

Supplementary Information

Rapid decline of Caspian Sea level threatens ecosystem integrity, biodiversity protection, and human infrastructure

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Russian translation of article abstract

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Russian translation of abstract

Абстракт

Каспийское море – крупнейший в мире замкнутый водоём, являющийся средой обитания для сотен эндемичных и мигрирующих видов, а также предоставляющий экосистемные услуги, обеспечивающие жизнедеятельность миллионов людей. Прогнозируется, что к 2100 году глобальное потепление приведёт к снижению уровня моря на величину до 21 м. С помощью методов геопространственного анализа мы оценили влияние снижения уровня моря на местообитания, особо охраняемые природные территории (ООПТ) и объекты инфраструктуры. Результаты исследования показывают, что снижение уровня моря всего на 5–10 м приведёт к критическому нарушению ключевых экосистем (включая местообитания эндемичных видов — каспийского тюленя и осетровых рыб), сократит площадь существующих морских ООПТ на величину до 94% и сделает непригодной для использования гражданскую и промышленную инфраструктуру стоимостью в миллиарды долларов. Для адаптации эндемичного биоразнообразия Каспийского моря к этим изменениям, а также для предотвращения конфликтов с мерами по смягчению последствий, направленными на защиту деятельности человека, рекомендуется заменить традиционное статичное планирование природоохранной деятельности на упреждающий, гибкий подход, позволяющий адаптировать границы ООПТ к смещению экосистем.

Definition of ecoregions of the Caspian Sea

Fendereski *et al.*, (2014) produced an ecogeographical classification of the Caspian Sea based on physical information derived from remote sensing and in situ data. The authors used a two-step classification procedure, consisting of (i) a data reduction with self-organizing maps (SOMs) and (ii) a synthesis of the most relevant features into a reduced number of marine ecoregions using the hierarchical agglomerative clustering (HAC) method. Six independent variables were used; sea surface temperature, bathymetry, sea ice, seasonal variation of sea surface salinity, total suspended matter and its seasonal variation. The classification yielded 10 distinct ecoregions, separating the northern and middle/southern basins, as well as differentiating nearshore and offshore waters.

Evaluation of differences in community composition based on recorded presence–absence patterns of 25 different species of plankton, fish and benthic invertebrate validates the ecoregions as proxies for habitats with common biological characteristics.

Reference:

Fendereski, F., Vogt, M., Payne, M.R., Lachkar, Z., Gruber, N., Salmanmahiny, A. and Hosseini, S.A., 2014. Biogeographic classification of the Caspian Sea. *Biogeosciences*, **11**(22), pp.6451-6470. DOI: 10.5194/bg-11-6451-2014. Available at: <https://bg.copernicus.org/articles/11/6451/2014/>

Supplementary Table 1. Ecoregions of the Caspian Sea.

Ecoregion	Acronym	Description/Characteristics
Northern Caspian Basin River Outflows	NCB-RO	Shallow, dominated by the Volga River outflows, high in sea surface salinity seasonality, high in total suspended matter and its seasonality, covered in ice in winter.
Northern Caspian Basin Western shelf	NCB-WS	Shallow, low in sea surface salinity and high in its seasonality, high in total suspended matter, covered in ice in winter.
Northern Caspian Basin Ural Furrow	NCB-UF	Shallow, low in sea surface temperature, low in sea surface salinity and its seasonality, covered in ice in winter.
Northern Caspian Basin Easternmost shelf	NCB-ES	Shallow, low in sea surface temperature, low in seasonal variation of sea surface salinity, high in total suspended matter and its seasonality, highly ice covered in winter.
Northern Caspian Basin Transition	NCB-T	Shallow, high in sea surface salinity seasonality, partly ice covered in winter.
Middle Caspian Basin Transition	MCB-T	Medium sea surface temperature, medium seasonal variation of sea surface salinity, medium total suspended matter and DTSM, partly ice covered in winter.
Middle Caspian Basin Coastal	MCB-C	Continental shelf area, High in sea surface salinity and low in seasonal variation of sea surface salinity, low in total suspended matter and its seasonality.
Middle Caspian Basin Offshore	MCB-OS	Deep, low in sea surface temperature, low in total suspended matter and its seasonality.
Southern Caspian Basin Coastal	SCB-C	Continental shelf area, High in sea surface temperature and sea surface salinity, low in total suspended matter and its seasonality.
Southern Caspian Basin Offshore	SCB-OS	Deep, high in sea surface temperature, low in total suspended matter and its seasonality.

Curation of Protected Area Data

Supplementary Table 2. Curatorial corrections/changes made to Protected Area data.

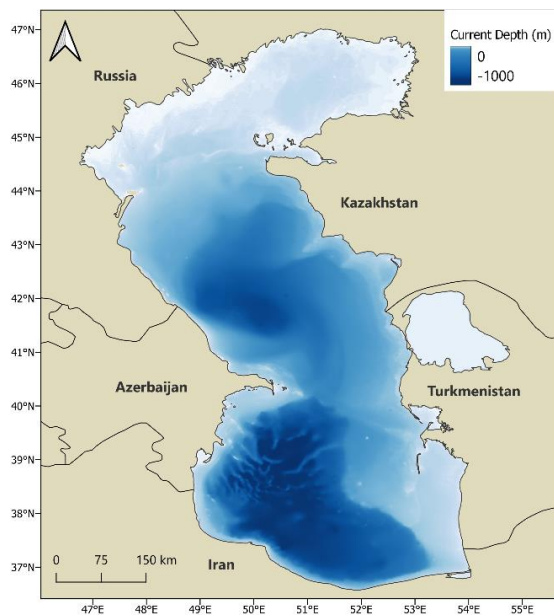
Site Name Changes			
Type	Study number designation	Original Name (World Database on Protected Areas* (WDPA) data)	Corrected Local Name
Marine	3	State Nature Reservat “Akzhaiyk” (1)	Akzhaiyk State Nature Reserve (A)
Marine	4	State Nature Reservat “Akzhaiyk” (2)	Akzhaiyk State Nature Reserve (B)
Marine	5	Bujagh National Park	Boujaq National Park and Protected Area
Marine	7	Volga Delta	Volga Delta Ramsar Site
Marine	8	Gil Island State Nature Sanctuary	Gil Adasi State Nature Sanctuary
Marine	9	National Gizilaghaj Park	Gizilaghaj National Park
Marine	12	Miankaleh Peninsula, Gorgan Bay and Lapoo-Zaghmarz Ab-bandan	Miankaleh Peninsula, Gorgan Bay and Lapoo-Zaghmarz Ramsar Site
Terrestrial	v	Karadegishskii	Karadegishskiy State Nature Reserve
Terrestrial	vi	State Nature Sanctuary Karakiya-Karakol (zoological)	Karakiya-Karakol State Nature Sanctuary
Terrestrial	vii	Kenderly-Kayasan State Reserved Zone	Kendirli-Kayasan State Reserved Zone
Terrestrial	viii	Lavandavil	Lavandevil Wildlife Refuge
Terrestrial	x	Samurskij	Samurskiy National Park (Samur Delta Site)
Terrestrial	xii	Sulakskaya laguna	Sulakskaya Lagoon Firth-Flooded Complex

