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17-YEAR PERIODS OF RISING AND FALLING WATER LEVELS IN THE KAZAKHSTAN SECTION OF THE CASPIAN SEA

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Abstract. *The Caspian is the largest endorheic lake on Earth, situated on the boundary of Europe and Asia, yet it is called a sea due to its sheer size and its seabed that has been formed by oceanic Earth crust. The Caspian Sea has a fluctuating hydrologic regime that causes both sharp drops and sudden increases in its water level. The present article examines the specifics of the relief of the sea floor in the Kazakhstan section of the Northern Caspian which is the most susceptible to underflooding (due to a rise in the water table) during water surges. This article analyses the dynamics of the fluctuating water levels in the Caspian Sea during the period of decreased and increased water levels from 1960 to 2013. It also offers the possible reasons for these changes in the water levels of the Caspian Sea.*

Key words: *Caspian, endorheic sea-lake, seal, sturgeon, beluga, oil, terrain and sloping of the seabed, dikes, sand bars, banks, rift, hydrologic regime, unstable level, amplitude, water surge, salt lakes, Kaydak, Olikoltyk, increase and decrease dynamics, tributary, evaporation, precipitation, forecasts, causes for fluctuation.*

Introduction. The Caspian Sea is the largest endorheic lake on Earth, but it is called a sea due to its sheer size, saline water and its demeanour that resembles a sea. The sea was named in the middle of the 16th century after the Caspian people that lived in the Transcaucasian region. There is still a city called Caspi that remains in Georgia today. The sea has also been called Hyrcanian Ocean (1st century), Khazar Sea (2nd-10th centuries), Khvalyn or Khvalis Sea (10th-12th centuries) and has had over 60 other names given to it by the people who have lived here over the last 3,000 years. The Caspian Sea separated from the Black Sea due to a rise in the earth's crust at the end of the Neogene period, which is considered to be the period when the sea was formed. The Caspian Sea has an area of 370,000km^2, which is over four times the size of the largest freshwater lake – Lake Superior in North America. The Caspian holds 78,600km^3 of water while its average and maximum depths are 208 and 1,025 metres, respectively. The surface of the Caspian Sea is 26.5 metres below the level of the ocean according to the Baltic Elevation System (BES).

The endorheic Caspian Lake is more similar to a sea due to its water quality and, correspondingly, the wildlife and plants that are found here. For example, it contains jellyfish that are usually found only in the sea. This is no accident, either. In times long past, the Caspian, Black and the Mediterranean Seas were part of a single large body of water, the so-called Tethys Sea. It existed during the era of the Dinosaurs and it occupied most of Eastern Europe 50 million years ago. The Tethys Sea subsequently significantly decreased in size, having been separated into a host of smaller water bodies that exist even today. Over the last 30 million years, the Caspian Sea has lost and regained its connection to the world ocean several times. Its salinity changed often, which, of course, affected the surrounding biosphere. There are presently many endemic species here, that is, species that are only found inside very limited local territories. For example, a unique animal inhabits these parts – the Caspian seal (seals are usually found only in the circumpolar latitudes). Meanwhile, the sea is rich in fish while its bed and shores are a source of oil and gas. The water body's most distinctive feature, however, is its unstable water level, characterised by sudden rises and falls. Recently, an increasingly alarming question has been, "Why is the water level in the Caspian Sea decreasing?" From 1929 until 1978, the level of the Caspian Sea has decreased from -26.0 to -29.0 metres BES (Baltic Elevation System) above sea level [1,4,14]. This resulted in the Caspian Sea dramatically decreasing in size (in 1929, it had an area of 420,000km^2). This alarmed many scientists, some of whom even began to develop projects to shift the flows of several rivers. However, in 1978, the decrease in the water level suddenly changed to an increase, a large territory was submerged under water, yet the previous levels were still never reached. "Are people at fault here?" and "Is there a reason to worry?" are both questions still cause heated discussions today. The water levels in the Caspian Sea are very unstable, a trend that will continue in the future.

Materials and Methods. The majority of the factual evidence utilised in this paper has been taken from monthly data pertaining to the levels of the Caspian Sea that has been gathered over many years at marine hydrological stations in Mangystau Oblast, it also includes archival and published materials as well as results of research conducted personally by the authors. Research methods – theoretical analysis of the long-term data regarding the dynamics of the water levels in the Caspian Sea during the periods of high and low levels between 1960 and 2013 and the assessment of the forecasted variability of the fluctuations. Information is presented in the form of a satellite image, charts, graphs and tables that include standard parameters.

