to exceed about 0.05 m. It is appropriate also to assess how well the four stations used to compute mean sea level do in fact represent mean sea level. An attempt should be made therefore to study periods of concurrent sea levels for large groups of stations for the longest periods of continuous record that are available. In this analysis, the records of each station should be normalised and expressed as a deviation from the mean of that station. Profiles may be plotted on a monthly basis to identify the occurrence of significant shifts in slope, and for the entire record, the cumulative mean of the four stations normally used in sea level analysis plotted against the cumulative mean of all stations (this should be on the basis of normalised data at each station).

For the updated analyses presented here, mean monthly water level data have been used, and end of month data estimated as the average between successive months. It is preferable to use actual end of month data although it is recognised that daily variability in levels may make this difficult in practise. It considered desirable to try and use end of month data and to compare results with those obtained using monthly data.

2.6.5 Improvement of Ice Storage Estimation

An improved method of determining ice storage in the Volga downstream of Volgograd, and in the Ural downstream of the lowest gauging station should be developed. Models for predicting ice thickness on rivers and open channels as a function of flow, hydraulic characteristics and cumulative temperature (degree days or similar) must have been developed in Russia and in Canada. From a literature review it should be possible to identify an approach that would be appropriate for inclusion in the water balance model.

2.6.6 Incorporation of KBG Study Findings

The water balance model should be updated to include the evaporation estimates now available for the KBG, and to include the improved elevation area characteristics. This will permit a more objective assessment of the actual capability of the KBG to regulate Caspian levels. The water balance model could include revised discharge relationships for potential structural solutions. It is important to consider the possibility of sediment inflow to the KBG, and the sustainability of maintaining storage within it.

2.6.7 Evaluation of the Sors of Mertvia Kultuk and Kaidak

Improved elevation area characteristics are required, and consideration given to the structural measures required to effect a closure

RBW DRAFT WORKING NOTE

Part 3. WATER BALANCE MODELLING: FURTHER STUDY REQUIREMENTS

3.1 DATA BASE DEVELOPMENT

A number of minor inconsistencies have been identified in the theh data base used for water balance modelling. Ideally we should be aiming to publish the data, model and model results on the CEP internet site, and it is therefore extremely important that the data sets are consistent and accurate. The water balance model will be used in the analysis of mitigation strategies, and if it is to be accepted, there must be confidence in the basic data that drives it.

It is recommended that the data from Roshydromet form the basis of the water balance model. It is recommended that eth following data quality control exercises be carried out:

3.1.1 Rainfall

Sea rainfall data from Roshydromet must be quality controlled to identify any obvious anomalies that may have resulted from data entry errors. The simplest way to do this is through identification of values that are more than say 2 standard deviations from the mean in a particular month, and plotting of the non-zero monthly data to a normal distribution to identify significant outliers. The method by which Roshydromet created the data must be determined and a note added to the database outlining the methodology and referencing some original publication that describes it. It is important that we understand this and accept it if we are using the data.

3.1.2 Sea Evaporation

Analysis has shown that sea surface temperatures and air temperatures are very closely linked. Under future climatic conditions it is likely that the pattern of evaporation across the sea may change. In the southern parts it may be that there is little variation in future temperatures, but in the northern part, it is possible that there will be less frequent ice coverage, and some increase in winter evaporation.

The processes governing the energy balance of the sea and driving the evaporation process are complex, and an energy balance approach to evaporation estimation difficult to achieve. An approach based on sea surface temperature alone may offer a robust alternative. The indications from the revised water balance model are that the Smirnova equation provides good estimates of sea evaporation (perhaps it was derived from water balance observations). The equation has been used with temperature measurements from four stations in the sea. It would be useful to determine how representative these stations were of average sea temperatures. This could be done using satellite estimates of sea surface temperature. It would be appropriate to compute average monthly sea surface temperatures for comparison with the station data, and also to compute surfaces of annual degree days. This would identify the most important regions of the sea for evaporation. This work would best be carried out in ArcView. A younger specialist working with one of eth more established experts would be the way to proceed. Alternatively, part of the work could be done by the Space Research Agency.

In the database there exists a file of historic sea evaporation estimates calculated using the Smirnova method. It is understood that this has come from Roshydromet. It is necessary to quality control this data in much the same way as has been outlined above for rainfall data. It is also desirable to include a note in the database outlining the source of the data and method of computation. These data are very similar on average to the model implied evaporation, and we should eventually be looking at how well the model is representing individual years. This will be done when all elements of the database are verified.

3.1.3 Sea Inflows

As has been indicated in the modelling report, the inflows being used to drive the model are currently net of delta losses. It is desirable that we have gross inflows to the sea, built up from individual river records. The data that we currently have are from Roshydromet. The manner in which the combined inflow record has been created must be defined, particularly with regard to delta losses. The data should then be reverse engineered as a first step to get gross inflows. These should then be quality controlled in much the same way as rainfall and evaporation data. As with the other data, notes on the method of creation of the data are important.