Designation changes (marine/terrestrial or coastal)			
<i>The designation of the following marine or coastal protection areas were altered from the WDPA designation to better reflect their relation to the Caspian Sea shoreline</i>			
Study number designation	Name	Change	Justification
9	Gizilaghaj National Park	Terrestrial to Marine	Area largely overlapped with polygon for the water of the Caspian Sea. The polygons of WDPA's National Giziliaghaj Park (WDPA ID 555651680) and Lesser Gizilaghaj State

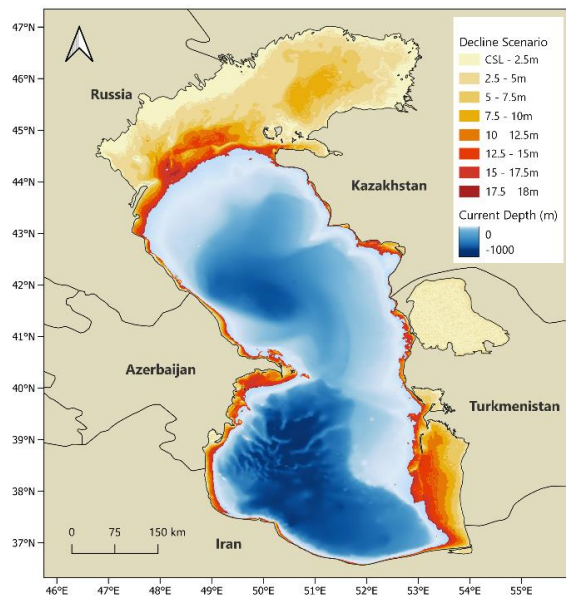
			Nature Sanctuary (WDPA ID 94019) were merged
15/x	Samurskiy National Park (Samur Delta)	The WDPA data consisted of an inland polygon and shore based/marine polygons. The inland polygon was discarded, and only the shoreline/marine based Samur Delta site was retained, with terrestrial and marine components evaluated separately.	
xii	Sulakskaya Lagoon Firth-Flooded Complex	Marine to Terrestrial	Sulakskaya Lagoon is not part of the Caspian Sea area, but separated from the sea by a sand bar ~100m wide and up to 2.5 m in high.

Exclusions and additions to WDPA data	
The WDPA polygon for the Astrakhanskiy State Nature Biosphere Reserve was removed from analysis as its entire area was represented within the Volga Delta Ramsar Site	
Shapefiles for the Dagestanskiy State Nature Biosphere Reserve (Kizlyar Bay site) were provided by Dagestanskiy State Nature Biosphere Reserve office.	
No GIS shape file was available for the Samur-Yalama National Park, Azerbaijan, a counterpart to the Samurskiy National Park in Russia (15/x). The site is shore-based and 117.7km ² , and is contained within the area of the Samur-Yalma EBSA. The distance to shore to increase is represented by that for site x. See https://en.wikipedia.org/wiki/Samur-Yalama_National_Park	
Malyy Zhemchuzhnyy Island State Nature Monument (Russia, 45°1'34"N 48°18'50"E, 35 ha). Being an island terrestrial site in the North there is no appropriate method to perform an increase in distance to shore calculation consistent with the rest of our study. https://www.keybiodiversityareas.org/site/factsheet/1600	
No GIS resource was available for the Adamtas State Nature Reserve (zakaznik), Mangystau Region, Karakiya District, Kazakhstan. This has a marine water area of 1546 ha, which is not significant at the Caspian-wide scale of our study. https://tehranconvention.org/system/files/russia/publication_part-2_eng_1.pdf	
Any other protected areas in planning, or not officially implemented as of July 2023 were not considered.	

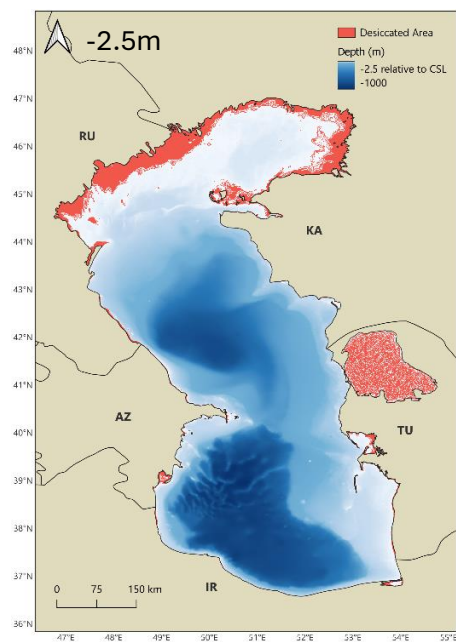
* <https://www.protectedplanet.net/en/thematic-areas/wdpa?tab=WDPA>