Discussion. Over the last half a million years, the sea's height has fluctuated between -140 and +50 metres above sea level, and it even regained its connection to the Black Sea several times. It is thus considered that the Caspian Sea has been studied fairly well, however, there are still numerous unsolved mysteries in its "marine" behaviour [1,3,5,6]. The Caspian Sea stretches in the meridional direction from north to south over 1,200km and is situated between 36°33'N and 47°07'N and 45°43'E and 54°03'E. At its maximum, its width is 435 kilometres while its average width is 310 kilometres. The Caspian Sea has a shoreline spanning 7,000km, while its waters border on Russia, Kazakhstan, Turkmenistan, Azerbaijan and Iran. The Kazakhstan Republic has 29% of the shoreline (2,340km), Turkmenistan – 21%, Azerbaijan – 2%, Russia – 16% and Iran – 14%. Mangystau Oblast holds 1,399.5km of the Caspian Sea shoreline.

The terrain of the Caspian Sea basin is divided into three physical regions – Northern, Middle and Southern Caspian, which are divided by the Mangyshlak and the Apsheron Thresholds, respectively. The boundary of the Northern Caspian lies along the Mangyshlak Threshold, whose terrain consists of an array of shallows and depositional islands, situated on the extension of the Tiub-Karagan Cape. The middle region spans from the Tiub-Karagan Cape to the Apsheron Threshold Cape, while the rest of the sea is the Southern Caspian. The northern region is shallow, with average depths reaching only 5-6 metres while the maximum depths of 15m-20m are mostly found on the border with the middle region (lines A-B and C-D on Diagram 1). This section of the Caspian Sea covers 24% of the total area. The middle region, with an average depth of 200m and a maximum depth of 788m, covers 36% of the total area. The southern region is the deepest with an average depth of 345m, a maximum depth of 1,025m and covers 40% of the total area. Our Republic of Kazakhstan borders on the fairly shallow parts of the Northern and Middle Caspian. There are not many islands in the Caspian Sea and they cover a total area of 2,045km^2, yet 88% of them are located in the Kazakhstan territory. The largest are Kulaly Island and Morskoy Island with an area of 73km^2 and 65km^2, respectively, and they are situated in the Tyuleniy Archipelago. On its eastern shores, the Caspian has several large capes such as Mangystau and Tiub-Karagan Cape as well as Buzachi (Diagram 1). The Caspian Sea is situated within two climate zones. In the north, it is nestled between the severe and the moderate continental climates of the temperate zone, the south-west is within a subtropical climate, while to the west there is the desert continental climate of Central Asia. In the summer time, the surface of the sea becomes very hot and, despite the sea covering a long area from north to south, the temperature remains fairly uniform throughout at +24°C, +26°C. Temperatures in the winter vary significantly. The winter is cold in the north with the average temperature in January being anywhere from -7°C to -11°C. In the middle section, +1°C to +5°C, in the south, +8°C to +10°C. Overall, winter on the eastern shores along the entire span of the sea is colder than on the western shores. In the winter, storm winds rage along the Caspian, blowing from Kazakhstan, while the northern section of the sea up to the line between the Chechen Island and Tiub-Karagan Cape, considered the boundary between the Northern and Middle Caspian, is covered with ice in December. The North Winds carry this floating ice far to the south.

It should be noted that this study examines the North-Eastern shores of the sea – the section of the Caspian Depression located within the borders of Mangystau Oblast, as the region that is most sensitive towards the sea's fluctuating water levels due to its shallow nature. The general features of the terrain of the Caspian Sea bed in its Kazakhstan section are characterised by the large geotectonic structures of the region, which are responsible for the division of the Caspian Sea into the Northern and Middle Caspian along the Mangyshlak Threshold. The northern section of the territory under examination is part of the Caspian Depression of the Pre-Palaeozoic Russian shelf and is closely interconnected with the geological and the geomorphological structures on the adjacent dry land. Primary landforms, created by salt tectonics, are eroded through abrasion, which includes the accumulative activities of currents, waves and water surges. The Northern Caspian Shelf is generally characterised by a gentle slope and weak stratification, with depths not exceeding 10 metres. There are several types of underwater depositional plains: marine, of a complex origin with islands and shallows, as well as the sloped plain of the underwater shore declination. The development of the terrain on the shores of the Northern Caspian, which are part of the Caspian Depression, is greatly affected by the fluctuations of the water level in the sea – the water surges. Large depositional landforms have been created within the coastal plain, which was itself created by currents and waves: shallows, dikes, sand bars and banks, especially in the eastern section [4, 7].

The specific geomorphological features that characterise the Northern Caspian take the form of a depression created by erosion and tectonic movement, the Ural and Mangystau Rifts. The terrain of the Northern section of the Caspian is a shallow, wavy plain. The terrain of the seabed particular to the section of the Caspian Sea under examination includes the following geomorphological regions, which will be further described in the present article:

– The region of the Northern Caspian located to the north from the line between Lake Chechen (43°57'58.60''N, 47°44'59.06''E) and Tiub-Karagan Cape (44°35'36''N, 50°16'5''E), which is the conventional boundary between the Northern and Middle Caspian (Diagram 1)

– The region of the Mangyshlak Threshold, which is a natural boundary between the Northern and Middle Caspian.