It is important to get the data for individual river systems, and to know the extent to which these have been infilled in the creation of the long term sea inflow record. It is important to know the range of uncertainty that exists in the inflow data, and to be able to document this.

3.1.4 Sea Water Level Records

The requirement to quality control the Roshydromet sea level records has been identified in the note on the water balance model. Average water level changes in any month are not expected to exceed about 0.05 m. It is appropriate also to assess how well the four stations used to compute mean sea level do in fact represent mean sea level. An attempt should be made therefore to study periods of concurrent sea levels for large groups of stations for the longest periods of continuous record that are available. In this analysis, the records of each station should be normalised and expressed as a deviation from the mean of that station. Profiles may be plotted on a monthly basis to identify the occurrence of significant shifts in slope, and for the entire record, the cumulative mean of the four stations normally used in sea level analysis plotted against the cumulative mean of all stations (this should be on the basis of normalised data at each station).

The available end of month sea level data must be quality controlled also, and checked against the monthly data. As with other data sets, notes on origins must be made.

3.1.5 Improved Water Balance Model

Following refinement of the modelling data base and the data quality control as outlined in the preceding sections, it will be possible to refine the water balance model further. At present a very simple attenuation function is used for delta floodplain storage, and an equally simple approach has been introduced for ice storage. The means of improving both of these must be investigated, as outlined in the balance model note. It is desirable that the model function well on individual years as well as on the long term average. This should be investigated by comparing implied evaporation with Smirnova calculated evaporation, or by using Smirnova calculated evaporation and determining model closure errors.

The model should incorporate revised elevation area characteristics for the KBG, and should also incorporate a different evaporation estimate for this area if it is being used in a predictive mode.

The influence of using mean monthly sea level data rather than end of month data on model results and computed evaporation should be investigated and reported on. This will require creation of an end of month data set. One exists at present, but it's origins are unknown. These must be established and the data quality controlled.

The code for my model has been left on disk. Dr Golbstov and Dr Lee are very welcome to use this, or they may improve their own monthly model in that has been done with my model. The objective is to demonstrate that the model does work well on individual years, and that our process representation is satisfactory. Ultimately we may expect that the model will be available to run from the internet. It must therefore be reliable.

RBW DRAFT WORKING NOTE:

Part 4. FLOOD MANAGEMENT

4.1 OVERALL OBJECTIVES:

- Delineation of flood depth duration frequency characteristics for a series of characteristic background sea levels (say –27 to -22)
- Creation of a set of good maps showing inundated infrastructure, settlements and agricultural land, linked to a database (perhaps through GIS) of flood depth damage characteristics
- Review of previous potential flood damage estimates
- Assessment of flood damage frequency characteristics at different characteristics background sea levels
- Identification of alternative flood mitigation strategies
- Assessment of the impact of alternative mitigation strategies on flood damage frequency characteristics
- Economic appraisal of alternative mitigation strategies
- Recommended approach for completion of strategy formulation in all riparian states.

4.2 BASIC DATA REQUIREMENTS:

- Good topographic mapping of the at risk areas with a minimum contour interval of 1m (and preferably 0.25 m in areas of particular interest) to provide bathymetric data for the surge model. Contouring at 1 m interval will be possible from the Space Research Centre mapping. Contouring at 1 m may also be possible from the reports and maps held by Dr Isanbayev. For areas of interest, such as Atrau, the will almost certainly be larger scale mapping available from the reports with Dr Isanbayev.
- As above presenting all significant infrastructure and significant settlements: roads, railways, power lines, oil pipelines, canals, airports, telephone lines etc. This mapping effectively exists at present and with the information in Dr Isanbayev's reports, we should be able to create a good GIS.
- For each significant settlement or industry, flood elevation damage characteristics are required – these may be in the form of depth area, depth length, or depth damage for different types of facility; clearly level data area required. This data will be available in some form through the Isanbayev reports. It would be best to identify classifications of property, and then to have property floor level area curves for different flood zones. Following the approach of Penning-Rowsell, it should be posible to come up with some depth damage curves for different property type per unit floor area.. For road and rail routes there will have to be traffic flow data.
- Surge depth frequecies determined for range of mean sea levels on basis preferably of historic sequence of weather conditions

4.3 DATA KNOWN TO BE AVAILABLE:

The report by Madi Kireyev identifies the following:

- Topographic mapping at 1:200,000 scale
- Geomorphologic map at 1:200,000 scale
- Map of flood zones with co-ordinates
- GIS of Aatyraiskaya oblast

It is important that the above maps are obtained now and reviewed such that further requirements for mapping can be identified. We now know that good mapping at 1:200,000 scale is available through the Space Research Centre, and that this can be obtained in digital form (for an unknown price). This digital data would be extremely valuable, given the limited resources of the project.