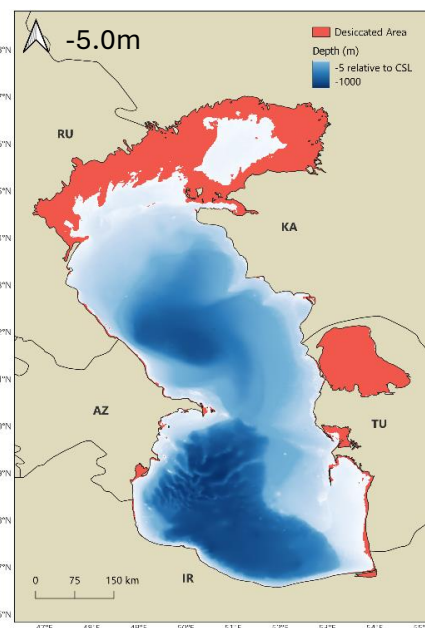
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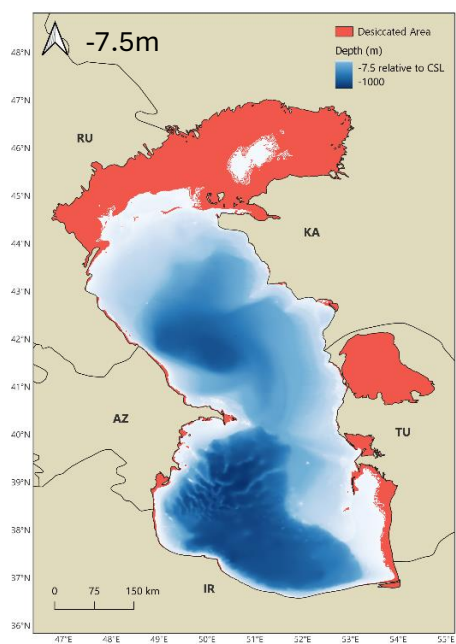
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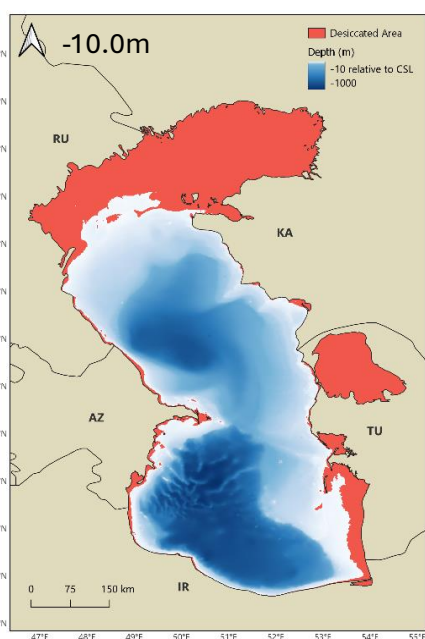
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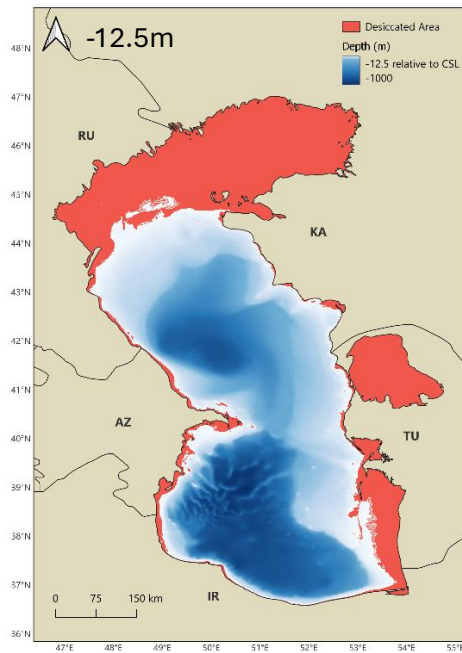
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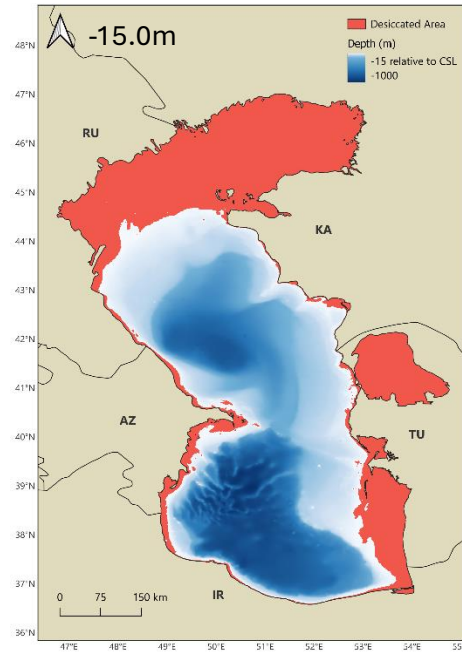
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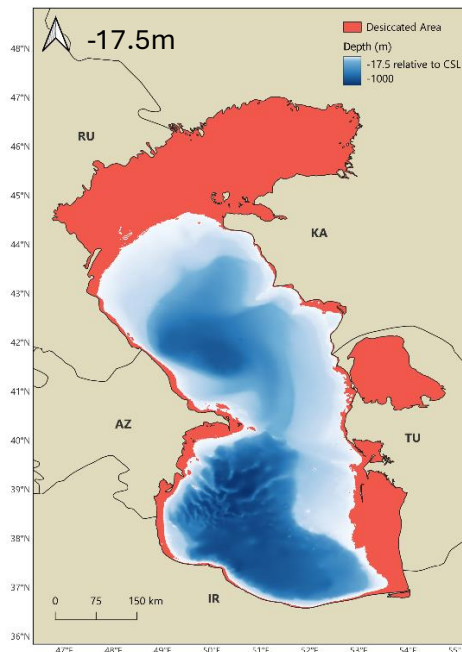
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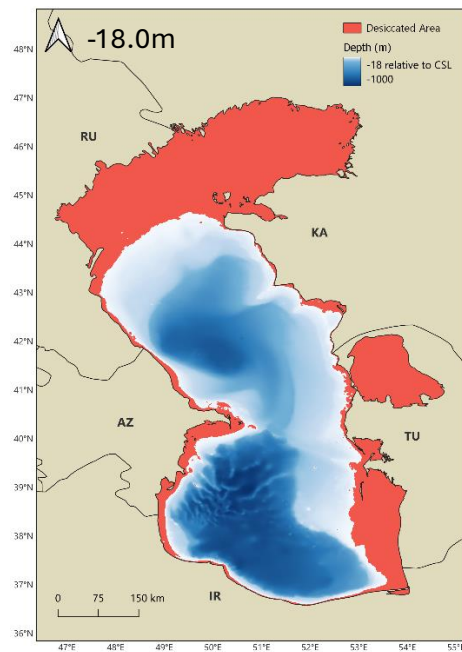
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Supplementary Figure 1. Caspian Sea bathymetry decline scenarios.

The Caspian Sea current bathymetry (a), and projected water area reduction under eight sea level decline scenarios (b). The area of water that becomes desiccated is shown in red under each individual decline scenario; 2.5m (c), 5m (d), 7.5m (e), 10m (f), 12.5m (g), 15m (h), 17.5m (i), and 18m (j).

Supplementary Table 3. The proportional reduction in water coverage of Important Ecologically or Biologically Significant Areas (EBSAs) in the Caspian Sea under different sea level decline scenarios.

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Supplementary Table 4. The proportional reduction in water coverage of Important Marine Mammal Areas (IMMAs) in the Caspian Sea under different sea level decline scenarios.

Sea Level at -27.5m datum			Decline Scenario															
			2.5m		5m		7.5m		10m		12.5m		15m		17.5m		18m	
IMMA	Total Area km ²	Area intersecting the Caspian Sea km ²	Area km ²	% Proportion of original area	Area km ²	% Proportion of original area	Area km ²	% Proportion of original area	Area km ²	% Proportion of original area	Area km ²	% Proportion of original area	Area km ²	% Proportion of original area	Area km ²	% Proportion of original area	Area km ²	% Proportion of original area
Caspian Seal Breeding Area	55864.36	55864.36	46437.30	83.13	23793.00	42.59	11604.60	20.77	5078.40	9.09	2339.55	4.19	711.60	1.27	451.20	0.81	401.70	0.72
Caspian Seal Moulting and Haul Out Areas	27939.24	27939.24	18228.90	65.24	9515.40	34.06	6054.90	21.67	3629.70	12.99	2275.20	8.14	1746.00	6.25	1108.35	3.97	994.20	3.56
Caspian Seal Transitory Migration and Feeding Area	163646.05	163646.05	151846.95	92.79	141271.80	86.33	129990.00	79.43	122078.55	74.60	116679.75	71.30	111857.40	68.35	106974.90	65.37	106045.05	64.80

Supplementary Table 5. The proportional reduction in water coverage of ecoregions in the Caspian Sea under different sea level decline scenarios.