The northern Caspian is characterised by depths from 1m to 6m and is a fairly flat and gently sloping plain with a stepped structure (Diagram 2). It also inclines towards the middle of the sea along the A-B line for 200km. The terrain of the seabed towards the Buzachi peninsula is more of a low-angle incline; however, there is a sudden drop towards the centre of this line, making this region especially susceptible to flooding during water surges (Diagram 3). This region can be considered the flooded section of the Caspian Depression.

The maximum depth does not exceed 26m, while 70% of the area has a depth of 6m. At the present time, the recently dry salt lakes have transformed into moist salt lakes, which includes large lakes such as Olikoltyk and Kaydak. On the opposite side at point A is the newest step – Volga's delta front – which rests on a fairly small shelf ledge that is 2 metres tall. The shallowest points have been recorded at the top of a small swell-like projection of the seabed on the east side of the basin, while the maximum has been recorded in a small local depression in the south-eastern part of the basin. Overall, the depths vary in a diagonal pattern from the north-western corner of the basin to its south-eastern corner. In the north-western regions, the sea is 1m-6m deep, while the basin's depths gradually increase towards its south-eastern section. The overall length of the C-D line that shows the seabed profile is 150km.

Diagram 1 – A satellite image with the lines showing the seabed profile of the Northern Caspian, using the ArcGIS 9

The 100km section of the Caspian Sea from the Tiub-Karagan Cape to the Chechen Island has a seabed profile comprised of dikes and sand bars whose highest point is located at a depth of 6m, while their deepest, on one straight line, is roughly at 10m (Diagram 2). For the other 50km until the (Caspian) Lagan Island, until point C, the crooked seabed profile suddenly drops from 6m to 17m from the surface of the water, which is like a “ramp” for the surging waters. Lagan (45°49'16.1''N, 48°36'12.7''E) was founded in 1870 as a settlement for those moving from Russia to the Caspian.

In 1944, during the deportation of Kalmyk people it was renamed to Caspiyskiy, was made a city in 1963 and in 1991 it was renamed back to Lagan. The sea has since receded and the city is presently located 9km away from the shore. The rise in water levels from 1978 to 1995 was not only unexpected, but also led to a number of negative consequences [8,11]. The zones that were flooded and subject to waterlogging were very extensive, especially in the northern (plains) section of Dagestan, in Kalmykia and Astrakhan Oblast. The rise of the water level affected the cities of Derbent, Caspiysk, Makhachkala, Sulak, Caspiyskiy (Lagan) and dozens of other smaller communities. In our Kazakhstan section of the Caspian Sea, the area that was affected by the waterlogging within the Buzachi peninsula is the location of functioning oil and gas deposits Komsomolskoye, Kalamkas, Karazhanbas and Arman. Although they are protected by dams made from local rocky soils, these dams are very permeable and rather susceptible to abrasion and erosion.

As for the residential areas, the most at risk for flooding and waterlogging are the Bautino Township, Fort Shevchenko and sections of Mangystau Oblast regional centre, the city of Aktau. In this respect, the issue of water and soil contamination by oil and gas is a very pressing issue for the coastal areas around the Caspian Sea where the flooded drilling holes are located. [13].

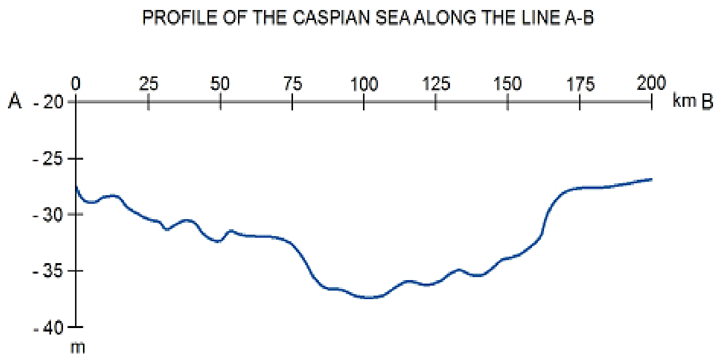

Diagram 2 – Seabed profile of the Caspian Sea along the A-B line

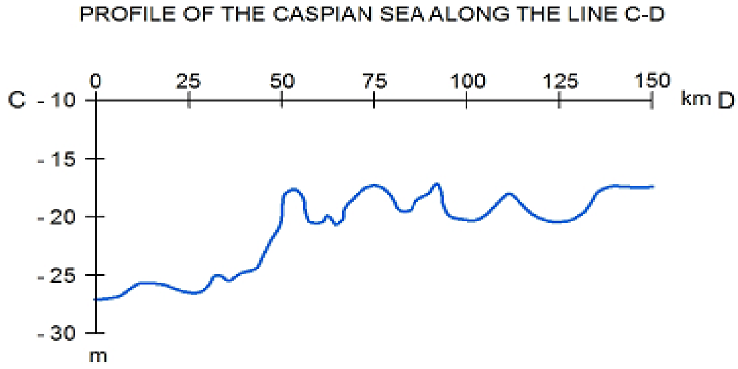

Diagram 3 – Seabed profile of the Caspian Sea along the C-D line

The fluctuations in the water levels have raised a number of issues, the most important of which is recovering and maintaining the commercial fishing importance of the Caspian Sea. To resolve these issues, it is necessary to determine the reasons for the decreases in the water level and to study the water balance. In this respect, the specifics of the water level fluctuations in the Caspian Sea, which are accompanied by sudden water level decreases and increases that last for various period of time, undoubtedly present a scientific interest.

