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RESEARCH AND WAYS OF SOLVING THE PROBLEM OF WATERLOGGING OF ARABLE LAND IN NORTHERN KAZAKHSTAN

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ABSTRACT: The article presents the results of scientific research and gives ways to solve the problem of waterlogging of arable land in Northern Kazakhstan. This work aims to find out the degree of waterlogging, drainage of wetlands of the study area, and their use in agricultural production. To work out the issues of conducting drainage reclamation of wetlands, the experimental site was identified in the North Kazakhstan region, where amelioration work to drain it was carried out. The description of waterlogged soils of ground and surface moisture based on the results of studying their properties is given; comparative data on their morphological features, physicochemical properties, organic matter concentration, silt fraction, and physical clay for the studied soil layers are presented. The main problems of rational use of agricultural lands are analyzed, and ways of solving the identified problems of waterlogging of arable lands in northern Kazakhstan are proposed. The volumetric weight in the 0-100 cm layer ranges from 1.34-1.49 t/m^3, and the humus concentration is 0.15-5.53%. Of the absorbed bases, calcium accounts for 80-90 %. By qualitative composition from the relict lakes of the Kamyshlov ravine - Big Salt Lake - salinity was 5.254 g/l. According to the assessment of alkalinity (according to the values of hydrogen index (pH), the surface waters of reservoirs - 1 and 2 - are neutral, and those from Big Salt Lake are slightly alkaline. This present work can serve as a guide for improving soil conservation, sustainability, and planning for future agricultural production.

Keywords: Waterlogged soils, Surface over-moistening, Ground waterlogging, Soil formation processes, Drainage, Amelioration.

1. INTRODUCTION

In 1975, the USSR joined the Ramsar Convention with the listing of 13 wetlands, two of which were located on the territory of Kazakhstan. For the first time at the international level, the word protection was used for swamps [1]. Human economic activity and climate change caused the degradation of wetlands around the world [2]. More than - a billion people around the world depend on wetlands as a source of their livelihood - that's about every eighth of people on Earth. However, these lands are the most fragile ecosystems on our planet. According to the U.N., since 1970, the total area of wetlands has decreased by 35% [3]. Wetlands have lost at least 50% of their natural area since the beginning of the 20th century, mainly due to human use of their water [4-7]. Given the anthropogenic activities of these environments, the Ramsar Convention was developed and signed by 170 countries to protect wetlands with a total area of more than 250 million hectares [8]. These formations include a wide range of vegetation types, from wet meadows to wet forests [9,10]. Globally, wetland area distribution is related to water content (i.e., both groundwater content and soil water content) due to the rising water table levels [11]. Thus, factors such as carbon cycle budget, topography, and precipitation are important in understanding the presence of wetlands due to the high levels of soil moisture in permanently wet soils [11].

Due to the global food crisis that has increased food prices worldwide, population growth, and lack of additional arable lands, there is a need to drain and use wetlands. Therefore, this requires the development of scientifically justified approaches to drainage, water disposal, and drainage of wetlands, allowing them to be included in agricultural circulation without negative environmental consequences for agricultural landscapes. In the world, studies of the effect of waterlogging on the growth and development of cultivated plants are being carried out, which show that without providing drainage, guaranteed crop yields are impossible [12-17]. To combat soil waterlogging, various drainage measures are used to lower the level of groundwater using closed drainage, open channels or water intake facilities, construction of dams, straightening river channels to protect against flooding, interception and discharge of atmospheric slope water, etc.

The Republic of Kazakhstan is located at the junction of two continents in the center of the Eurasian continent; its area is 272.5 Mha. Part of the territory of Kazakhstan is located in Europe, and the main part – is situated - in Asia. In terms of land area, Kazakhstan is among the ten largest countries in the world, and in terms of land availability per capita, it ranks third in the world after Australia and Canada. Agricultural lands have a special legal regime and are subject to protection aimed at limiting the withdrawal of these lands, preserving and increasing their fertility. The area of lands of this category in the structure of the land fund is 114.0 Mha or 43.3% of the used lands. Wetlands in Kazakhstan spread over an area of 1.1 Mha, of which 23.9 thousand hectares are in arable land, and 15.4 thousand hectares are in irrigated arable land and have formed under conditions of excessive moisture only in the North -Kazakhstan region [18].