			Decline Scenario															
		Sea Level at -27.5m datum	2.5m		5m		7.5m		10m		12.5m		15m		17.5m		18m	
Ecoregion	Shorthand	Total Area km²	Area km²	% proportion of original area	Area km²	% proportion of original area	Area km²	% proportion of original area	Area km²	% proportion of original area	Area km²	% proportion of original area	Area km²	% proportion of original area	Area km²	% proportion of original area	Area km²	% proportion of original area
Middle Caspian Basin - Coastal	mcb-c	69551.19	69348.48	99.71	68695.77	98.77	67789.06	97.47	66533.03	95.66	64754.21	93.10	62721.37	90.18	60311.16	86.71	59869.49	86.08
Middle Caspian Basin - Offshore	mcb-os	55633.34	55603.86	99.95	55543.04	99.84	55444.38	99.66	55385.36	99.55	55339.06	99.47	55296.32	99.39	55252.62	99.32	55243.78	99.30
Middle Caspian Basin - Transition	mcb-t	30619.52	29405.90	96.04	26669.39	87.10	25003.20	81.66	23638.28	77.20	22591.67	73.78	21600.03	70.54	20601.00	67.28	20410.19	66.66
Northern Caspian Basin - Easternmost Shelf	ncb-es	11359.10	4962.38	43.69	68.05	0.60	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Northern Caspian Basin - River Outflows	ncb-ro	8385.90	2839.72	33.86	495.46	5.91	4.60	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Northern Caspian Basin - Transition	ncb-t	21941.55	21522.54	98.09	16303.38	74.30	12178.06	55.50	9474.71	43.18	5930.38	27.03	3464.93	15.79	1711.82	7.80	1444.20	6.58
Northern Caspian Basin - Ural Furrow	ncb-uf	17094.46	15782.79	92.33	10720.80	62.72	3951.46	23.12	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Northern Caspian Basin - Western Shelf	ncb-ws	18963.32	12957.72	68.33	2765.90	14.59	357.88	1.89	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Southern Caspian Basin - Coastal	scb-c	52461.16	51394.57	97.97	49126.38	93.64	44949.70	85.68	40676.57	77.54	35459.33	67.59	30979.63	59.05	28495.96	54.32	28085.77	53.54
Southern Caspian Basin - Offshore	scb-os	80336.73	80328.88	99.99	80299.82	99.95	80250.18	99.89	80183.46	99.81	80092.49	99.70	79991.83	99.57	79870.21	99.42	79843.56	99.39

Supplementary Table 6. The proportional reduction in water coverage of seasonal sturgeon ranges in the Caspian Sea under different sea level decline scenarios.

		Decline Scenario																	
		Sea Level at -27.5m datum		2.5m		5m		7.5m		10m		12.5m		15m		17.5m		18m	
Season	Total Area km²	Area km²	% proportion of original area	Area km²	% proportion of original area	Area km²	% proportion of original area	Area km²	% proportion of original area	Area km²	% proportion of original area	Area km²	% proportion of original area	Area km²	% proportion of original area	Area km²	% proportion of original area	Area km²	% proportion of original area
Summer/ Autumn	141149.20	132972.17	94.21	107030.10	75.83	89549.30	63.44	78689.95	55.75	70337.23	49.83	62754.85	44.46	57662.31	40.85	56800.24	40.24		
Winter/Spring	103167.34	102998.79	99.84	102617.16	99.47	101411.59	98.30	98560.00	95.53	94183.74	91.29	89792.87	87.04	86955.94	84.29	86459.84	83.81		

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Supplementary Table 8. The change in distance to shore for coastal and terrestrial protected areas, from their centroid, in the Caspian Sea under different sea level decline scenarios.

		Sea Level at -27.5m datum	Decline Scenario															
			2.5m		5m		7.5m		10m		12.5m		15m		17.5m		18m	
Protected Area	Category/ Description	Distance to shore from centroid, km	Distance to Shore, km	Change in distance to shore, km	Distance to Shore, km	Change in distance to shore, km	Distance to Shore, km	Change in distance to shore, km	Distance to Shore, km	Change in distance to shore, km	Distance to Shore, km	Change in distance to shore, km	Distance to Shore, km	Change in distance to shore, km	Distance to Shore, km	Change in distance to shore, km	Distance to Shore, km	Change in distance to shore, km
Aktay-Buzachi State Nature Sanctuary	State Nature Sanctuary	7.22	8.68	1.46	17.24	10.02	21.10	13.88	46.02	38.79	53.36	46.14	68.28	61.05	68.71	61.49	68.93	61.71
Alborz-e-Markazy Protected Area	Protected Area	47.15	47.15	0.00	47.15	0.00	47.15	0.00	47.15	0.00	47.15	0.00	47.15	0.00	47.15	0.00	47.15	0.00
Amirkelayeh Lake Ramsar Site	Ramsar Site, Wetland of International Importance	1.65	2.25	0.60	3.11	1.47	3.50	1.85	4.23	2.59	5.43	3.79	6.16	4.51	6.53	4.88	6.53	4.88
Gomishan Lagoon Ramsar Site	Ramsar Site, Wetland of International Importance	3.15	3.15	0.00	4.50	1.35	10.48	7.33	16.24	13.09	19.46	16.31	28.92	25.76	34.32	31.17	36.00	32.85
Karadegishskiy State Nature Reserve	State Nature Reserve	28.03	28.20	0.17	32.96	4.93	38.95	10.92	45.75	17.72	48.64	20.61	55.70	27.67	61.67	33.64	62.87	34.84
Kendirli-Kayasan State Nature Reserved Zone	State Natural Protected Zone	62.26	62.26	0.00	62.47	0.21	68.02	5.76	71.71	9.45	72.19	9.94	72.84	10.58	74.60	12.34	75.25	12.99
Lavandevil Wildlife Refuge	Wildlife Refuge	0.00	0.99	0.99	2.75	2.75	4.57	4.57	5.73	5.73	7.85	7.85	12.22	12.22	13.31	13.31	13.58	13.58
Lisar Protected Area	Protected Area	14.46	14.71	0.25	15.42	0.97	16.41	1.96	17.58	3.12	19.52	5.07	19.52	5.07	19.52	5.07	19.52	5.07
Samurskiy National Park (Samur Delta Site)	National Park	0.45	4.44	3.99	4.87	4.41	5.19	4.74	5.69	5.24	6.11	5.66	6.54	6.09	7.10	6.64	7.24	6.79
Shirvan National Park	National Park	9.73	9.73	0.00	10.41	0.68	12.37	2.64	14.36	4.63	14.36	4.63	14.76	5.03	14.94	5.21	15.17	5.43
Karakiya-Karakol State Nature Sanctuary	State Nature Sanctuary	1.96	2.21	0.25	2.55	0.59	2.89	0.94	3.56	1.60	4.23	2.27	5.80	3.85	7.55	5.59	8.27	6.31
Sulakskaya Lagoon Firth- Flooded Complex	Firth-Flooded Complex	0.89	1.55	0.66	2.28	1.39	2.85	1.96	3.66	2.77	8.01	7.12	12.54	11.65	15.27	14.38	18.42	17.53

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Supplementary Table 9. The change in distance to shore for human settlements, located on the coast of the Caspian Sea, under different sea level decline scenarios.