The reasons for the water level fluctuations have not yet been ascertained, although there are speculations that they could be connected to the fluctuations in the river flow, the deformation of the seabed, an influx of water from beneath the earth or due to climate change. Geologic and paleogeographic research allows us to look into the distant past of this region. Over the last 10,000 years, the level of the Caspian Sea, situated lower than the level of the world ocean, has fluctuated between -20 and -40 metres. It is enough to note that the sea's water level in the 4^{th}-2^{nd} centuries B.C. was no higher than -36m, in the 6^{th} century it was at the absolute marker of -34m, in the 10^{th} century it was at -29m, at the beginning of the 14^{th} century at -19m, while at the present time it is roughly at -27m. For researching the fluctuations of the water level as early as in 1829, Heinrich Friedrich Emil Lenz proposed to install a depth gauge in Baku, which has since provided the longest series of observations on the matter [5,6,8]. The analysis of the reconstructed water levels in the Holocene (10,000 years), Historical (2,500-3,000 years) and the Instrumental (1835-2003) periods (according to Rudolph Klige, 1994) allowed the authors to define the maximum, average and the minimal points in the fluctuating water levels of the Caspian Sea. The amplitude of the fluctuation of the water levels in the Instrumental period is based on data collected by hydrological stations and is 3.8m, with an average of 2.3m (Table 1). There are 8 functioning hydrological stations in Mangystau Oblast (Fetisovo, Kalamkas, Saura, Khazar, Mys Peschanyy, Aktau weather station, Fort Shevchenko and Kulaly), each of which take measurements of the sea four times daily. At 00, 06, 12 and 18 hours, the stations measure the water level, the height and the direction of the waves, the temperature of the water and its salinity, the condition and the location of any freezing, the thickness of the ice, wind direction and speed, the amount of precipitation and the clarity of the water [1,2,4].

Table 1 – The amplitudes of the fluctuation in the water levels of the Caspian Sea (m)

Water level	Periods		
	Holocene (10,000 years)	Historical (2,500-3,000 years)	Instrumental (1835-2003)
Maximum	- 9	- 20	- 25,2
Average	- 25	- 27	- 26,6
Minimum	- 34	- 34	- 29
Amplitude of the fluctuations	25 (0.35 cm/year)	14 (0.55 cm/year)	3,8 (2,3 cm/year)

The analysis of these observations made by those researching these issues allowed the authors to establish that from 1850, the fluctuations in the water levels had a cyclical character, however, since 1869 the levels of the water has been steadily decreasing. At the beginning of the 20th century, the water level was fairly stable. Then the water level suddenly dropped by 1.9m from 1929 to 1941. By 1956, the water level was 2.5m lower than it had been in 1929. Between 1956 and 1960, the water level had somewhat stabilised [3,7,9]. The fluctuations in the water level of the Caspian Sea within Mangystau Oblast of the Republic of Kazakhstan from 1960 to 2013 have been put together from data provided by Kazhydromet and are shown in Diagrams 4, 5 and 6.

Compared with 1960, in 1962 the water level had dropped by 28cm while in 1964 it increased by 14cm. The water level was at -28.27m in 1966, which is 3cm lower than the water level in 1960 at -28.23 BES. Between 1966 and 1969, the water level dropped by 22cm, then by 1970 the water level had increased by 14cm. From 1970, the water level began to decrease again. As such, the water level in 1973 had decreased by 25cm, and remained stable throughout the year. Since 1974, there has been an observable sudden drop in the water level amounting to 1.4m, which reached the lowest point for the current century in 1977 at -29.0m BES. This was the final year in a 17-year period of decreasing water levels in the Caspian Sea from 1960-1977 (Diagram 4) [1,2].

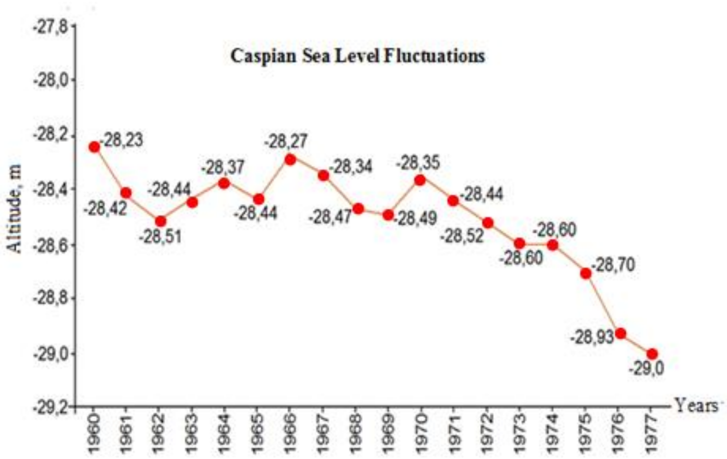

Diagram 4 – The fluctuations (decrease) in the water level of the Caspian Sea in Mangystau Oblast for 1960-1977 (Kazhydromet)