The land fund of the North Kazakhstan region is 9799.3 thousand hectares, of which 8394.3 thousand hectares are agricultural land, including 20.4 thousand hectares of swamp. The use of such lands as part of arable land is not possible since they require amelioration measures for drainage. This practice is absent in the Republic of Kazakhstan due to the lack of knowledge of the issue, lack of practically developed drainage technologies, and lack of incentives for agricultural producers therefore only by applying scientific and methodological approaches can it be possible to reduce and eliminate the consequences of swamping of arable lands located here.

At present, solving the problems of optimal use of wetlands, restoration, and stabilization of the geoecological state is relevant. The territory of the North Kazakhstan region is located in the south of the West Siberian lowland. It is a flat or slightly undulating accumulative plain, poorly drained by river valleys and lake pits. The territory of the region is confined to the zone of subsidence of the Paleozoic folded basement and the development of a thick stratum of Mesozoic-Cenozoic deposits. According to the conditions of formation, accumulation, and occurrence of groundwater within the region, the valleys of the Ishim River and its tributaries and flat interfluve spaces of the Ishim-Irtysh rivers are distinguished. In the interfluve of rivers, among the relief forms, the most ancient runoff valley called the Kamyshlov ravine, which is occupied by a chain of freshwater lakes.

Almost the entire North Kazakhstan region lies in one zone, but despite this fact, its soil surface is extremely variegated. On its territory, there are all main types, subtypes, and kinds of soils that are characteristic of the chernozem zone of the West Siberian Lowland. The diversity of soil surface is explained by the fact that within the region, there is a junction of forest and steppe bioclimatic zones and two geomorphological regions: West Siberian lowland and Central Kazakhstan small hills. The soil-forming rocks for them are non-saline loams, less often sandy loams and clays. The vegetation is represented by forb-fescue-feather grass and forb-feather grass steppes [19,20].

A characteristic feature of the hydrography of the North Kazakhstan region is the presence of drainage basins on its territory, which is explained by the exceptional flatness of the territory, very poor drainage, and continental climate. Due to the very poor drainage of the territory, its surface is replete with a large number of lakes. The total number of lakes in the region is 2328 (including 473 salts), with a total area of 4600 km^2. The lake content of the territory is about 3.5% - the highest among the regions of Kazakhstan. The prevailing depths of the lakes are 1.5-3.0 meters. The average long-term module of surface runoff varies from 0.05 l/sec per 1 km^2 in the east to 0.25 l/sec per 1 km^2 in the southwest. The approved reserves of groundwater amounted to 170.62 thous. m^3/day. (62.28 mln. m^3/year) by category: A - 48.55 thous. m^3/day. (17.72 mln. m^3/year); B - 77.86 thous. m^3 / day. (28.42 mln. m^3/year), C1 35.46 thous. m^3/day. (12.94 mln. m^3/year), C2 8.75 thous. m^3/day. (3.19 mln. m^3/year). Mineralization of groundwater ranges from 0.5 to 100 g/l, in most cases - from 5 to 26 g/l. Fresh and slightly salt waters are found in swampy and wooded areas [20].

Lake basins and over-deep areas are composed of lacustrine sandy-argillaceous deposits. The thickness of flooded silty loams, sandy loams, and sandy clays varies from 0.4 to 14 m. The waters lie at a depth of up to 3 m. The filtration coefficient is 0.3-0.5 m/ day. Mineralization of water reaches 10-50 g/l and more. Fresh and slightly brackish waters are confined to the most drained areas. The water level is closely dependent on surface water and precipitation. The maximum level is observed in the spring, during the period of snowmelt, and the minimum – is in the summer.

The current ecological and amelioration situation on arable lands of Northern Kazakhstan poses several tasks: first of all, regulation of the amelioration regime, optimization of irrigation technology parameters, soil salinization, taking into account soil and climatic conditions, through a comprehensive study of soil and ecological processes in aeration zone. Salt, nutrition, and thermal regimes are significant factors in amelioration situations on irrigated lands, which determine soil fertility, soil structure, growth conditions, and the development of plants. Maintaining a favorable environmental and amelioration regime entirely depends on the choice of drainage system operation mode, which ensures optimal control of amelioration processes in soils of the active zone on irrigated lands. At the same time, the use of water-saving methods, equipment, and technologies for irrigating crops should be linked to the mode of operation of drainage systems and be carried out based on the minimum cost of irrigation water.