				Decline Scenario																
				Sea level at -27.5m datum	2.5m		5m		7.5m		10m		12.5m		15m		17.5m		18m	
Human Settlement	Country	Latitude	Longitude	Distance to shore, km	Distance to shore, km	Change in distance to shore, km	Distance to shore, km	Change in distance to shore, km	Distance to shore, km	Change in distance to shore, km	Distance to shore, km	Change in distance to shore, km	Distance to shore, km	Change in distance to shore, km	Distance to shore, km	Change in distance to shore, km	Distance to shore, km	Change in distance to shore, km	Distance to shore, km	Change in distance to shore, km
Neka	Iran	36.65	53.30	21.32	21.32	0.00	21.83	0.51	22.45	1.14	23.20	1.88	24.88	3.56	26.36	5.04	27.95	6.63	28.29	6.97
Rud Sar	Iran	37.15	50.28	2.24	2.49	0.25	2.92	0.68	3.78	1.54	4.64	2.41	5.68	3.44	6.55	4.31	7.42	5.18	7.72	5.48
Now Shahr	Iran	36.60	51.50	5.48	5.48	0.00	5.70	0.22	5.84	0.36	6.12	0.64	6.40	0.92	7.27	1.80	7.96	2.49	8.11	2.63
Astara	Iran	38.39	48.85	2.18	3.08	0.91	4.50	2.33	6.50	4.33	7.78	5.60	9.23	7.06	12.84	10.67	14.46	12.29	14.62	12.44
Tonekabon	Iran	36.84	50.84	0.88	0.88	0.00	0.88	0.00	1.11	0.23	1.24	0.36	1.66	0.78	2.03	1.15	2.42	1.53	2.42	1.53
Fereydunkenar	Iran	36.69	52.56	0.81	0.99	0.18	1.12	0.31	1.45	0.64	1.91	1.10	2.37	1.56	2.84	2.03	3.30	2.49	3.34	2.53
Neftcala	Azerbaijan	39.37	49.26	5.32	5.62	0.30	9.21	3.88	9.48	4.15	9.78	4.46	10.05	4.73	10.32	5.00	10.62	5.30	10.62	5.30
Fort Shevchenko	Kazakhstan - North basin	44.51	50.26	1.80	1.86	0.06	1.86	0.06	1.86	0.06	2.52	0.72	6.47	4.67	8.69	6.89	9.98	8.18	10.24	8.43
Zyrya	Azerbaijan	40.37	50.28	4.34	4.34	0.00	4.34	0.00	4.71	0.37	6.87	2.54	11.87	7.53	14.20	9.87	15.51	11.18	15.85	11.52
Mardakyan	Azerbaijan	40.49	50.16	2.32	2.70	0.38	3.11	0.78	3.47	1.15	4.11	1.79	5.41	3.09	7.18	4.86	11.31	8.99	11.75	9.42
Qobustan	Azerbaijan	40.09	49.41	0.26	1.43	1.17	5.89	5.64	7.88	7.62	8.37	8.11	10.69	10.44	18.50	18.24	24.80	24.54	27.07	26.82
Pirallahi	Azerbaijan	40.47	50.34	0.34	1.01	0.67	1.31	0.97	1.86	1.52	2.16	1.82	2.89	2.55	5.41	5.06	6.30	5.96	6.43	6.09
Hovsan	Azerbaijan	40.39	50.09	2.21	2.72	0.51	3.65	1.44	4.15	1.93	5.54	3.33	13.83	11.62	19.74	17.52	22.30	20.08	22.74	20.53
Turkan	Azerbaijan	40.37	50.21	1.47	1.73	0.26	1.98	0.51	2.54	1.07	5.57	4.10	14.13	12.66	18.58	17.10	20.84	19.37	21.17	19.70
Nardaran	Azerbaijan	40.56	49.98	2.79	3.47	0.68	3.65	0.86	3.92	1.13	4.20	1.41	4.63	1.85	5.08	2.29	5.97	3.18	6.42	3.63
Bekdash	Turkmenistan	41.55	52.58	2.11	2.11	0.00	2.11	0.00	2.11	0.00	2.29	0.18	2.48	0.37	2.73	0.62	3.02	0.91	3.10	0.99
Fetisovo	Kazakhstan	42.77	52.65	1.60	1.78	0.18	2.80	1.20	7.57	5.97	12.49	10.89	14.19	12.59	15.76	14.16	17.72	16.12	19.11	17.51
Kuryk	Kazakhstan	43.18	51.68	2.05	2.19	0.14	3.14	1.09	4.10	2.05	6.22	4.17	8.31	6.26	8.89	6.84	9.46	7.41	9.56	7.52
Xacmas	Azerbaijan	41.37	48.94	8.94	9.43	0.50	10.63	1.69	11.21	2.27	11.60	2.66	15.55	6.62	16.66	7.72	17.61	8.67	17.78	8.84
Zarat	Azerbaijan	40.95	49.28	0.81	1.56	0.75	1.85	1.04	2.47	1.66	4.08	3.27	5.78	4.97	7.20	6.39	8.83	8.02	9.11	8.30

(continued)