In the second half of the 1970s, the decrease in the water levels had a more gradual character than in the 1930s-1940s. It then slowed and even stopped, and from 1978 the Caspian Sea had even began to rise (Diagram 5). As such, in 1978, the sea level was at the -28.95 marker, which is just 5cm more than in 1977. In 1980 the water level reached the -28.48 marker, that is, in just two years from the beginning of the increasing water levels, the sea had increased by 47cm. By 1985, the level of the water in the Caspian Sea had risen 80cm and flooded the coastal area around the Buzachi peninsula and the Tiub-Karagan Cape, while also flooding 50-55km of the large bay-salt flats Olikoltyk and Kaydak, which had previously dried up due to the lower water levels. This led to an increase in the area of the shallows and, as a result, increased the amount of evaporation (to 10km^3/year). This high water level also increased the outflow of water into Garabogazköl. This water rise did not cease in the subsequent years. Over the next ten years in the 1990s, the water levels increased by almost an entire metre and pushed the sea levels up to -27.53m (95cm). This process did not just create various environmental and economic issues related to the subsequent flooding, but it also brought new mysteries for scientists to research. Could this possibly be a new marine transgression or one of those small accidental increases that have happened numerous times over the previous decades? In 1995, the water level was at -26.62m, a 91cm increase over 5 years. From 1978 to 1995, the water level had increased by a total of 2.33m. In terms of annual change, the maximum water levels are found in July and August while the minimums are in February. The water fluctuates by 29-34cm within a given year. It is also necessary to note that if the water in the rivers that flow into the Caspian Sea would not be removed at a rate of 40km^3, which is practically 40 billion cubic metres of water, for day to day needs and irrigation (which equals to 10cm of sea level), then this level of -26.62 BES would be 1.5

metres higher and would be close to the 160-year record high mark of the last century (Diagram 5). Therefore, in the present case, 1995 ends another 17-year cycle from 1978-1995, a cycle of increasing water levels in the Caspian Sea (Diagram 5). In 1996, the water levels dropped by 17cm from -26.62m to -26.79m BES. This year begins the third cycle since 1960, but this cycle will be of decreasing water levels [1,15].

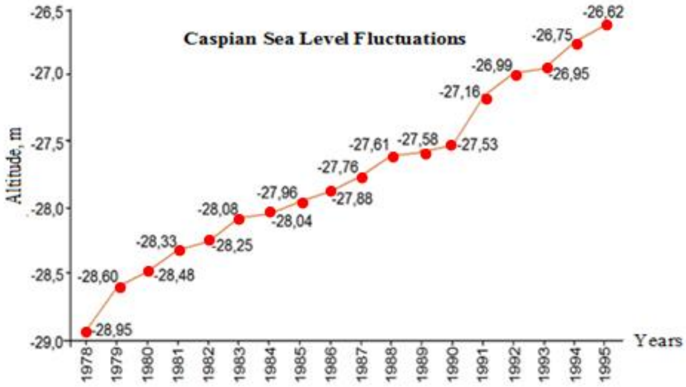

Diagram 5 – The fluctuations (increase) in the water level of the Caspian Sea in Mangystau Oblast for 1960-1977 (Kazhydromet)

In the subsequent years following 1996, there has been an observable annual decrease in the water level until 2001, when the sea had reached a marker of -27.17m, a 38cm decrease (Diagrams 6, 7). However, in 2005, the water level increased once again by 26cm up to the marker of -26.91m. In 2006-2007, the water level was at -27.04m with a decrease of 7cm as compared with 2005. According to the data gathered by National Hydrometeorology Organisations in the nations surrounding the Caspian Sea, there was an abnormal seasonal decrease in the Caspian Sea water level in the second half of 2010, a decrease that was 1.5 times greater than the average markers over the last 50 years. After the flow of the Volga River was regulated in the middle of the last century, a majority of the stations located on the coast of the Caspian Sea noted that seasonal decrease in the water levels of the sea was an average of 15-19cm. From July to October of 2010, however, the water level on the Western shore of the Middle Caspian, in the area of the city of Makhachkala, decreased by 30cm (data from Roshydromet), while on the Eastern shores around Aktau city, water levels decreased by 31cm in July (data by the Kazhydromet (Diagram 6)). The levels of the seasonal water level decreases in 2010 were significantly higher than the average between 1961 and 2009.