The reports held by Dr Isanbayev are certainly very comprehensive and should form the basis of developing depth damage characteristics. An explanation of the approach that we would like to see to depth damage assessment may permit him to set some students or others to the task of developing a system for the project area. There may have to be some updating of property use, and clearly some broad assumptions will have to be made.

4.4 DATA REQUIRED:

- We need to develop some property and contents valuations for different flood depths; this would cover domestic, commercial and industrial units (including oil wells); environmental consequences should also be a consideration.
- Unit rates are required for earthworks (protective embankments), and for relaying roads and railways at higher elevations
- Protection of Atrau may involve more complex engineering – surge barriers, difficult ground etc., and could not go into details
- The study should concentrate on Kazakhstan, but there will have to be some measure of flood damages in all of the countries. The best approach would be to have them prepare depth damage estimates for infrequent surge induced flooding; for asset loss in the case of background sea level rise and subsequent inundation, asset replacement / improvement / moving cost rather than damage is appropriate.
- Typical costs for embankments and walls of different heights need to be prepared
- Loss of agricultural production may be a problem in some areas, and on the Iranian coast there may be water logging and drainage problems from agricultural land. A review of agricultural damages and possible mitigation strategies could be carried out by in country contracts.

RBW Working Notes on Golubstov and Lee KBG Report

1. The report presents a revised elevation area curve for the KBG. This should be incorporated in the water balance model.
2. The report presents monthly and annual evaporation estimates from the KBG made between 1921 and 1935 on the basis of water balance estimates. These values seem to be very consistent and indicate mean annual evaporation of 1225 mm from eth Kara Bogaz Gol.
3. On the basis of inflow and water level records between 1995 and 1998, Golubstov and Lee have determined evaporation by water balance techniques. There is however a wide variability in the results achieved – 887 mm in 1998 and 1587 mm in 1995. Inflow was estimated to have been 46.38 km^3 in 1995, and was 16.84 km^3 in 1997. It is likely that problems with inflow estimation are the source of inconsistencies in evaporation estimation. It would be helpful if the report commented on the likely quality and adequacy of the data.
4. Estimates of evaporation in the KBG have been made using sea surface temperature data obtained from satellite. Both the Smirnova equation and the Penman equation have been applied. For 1997, the Penman estimate is about 1085 mm, and the Smirnova estimate 975 mm. For 1999, the Penman estimate is 1135 mm, and the Smirnova estimate 1050 mm. The Smirnova equation was I think developed for application to the sea as a whole, and may not be appropriate in its standard form when applied to one particular location. It results in evaporation for the KBG that is close to the evaporation from eth sea. The Penman estimates are probably more realistic for the KBG, although it is not clear if it has been applied with a coefficient.
5. Estimates of evaporation were made from the northern part of the sea using Penman and the Smirnova method. In 1997 the Penman estimate was 940 mm, and the Smirnova estimate 830 mm. In 1999, the Penman estimate was 985 mm, and the Smirnova estimate 850 mm.The Smirnova estimates are consistently lower than Penman by about 100 mm. The Penman estimate is probably reasonable, being lower than the implied average sea evaporation in this region as would be expected..
6. On the basis of the historical evaporation estimates, and on those made from sea surface temperatures, annual evaporation from the KBG is expected to be in the range of 1100 – 1200 mm. For water balance modelling in which the KBG is being investigated with controlled inflows, it is suggested that the monthly distribution of evaporation observed in the 1920 water balance be compared with the distribution indicated by the Penman method, to develop an average distribution that can be applied with 1100 mm per year of evaporation. This is likely to be conservative and actual evaporation may be higher.
7. In water balance modelling including the Sors of Mertvia, the Penamn estimates of evaporation for the northern part of the sea may be used and incorporated in the water balance model. This will result in evaporation rates slightly lower than those experienced in the sea as a whole, and is again an improvement.

CEP_II RBW Inputs for 2001

Proposed Activities:

1. Finalisation of water balance model
2. Evaluation of water use patterns in Volga and Ural basins, consideration of future water use developments for inclusion in Grid model
3. Discussion with State Institute of Hydrology on reservoir system modelling as an additional overlay for the Grid model
4. Review of progress on flood management and assistance in evaluation of flood management options and economic analyses

Timing:

Inputs are possible as follows:

a) January or February, maximum of one week.
b) 4th March or 11 March for two weeks;
c) 19 August or 2 September for 2 weeks
d) mid November for 2 weeks

Proposal:

St Petersburg for two weeks from 4th March, addressing items 1, 2 and 3 above.
Almaty for 2 weeks from 19 August addressing items 1 and 4.
Almaty for 2 weeks from mid November addressing item 4.

In addition t may be possible to spend a day or two on the project in Almaty at the end of March / beginning of April.