				Sea level at -27.5m datum	Decline Scenario															
					2.5m		5m		7.5m		10m		12.5m		15m		17.5m		18m	
Human Settlement	Country	Latitude	Longitude	Distance to shore, km	Distance to shore, km	Change in distance to shore, km	Distance to shore, km	Change in distance to shore, km	Distance to shore, km	Change in distance to shore, km	Distance to shore, km	Change in distance to shore, km	Distance to shore, km	Change in distance to shore, km	Distance to shore, km	Change in distance to shore, km	Distance to shore, km	Change in distance to shore, km	Distance to shore, km	Change in distance to shore, km
Nabran	Azerbaijan	41.76	48.69	0.38	0.73	0.36	1.00	0.63	1.00	0.63	1.54	1.16	1.88	1.51	2.46	2.09	2.95	2.57	2.95	2.57
Muxtedir	Azerbaijan	41.66	48.78	0.05	1.44	1.39	2.01	1.96	2.93	2.88	3.66	3.61	4.09	4.04	4.49	4.45	4.89	4.84	5.04	5.00
Gilazi	Azerbaijan	40.87	49.34	2.26	3.18	0.92	4.04	1.78	6.53	4.27	6.88	4.63	7.11	4.85	7.69	5.43	9.21	6.95	9.49	7.23
Bandar-e Torkaman	Iran	36.90	54.07	2.09	2.77	0.68	12.06	9.97	16.30	14.21	21.30	19.21	28.75	26.66	38.21	36.13	43.57	41.48	45.64	43.55
Xudat	Azerbaijan	41.63	48.68	8.63	9.50	0.87	10.06	1.43	10.62	1.99	11.48	2.85	12.05	3.42	12.55	3.92	12.87	4.24	13.11	4.48
Karshy	Turkmenistan	40.72	52.86	0.59	0.90	0.31	1.22	0.63	1.78	1.19	2.62	2.03	3.30	2.71	3.65	3.06	4.36	3.77	4.71	4.12
Bautino	Kazakhstan - North basin	44.54	50.26	0.30	0.30	0.00	1.06	0.77	1.53	1.23	3.47	3.17	5.88	5.59	7.61	7.32	12.64	12.34	12.96	12.66
Kanga	Kazakhstan - North basin	44.62	50.59	1.32	1.53	0.21	1.63	0.31	1.79	0.47	2.19	0.87	3.79	2.47	16.21	14.89	19.21	17.90	19.21	17.90
Erkinkala	Kazakhstan - North basin	47.02	51.81	16.10	22.73	6.63	50.25	34.14	73.23	57.13	276.40	260.30	280.01	263.90	284.86	268.75	285.41	269.31	285.41	269.31
Kyzylbalyk	Kazakhstan - North basin	46.98	51.79	12.62	18.57	5.95	45.35	32.73	68.28	55.66	271.44	258.82	275.05	262.43	279.91	267.28	280.46	267.84	280.46	267.84
Zhanatalap	Kazakhstan - North basin	47.00	51.82	15.37	21.57	6.19	48.33	32.95	70.99	55.61	274.28	258.91	277.91	262.54	282.78	267.41	283.34	267.96	283.34	267.96
Kurmangazy	Kazakhstan - North basin	46.97	51.78	11.43	17.17	5.74	43.92	32.49	66.95	55.52	270.05	258.62	273.65	262.22	278.50	267.07	279.06	267.63	279.06	267.63
Damba	Kazakhstan - North basin	46.96	51.75	9.58	15.21	5.62	42.21	32.62	65.53	55.95	268.48	258.89	272.06	262.47	276.88	267.30	277.44	267.86	277.44	267.86
Peshnoy	Kazakhstan - North basin	46.91	51.68	2.47	7.24	4.77	34.48	32.01	58.74	56.27	261.02	258.55	264.53	262.06	269.31	266.84	269.86	267.39	269.86	267.39
Taskala	Kazakhstan - North basin	47.03	51.91	20.79	29.24	8.45	54.00	33.21	76.49	55.70	280.22	259.43	283.85	263.06	288.91	268.12	289.47	268.68	289.47	268.68
Kraynovka	Russia - North basin	43.98	47.38	1.33	1.78	0.45	15.75	14.41	25.50	24.17	41.97	40.64	47.96	46.63	54.05	52.72	59.74	58.41	61.64	60.31
Noviy Biryuzyak	Russia - North basin	43.78	47.30	16.07	19.00	2.94	27.32	11.26	30.94	14.87	34.91	18.84	40.87	24.81	47.49	31.42	53.74	37.68	55.12	39.05
Kallektivizator	Russia - North basin	43.96	47.39	0.51	1.29	0.78	15.25	14.75	24.90	24.40	41.06	40.55	47.32	46.81	52.89	52.38	57.81	57.30	59.46	58.96
Novoterechnoe	Russia - North basin	44.02	47.35	1.07	1.45	0.38	14.72	13.65	26.67	25.60	42.72	41.64	48.90	47.83	55.20	54.13	62.76	61.69	65.13	64.05
Noviy Bakhtemir	Russia - North basin	44.13	47.27	0.00	2.16	2.16	14.07	14.07	34.08	34.08	48.08	48.08	53.82	53.82	60.12	60.12	66.66	66.66	68.75	68.75

(continued)

				Decline Scenario																
				Sea level at -27.5m datum	2.5m		5m		7.5m		10m		12.5m		15m		17.5m		18m	
Human Settlement	Country	Latitude	Longitude	Distance to shore, km	Distance to shore, km	Change in distance to shore, km	Distance to shore, km	Change in distance to shore, km	Distance to shore, km	Change in distance to shore, km	Distance to shore, km	Change in distance to shore, km	Distance to shore, km	Change in distance to shore, km	Distance to shore, km	Change in distance to shore, km	Distance to shore, km	Change in distance to shore, km	Distance to shore, km	Change in distance to shore, km
Suyutkino	Russia - North basin	44.19	47.24	0.00	2.59	2.59	17.05	17.05	37.97	37.97	50.00	50.00	55.73	55.73	61.99	61.99	67.80	67.80	70.05	70.05
Krasniy Rybak	Russia - North basin	44.18	47.25	0.00	2.42	2.42	16.43	16.43	37.31	37.31	49.65	49.65	55.34	55.34	61.64	61.64	67.52	67.52	69.75	69.75
Noviy Chechen	Russia - North basin	44.26	47.07	0.31	3.08	2.77	28.60	28.29	53.29	52.98	63.54	63.22	69.91	69.60	75.70	75.39	81.18	80.87	83.50	83.19
Bryanskiy Rybozavod	Russia - North basin	44.31	47.04	0.07	4.86	4.79	30.47	30.39	58.00	57.92	66.17	66.10	72.41	72.34	77.88	77.81	83.76	83.68	86.03	85.96
Bryansk	Russia - North basin	44.33	46.98	4.59	7.62	3.03	35.36	30.77	61.94	57.35	71.29	66.70	77.38	72.79	80.00	75.41	88.84	84.25	91.10	86.51
M. Gadzhieva	Russia - North basin	43.98	47.32	5.51	5.75	0.24	19.52	14.01	29.67	24.16	46.05	40.54	52.11	46.60	58.35	52.84	64.02	58.51	65.64	60.13
Suraxani	Azerbaijan	40.42	50.00	8.06	8.63	0.57	9.65	1.59	10.98	2.92	13.09	5.03	17.33	9.27	19.13	11.07	20.55	12.49	20.83	12.77
Mastaga	Azerbaijan	40.54	50.00	5.33	5.84	0.52	6.30	0.98	6.30	0.98	6.76	1.44	7.23	1.90	7.69	2.36	8.58	3.25	8.69	3.37
Sabuncu	Azerbaijan	40.52	49.97	7.30	7.44	0.14	7.69	0.40	8.14	0.84	8.72	1.42	9.18	1.88	9.62	2.32	10.51	3.21	10.95	3.65
Galugah	Iran	36.73	53.81	7.35	8.38	1.03	20.72	13.37	21.49	14.14	25.67	18.32	29.42	22.07	33.86	26.51	37.59	30.24	38.24	30.89
Bandar-e Gaz	Iran	36.77	53.95	1.97	3.08	1.10	18.64	16.67	21.30	19.32	25.51	23.53	32.12	30.15	37.81	35.84	42.84	40.87	43.46	41.48
Kord Kuy	Iran	36.79	54.11	7.31	9.40	2.09	23.14	15.83	27.21	19.90	32.25	24.94	39.35	32.04	47.93	40.62	52.86	45.55	54.57	47.26
Sulak	Russia	42.43	47.90	3.83	6.03	2.20	6.25	2.41	6.75	2.92	8.12	4.29	9.04	5.21	11.16	7.33	11.71	7.88	11.71	7.88
Lagan	Russia - North basin	45.39	47.35	18.30	20.39	2.09	59.91	41.60	71.83	53.53	72.12	53.82	72.53	54.23	72.95	54.65	130.43	112.13	140.80	122.50
Zhanbay	Kazakhstan - North basin	47.04	50.81	10.94	17.45	6.51	44.12	33.19	91.55	80.61	240.91	229.97	262.26	251.33	265.74	254.81	266.25	255.31	266.25	255.31
Burynshik	Kazakhstan - North basin	45.40	51.77	3.14	6.58	3.44	30.92	27.78	40.25	37.11	118.27	115.14	122.93	119.79	136.87	133.74	138.96	135.82	138.96	135.82
Hazar	Turkmenistan	39.42	53.10	0.00	0.36	0.36	0.72	0.72	1.14	1.14	2.31	2.31	4.03	4.03	7.73	7.73	10.40	10.40	11.96	11.96
Esenguly	Turkmenistan	37.46	53.97	7.59	8.77	1.19	15.26	7.67	21.63	14.04	30.97	23.38	38.14	30.55	43.79	36.20	48.54	40.95	49.41	41.82
Sumqayit	Azerbaijan	40.61	49.66	0.33	1.23	0.91	1.51	1.19	1.81	1.48	2.13	1.81	2.64	2.31	3.54	3.21	5.99	5.67	6.56	6.23
Lankaran	Azerbaijan	38.76	48.85	0.68	1.11	0.43	1.96	1.28	3.68	3.00	5.53	4.85	8.98	8.30	11.78	11.11	16.81	16.13	16.92	16.24