The Azerbaijani coast of the Southern Caspian Sea (data from Azhydromet (Azerbaijan HydroMet)) saw the water levels decrease by 32cm from June to October, while the Iranian shores saw a decrease of 31cm, according to data provided by the National Research Centre. In our Western

Kazakhstan section of the Northern Caspian around the Tyuleniy Island, the seasonal decrease in water levels amounted to 32cm, while in the Eastern section (Kulaly Island) it was 44cm according to data provided by Kazhydromet. The reason for the sudden decrease in the water levels, as compared to the last five year, is the abnormally hot and dry summer in Mangystau Oblast, as well as the decreased water levels in the Volga. Within these conditions, only a third of the usual amount of summer precipitation was recorded on the Western shores of the Middle Caspian around Mangystau Oblast, while the average temperature was 3.5 degrees lower than the norm. Meanwhile, the water flow in the Volga was 35km^3 lower than usual over the first nine months, according to Roshydromet [5,11,12]

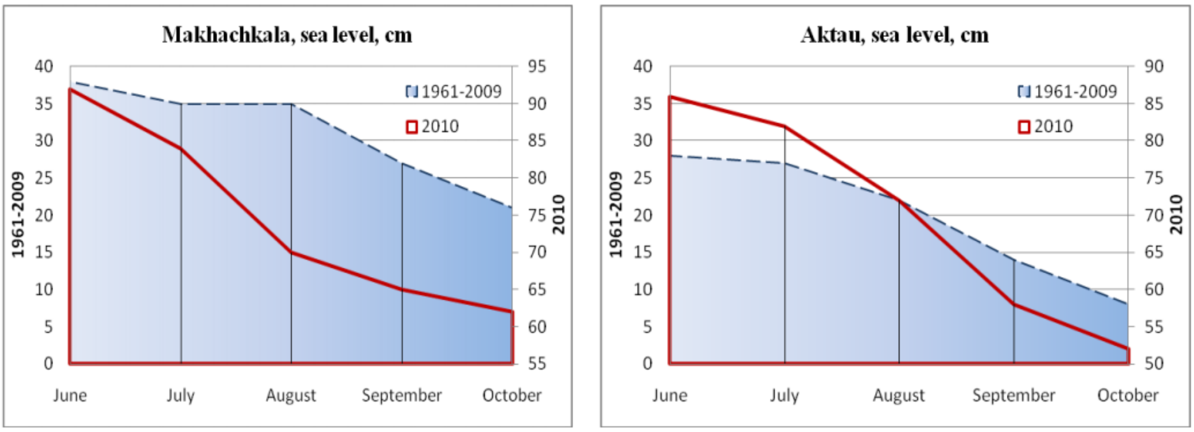

Diagram 6 – The seasonal decrease in the Middle Caspian water levels for 2010 on the Western and Eastern shores, as compared with the long-term data recorded at the Makhachkala and Aktau stations.

Specialists from the Coordinating Committee on Hydrometeorology and Pollution Monitoring of the Caspian Sea consider the sudden seasonal decrease of the water level in 2010 by 25cm (from -27.25m to -27.50m) to prove their hypothesis regarding the fact that the sea level will be a minimum of 15-20cm lower in the middle of 2011 than it was in 2010 (Diagram 7). With a high probability, it is expected that in 2012 the water level will continue to decrease and will fall by a further 10-15cm, and any changes in the fluctuation tendencies of the Caspian Sea would only be noted in 2013. According to data available in the General Catalogue of the water levels in Caspian Sea, the levels at which the water has decreased in the sea have increased since the beginning of the century. In 2010, the level of the sea decreased by 9cm, while in 2011 – by 25cm. For the region studied in this paper, the sea levels in 2009 amounted to -27.19m, while in 2010 they were at -27.25m with a decrease of 6cm and in 2011 they were at -27.50m – a sudden drop (Diagram 7). The Federal Service for Hydrometeorology and Environmental Monitoring of Russia had forecasted that the tendency in the decreasing levels of the sea would continue in 2012 with the sea levels decreasing by 10-15cm. The Coordinating Committee has forecasted a 13cm decrease and proposed that the main reason for the decreasing water levels in the Caspian Sea is the lower water flows in the Volga River. It is true that the water flow in the Volga was overall lower than normal in 2012 and reached before unseen levels at the top of the delta, equal to 25km^3. This led to the levels of the seasonal decrease in the water levels over the second half of 2012 to be lower than in the previous two years [13]. In 2010, the water level fell by 6cm per month in the second half of the year, in 2011 – by 5cm, while in 2012 – by 4cm. According to monthly data collected at the hydrological stations at Kalamkas, Kulaly, Fort Shevchenko, Aktau, Saura and Mys Peschanyy, located around the entire coastline of Mangystau Oblast, the speed of the seasonal drop in the water levels in the second half of 2012 fluctuated with a 3cm to 9cm average absolute value (4.5cm/month), the speed was 1.5cm more than the average speed of the seasonal increase in water levels for the first half of 2012 (3cm/month). As a result, the average annual level of the sea in 2012 within Mangystau Oblast had decreased by 5cm as compared with 2011 and equalled -27.55 BES.

In December of 2012, the average water level in the Caspian Sea reached the -27.64m marker, while in the 2013, the level was observed to be at -27.61m BES (Diagram 7). At the same time, according to the long-term data found in the General Catalogue of Caspian Sea water levels, the rate of the sea's seasonal increase from January to June is more stable in comparison with the rate of its seasonal decrease from July to December. The seasonal water level increase is usually between 2cm and 4cm per month. Based on this information, the Coordinating Council has suggested that the average water level in 2013 will be between the -27.40m and -27.50m BES absolute markers. Although insignificant, this would have been the water level increase in the last five years. Unfortunately, the proposals and the forecasts turned out to be mistaken. For example, the Kazhydromet (Kazakhstan HydroMet) had made a forecast of the water levels in the sea in their publication *Level of the Caspian Sea in its unfrozen sections for January 16-21, 2014.* They predicted that water levels in the Central Caspian would be fluctuating around the -27.68m mark, reaching a maximum of -27.40m and a minimum of -27.83m [15]. From January 9 to 15, 2014, the most up-to-date information on the Central Caspian water levels was provided by the following Kazhydromet marine stations and posts: Peshnoy, Zhanbay, Kalamkas, Kulaly and the Roshydromet station on Tyuleniy Island, whereby the average water levels equalled -27.65m. According to the most up-to-date data provided by the following Kazhydromet marine stations and posts: Fort Shevchenko, Aktau, Fetisovo and the Roshydromet in Makhachkala, the average water level in the sea's deeper sections amounted to -27.70m, with a maximum of -27.47m and a minimum of -27.81m.

Because this study does not intend to provide an in-depth analysis of numerous forecasts for the fluctuations in the water levels of the Caspian Sea, it will instead offer a hypothesis from assessing the results of these analyses below. As such, there has currently not been a single successful forecast.

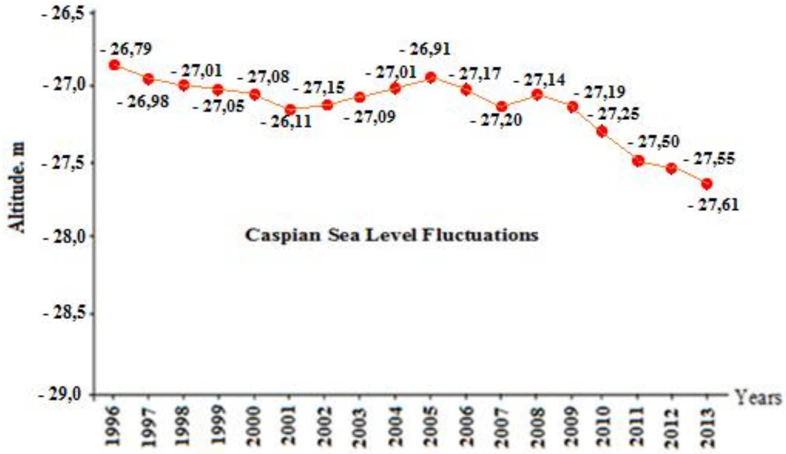

Diagram 7 – The fluctuations (decrease) in the water level of the Caspian Sea in Mangystau Oblast for 1960-1977 (Kazhydromet)

This is due to the fact that forecasts have various approaches (deterministic and probabilistic). Deterministic forecasts rely on the levels of the sea's water balance. In this respect, the insufficiently developed theory and practice of long-term forecasts surrounding climate change, along with the fluctuations of water levels in a sea spanning large territories, hinder the usage of deterministic forecasts. Between 1995-2005-2008, when the water level began to rise, a majority of the forecasts suggested that, especially in 1996, the sea would continue an almost linear accelerating increase up to -25.0m BES. However, these forecasts did not take into account the following circumstances. Firstly, the intermittent nature of the fluctuation of water levels in endorheic basins like the Caspian Sea. This also includes the instability of the water levels in the Caspian Sea, as well as its intermittent nature, which are confirmed through analysing past and present fluctuations. Secondly, when the water levels in the sea were at -26 absolute metres in 1995, this led to flooding of the large bay-salt lakes on the north-eastern shores of the Caspian Sea – the Mertvyy Kultuk and Kaydak, which had previously dried up due to the lower water levels, also flooding lowland territories in other locations around the shoreline. This increased the area of the shallows and, as a result, increased the amount of evaporation (to 10 km^3/year). Additionally, the increased water levels also increased the outflow of water into Garabogazköl, which slowed the rate of water level increase in the Caspian Sea. Finally, fluctuations of the water levels in the sea within the modern climatic environment (the last 2,000 years) are higher, but limited by the risk zone (from -30 to -25 absolute metres). In this respect, this trend of decreasing water levels will continue until at least 2015. Accounting for the anthropogenic decrease of the outflow into the sea in the nearest 15-17 years, the water levels are unlikely to exceed the -26 to -26.5 absolute metre mark.