(continued)

				Decline Scenario																
				Sea level at -27.5m datum	2.5m		5m		7.5m		10m		12.5m		15m		17.5m		18m	
					Distance to shore, km	Change in distance to shore, km	Distance to shore, km	Change in distance to shore, km	Distance to shore, km	Change in distance to shore, km	Distance to shore, km	Change in distance to shore, km	Distance to shore, km	Change in distance to shore, km	Distance to shore, km	Change in distance to shore, km	Distance to shore, km	Change in distance to shore, km	Distance to shore, km	Change in distance to shore, km
Human Settlement	Country	Latitude	Longitude	Distance to shore, km	Distance to shore, km	Change in distance to shore, km	Distance to shore, km	Change in distance to shore, km	Distance to shore, km	Change in distance to shore, km	Distance to shore, km	Change in distance to shore, km	Distance to shore, km	Change in distance to shore, km	Distance to shore, km	Change in distance to shore, km	Distance to shore, km	Change in distance to shore, km	Distance to shore, km	Change in distance to shore, km
Atyrau	Kazakhstan - North basin	47.09	51.91	27.10	33.90	6.80	60.76	33.66	83.21	56.11	286.78	259.68	290.46	263.36	295.37	268.27	295.93	268.83	295.93	268.83
Sari	Iran	36.57	53.06	23.97	23.97	0.00	24.28	0.31	24.71	0.73	25.14	1.16	25.76	1.79	26.56	2.59	27.20	3.23	27.55	3.58
Babol	Iran	36.56	52.67	17.38	17.38	0.00	17.63	0.25	17.93	0.55	18.32	0.94	18.72	1.34	19.23	1.85	19.75	2.37	19.97	2.59
Amol	Iran	36.47	52.36	20.06	20.06	0.00	20.13	0.07	20.41	0.35	20.67	0.61	20.99	0.93	21.31	1.25	21.56	1.50	21.66	1.60
Gorgan	Iran	36.84	54.44	35.54	36.28	0.75	44.79	9.26	48.75	13.22	54.47	18.93	61.66	26.12	71.70	36.16	77.39	41.86	79.44	43.90
Makhachkala	Russia	42.99	47.47	1.90	1.90	0.00	1.90	0.00	1.96	0.06	2.36	0.46	4.34	2.45	9.78	7.88	14.52	12.62	15.21	13.32
Astrakhan	Russia - North basin	46.35	48.08	55.00	65.97	10.98	119.28	64.28	149.68	94.69	157.18	102.18	168.53	113.53	174.49	119.49	218.14	163.15	218.71	163.71
Rasht	Iran	37.27	49.59	21.39	21.44	0.05	21.67	0.29	21.91	0.52	22.36	0.97	22.54	1.15	22.92	1.53	23.29	1.90	23.29	1.90
Baku	Azerbaijan	40.38	49.87	0.77	0.86	0.09	1.37	0.60	3.44	2.67	7.02	6.25	11.07	10.29	15.21	14.44	26.13	25.35	26.59	25.81
Aktau	Kazakhstan	43.65	51.17	2.35	2.35	0.00	2.35	0.00	2.35	0.00	2.42	0.07	2.78	0.43	3.07	0.72	3.75	1.40	3.88	1.53
Bandar-e Anzali	Iran	37.47	49.48	0.50	0.55	0.05	0.55	0.05	1.01	0.51	1.01	0.52	1.47	0.97	1.54	1.04	1.93	1.44	1.93	1.44
Derbent	Russia	42.06	48.29	0.00	1.62	1.62	1.95	1.95	2.09	2.09	2.41	2.41	3.40	3.40	4.19	4.19	4.68	4.68	4.85	4.85
Kaspiysk	Russia	42.89	47.62	4.86	4.86	0.00	4.86	0.00	4.86	0.00	4.86	0.00	4.86	0.00	5.62	0.76	7.65	2.79	7.95	3.09
Chalus	Iran	36.66	51.42	3.47	3.47	0.00	3.47	0.00	3.60	0.13	3.82	0.35	3.91	0.44	4.18	0.71	4.35	0.88	4.35	0.88
Turkmenbashi	Turkmenistan	40.03	52.96	2.42	5.18	2.76	5.89	3.47	14.26	11.83	15.03	12.61	15.60	13.17	16.47	14.04	17.29	14.87	17.35	14.92
Izberbash	Russia	42.56	47.87	0.00	2.21	2.21	2.44	2.44	2.73	2.73	2.99	2.99	3.27	3.27	3.42	3.42	3.55	3.55	3.64	3.64
Behshahr	Iran	36.69	53.54	13.33	20.85	7.53	21.69	8.36	22.30	8.97	23.40	10.07	25.51	12.19	27.76	14.43	30.19	16.86	30.75	17.42
Langarud	Iran	37.21	50.08	15.97	16.96	0.99	17.66	1.70	18.30	2.34	19.09	3.12	20.04	4.08	20.90	4.94	21.61	5.65	21.77	5.80
Qaracuxur	Azerbaijan	40.40	49.98	5.63	5.85	0.22	6.24	0.61	7.81	2.17	11.29	5.66	14.37	8.74	18.44	12.81	23.79	18.15	23.92	18.28

Supplementary Table 10. The change in distance to shore for human infrastructure by, or within, the Caspian Sea under different sea level decline scenarios.

					Decline Scenario																
					Sea level at -27.5m datum	2.5m		5m		7.5m		10m		12.5m		15m		17.5m		18m	
Operator/ Location	Infrastructure type	Country	Latitude	Longitude	Distance to shore, km	Distance to shore, km	Change in distance to shore, km	Distance to shore, km	Change in distance to shore, km	Distance to shore, km	Change in distance to shore, km	Distance to shore, km	Change in distance to shore, km	Distance to shore, km	Change in distance to shore, km	Distance to shore, km	Change in distance to shore, km	Distance to shore, km	Change in distance to shore, km	Distance to shore, km	Change in distance to shore, km
BP	Gas Processing Plant	Azerbaijan	40.15	49.47	0.00	0.45	0.45	0.81	0.81	1.52	1.52	3.58	3.58	5.07	5.07	16.87	16.87	24.09	24.09	27.16	27.16
SOCAR	Gas Processing Plant	Azerbaijan	40.27	49.69	0.00	0.00	0.00	1.54	1.54	3.14	3.14	4.13	4.13	6.21	6.21	10.69	10.69	27.51	27.51	30.11	30.11
SOCAR	Oil Refinery	Azerbaijan	40.37	50.01	2.91	3.73	0.82	5.48	2.57	7.01	4.10	9.73	6.82	12.29	9.38	16.09	13.18	25.49	22.58	25.81	22.90
SOCAR	Oil Refinery	Azerbaijan	40.32	49.85	0.00	0.00	0.00	0.65	0.65	0.77	0.77	2.69	2.69	5.09	5.09	8.95	8.95	30.86	30.86	32.23	32.23
Dagestan Oil	Oil Refinery	Russia	43.01	47.46	0.62	0.74	0.12	0.98	0.36	1.25	0.63	1.73	1.11	4.79	4.17	10.99	10.37	15.53	14.91	16.29	15.67
KMG	Oil Refinery	Kazakhstan	43.61	51.30	5.61	5.61	0.00	5.91	0.30	6.18	0.57	6.51	0.90	7.01	1.40	7.57	1.96	9.01	3.40	11.31	5.70
Turkmenneftgas	Oil Refinery	Turkmenistan	40.01	52.98	1.46	2.66	1.20	3.01	1.55	13.44	11.97	14.51	13.05	15.58	14.11	16.39	14.93	17.22	15.75	17.24	15.77
National Iranian Oil Engineering & Construction Co	Oil Refinery	Iran	36.81	53.49	6.69	6.69	0.00	7.66	0.98	8.64	1.96	9.57	2.88	11.32	4.63	13.64	6.95	16.05	9.36	16.62	9.94
Lagan Port	Port	Russia	45.38	47.45	9.91	13.78	3.86	54.76	44.85	67.17	57.26	67.40	57.48	67.83	57.92	68.27	58.35	125.24	115.32	135.96	126.04
Makhachkala Sea Trade Port	Port	Russia	43.00	47.48	0.65	0.65	0.00	0.65	0.00	0.87	0.22	1.16	0.52	3.27	2.63	9.05	8.41	13.73	13.08	14.44	13.80
Dubandi Port	Port	Azerbaijan	40.43	50.28	0.19	1.33	1.14	1.63	1.44	2.27	2.08	6.39	6.20	8.56	8.37	10.86	10.67	12.36	12.17	12.67	12.48
Port Bandar-e Anzali	Port	Iran	37.45	49.44	3.17	3.17	0.00	3.57	0.39	3.92	0.75	4.11	0.94	4.38	1.21	4.56	1.38	4.85	1.67	4.85	1.67
Nowshahr Port	Port	Iran	36.60	51.49	5.93	5.93	0.00	6.16	0.23	6.33	0.40	6.59	0.66	6.92	0.99	7.74	1.81	8.44	2.51	8.58	2.65
Neka Port	Port	Iran	36.82	53.27	2.94	2.94	0.00	3.49	0.55	4.05	1.10	5.13	2.19	6.73	3.79	8.56	5.61	9.82	6.87	10.11	7.17
Okarem	Port	Turkmenistan	38.01	53.84	1.53	2.12	0.60	3.94	2.42	10.89	9.37	22.27	20.75	37.32	35.80	57.04	55.52	64.80	63.28	67.14	65.62
Hazar Port	Port	Turkmenistan	39.34	53.22	0.00	0.45	0.45	2.22	2.22	6.21	6.21	9.69	9.69	16.13	16.13	19.37	19.37	22.33	22.33	22.69	22.69
Kiyanly	Port	Turkmenistan	40.16	52.78	0.68	1.53	0.85	2.24	1.56	3.01	2.32	4.29	3.60	5.10	4.41	6.05	5.37	6.87	6.18	7.03	6.35
Kuryk Port	Port	Kazakhstan	43.18	51.67	1.22	1.22	0.00	2.47	1.25	3.47	2.25	5.46	4.24	7.61	6.39	8.25	7.03	8.82	7.59	8.98	7.76
Aktau Port	Port	Kazakhstan	43.60	51.22	0.57	0.57	0.00	0.57	0.00	0.94	0.37	1.59	1.03	2.27	1.70	3.23	2.67	5.07	4.50	5.40	4.83
Fort Shevchenko Port	Port	Kazakhstan	44.54	50.26	0.00	0.00	0.00	0.72	0.72	1.19	1.19	3.31	3.31	5.56	5.56	7.25	7.25	12.64	12.64	12.98	12.98
Turkmenbashi International Seaport	Port	Turkmenistan	40.01	52.99	1.31	2.33	1.02	2.70	1.39	13.55	12.24	14.63	13.32	15.65	14.34	16.57	15.26	17.37	16.06	17.41	16.11
Prorva Port	Port	Kazakhstan	45.84	53.01	7.83	33.39	25.57	68.84	61.01	94.89	87.07	224.56	216.73	230.03	222.21	245.44	237.62	247.67	239.84	247.67	239.84