As for the main causes of the fluctuations in the Caspian Sea water levels, the authors will offer an analysis of the experiences and the achievements of research that has been conducted on this issue. As early as in 1836, Heinrich Friedrich Emil Lenz, and then subsequently Aleksandr Voyeykov in 1884, attempted to explain the fluctuating levels of the water in the Caspian Sea for the first time as being the product of various climatic factors, in particular evaporation within the hot climate of Turkmenistan and Mangystau Oblast, while also being influenced by the amount of atmospheric precipitation. At the beginning of the 19th century, hydrologists, oceanologists and scientists studying physical geography maintained and were adamant about the fact that the water level fluctuations depend on the changes in the various components of the water balance [3,4,7]. Meanwhile, a majority of the research was based on composing the equation of the water balance and analysing its components. As such, the fluctuations in the volume of water in the sea are the difference between the inflowing waters (river and subterranean) together with atmospheric precipitation on the surface of the sea and the outflowing components (the evaporation from the surface of the sea and the outflow to the Garabogazköl) of the water balance. The fluctuating water levels in the Caspian Sea are the quotient of the fluctuating volume of its waters over the area of the sea. Additionally, the correlation between the inflow of the Volga, Ural, Terek, Sulak, Samur and Kura Rivers and the visible or effective evaporation as well as the difference between the evaporation and atmospheric precipitation on the surface of the sea play a key role in the sea’s water balance. It has also been established that the largest contributor (up to 72% of the dispersion) to the fluctuation of the water level is the inflow of river waters, or, more specifically, the flow formation zone in the Volga basin. Many researchers believe that the fluctuations in the flow of the Volga are related to the fluctuations in the atmospheric precipitation in the winter, depending on the atmospheric circulation. Malinin V. N. has proposed that the search for the initial sources of the moisture coming into the Volga basin should start in the North Atlantic or, more specifically, in the Norwegian Sea. The increased evaporation from the surface of the sea there causes the increased amount of moisture in the Volga basin. As such, information regarding the water balance in the Caspian Sea that was obtained by R. E. Nikonova and V. N. Bortnik from the State Oceanographic Institute conclusively proves that the main reasons for the sudden drop in the water levels of the Caspian Sea in the 1930s as well as their abnormal increase in 1978-1995 were caused by changes in the inflow of river water and visible evaporation. Assuming that the inflow of the Volga is the main factor influencing any changes in the water balance of the Caspian Sea, by giving no less than 80% of the total inflow and around 70% of the inflowing waters, this raises the question of the connection between the water levels in the sea and the inflow of water provided by the Volga alone. The correlation of these values, however, does not give satisfactory results. However, the connection between the water levels in the sea and the inflow of the Volga can be traced quite accurately while considering the inflow of the river not for a given year, but instead taking the consecutive sum of the standard deviation in the annual values of the inflow from the long-time average annual value (the norm) [7,8,10]. Even the visual comparison of the values of the average annual water levels in the Caspian Sea and the differential integral curve of the Volga inflow reveals their similarities. Taking a period of sudden decrease (1929-1941) and increase (1978-1995) in the water levels for analysis, the total correlation coefficient will be 0.987, separately, this value is 0.990 and 0.979 for each period, respectively [11,13].

Conclusions.

The abovementioned calculations completely prove the hypothesis that during periods of sudden decreases or increases in the water levels of the Caspian Sea, the water levels are tightly related to the inflow of water or, more specifically, the sum of its annual deviations from the norm. Forecasts have predicted that from the 1940s, irrecoverable water usage will lead to a decrease in the inflow of all river waters towards the Caspian Sea and the decrease of its water levels as compared to its natural levels. According to V. N. Malinin, by the end of the 1980s, the difference between the actual level of the sea and its reconstructed (natural) level was almost 1.5m. At the same time, the total irrecoverable water used in the Caspian basin was evaluated in those years to be 36-45km^3/year, almost 26km^3/year of which were taken from the Volga. If the river waters were not extracted, then the water levels in the sea would start increasing not at the end of the 1970s, but at the end of the 1950s. As for assessing the influence that irrecoverable water usage has on the level of the Caspian Sea, it is necessary to note that the forecast of the volumes of water intake and water loss caused by evaporation from the surface of water bodies in the Volga basin are, apparently, significantly overstated. Additionally, another important factor is the possible increase in the water level in accordance to the Archimedes principle, due to the submerging of drilling equipment and entire shelves, artificial islands, concrete caissons and oil refining complexes into the sea, the volumes and areas of which are, at the present time, very difficult to calculate. In accordance with the abovementioned information, it can be stipulated that 2014 will be the year that begins the new 17-year cycle of water level increase until 2040. At the same time, the fluctuations are expected to increase by 9-11cm and in 2015 the water level should reach -27.50m BES. Meanwhile, the cycles of decreased water levels will last no more than 2-3 years.

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