For these purposes, in the framework of the budget program 267, "Improving the availability of knowledge and scientific research" under subprogram 101, "Program-targeted financing of scientific research and activities," the research was carried out in the North Kazakhstan region since the proportion of wetlands compared to the total area of agricultural land in the North Kazakhstan region is the largest in comparison with other regions of Kazakhstan. This research aims to ensure the conservation and reproduction of natural resources in agriculture.

2. RESEARCH SIGNIFICANCE

According to the results of the material collection, it was noted that the proportion of wetlands compared to the total area is the largest in the North Kazakhstan region of the Republic of Kazakhstan. The most characteristic feature of the hydrography of the North Kazakhstan region is the presence of drainage basins on its territory, which is explained by the exceptional flatness of the territory, its very weak drainage, and its continental climate. Therefore, soil survey work was carried out in the North Kazakhstan region. Wetlands have been selected for the development of optimal reclamation measures to solve the problem of waterlogging of arable land. Unfortunately, it should be noted that in Northern Kazakhstan, these issues have not been studied at all. Therefore, based on the conducted experiments, we are able to give certain recommendations.

3. MATERIALS AND METHODS

The object of the study is the arable land of the northern region of Kazakhstan (North Kazakhstan region, Bulaevo settlement, M. Zhumabaev district, the composition of the Esil water management basin in the Ishim-Irtysh interfluve with the code of water management area 04.02.00.02 (Forest-steppe - F.S., moisture coefficient C_m = 0.55-0.50) To determine the areas of swamping of arable lands in the North Kazakhstan region and select a typical pilot site for studying the processes of regulation of the amelioration regime during drainage amelioration on wetlands, survey work was carried out using the method of remote sensing of the Earth (R.S.), which allowed in the village of Bulaevo, North Kazakhstan region, to select an experimental site for research to solve the problem of waterlogging of arable land in the northern regions of Kazakhstan.

Primary soil diagnosis of the study area was carried out according to the morphological structure of the soil section profile, followed by clarification of the soil genetic status based on the results of chemical analysis. Carbonate medium-humus chernozems develop directly on Tertiary clays or on a small layer of Quaternary deposits covering these clays. The most common soil-forming rocks in the region are loess-like loams and tertiary clays. The relief of the study area: wavy, the microrelief is weakly expressed in the form of single, very small saucer-shaped depressions. The soil-forming rock is brown loam, underlain at a depth of 90 cm. Effervescence is 0-5 cm. Small calcareous concretions are found from the very surface.

Arable land (54°53'40.0"N 70°29'39.5"E) horizon A 0-20 cm -Dark grey, dry (ploughed), loose, lumpy structure, loamy, the transition is gradual; AB 21-37 cm -Brownish-dark grey, dry, granular-lumpy, weakly compacted, with vertical cracks, loamy gradual transition to the next horizon; B 38-70 cm - Inhomogeneous: dark grey with narrow brown wedges, dry, lumpy-rusty, weakly compacted, medium loamy, the transition is gradual; BC 71-84 cm - Brown, dark grey streaked, moist, stratified-granular, finely porous, loamy; C 85-110 cm -Brownish grey clay, moist, dense, clastic, with crystalline gypsum secretions.

Waterlogged soils (54°53'27.2"N 70°29'28.2"E) horizon A 0-19 cm - Brownish-dark grey, moist, granular structure, beads forming on roots, loose, loamy, transition to the next horizon prominent; AB 20-50 cm - Dark grey, moistened, dense, lumpy structure, heavy loam, with vertical cracks, abundant carbonate formation of white-eye form, the next horizon is poorly pronounced; B 51-95 cm - Inhomogeneous: dark grey, moist, dense, lumpy, with single thin humus streaks, heavy loam; BC 96-115 cm – Variegated clay, brown with grey wedges, compacted, moist, non-structural, rarely calcareous pebbles, heavy loamy; C 116-140 cm - Grey-brown clay, very damp viscous, underneath transitioning to green-grey damp very dense clay with coarse calcareous pebbles.

From the morphological description of the section, it can be seen that carbonate chernozems do not have the black color of the upper horizons which is inherent in ordinary chernozems, and have a rather extended humus horizon. Horizon A is characterized by a granular structure. The humus part of the profile is slightly tongue-like. For proper drainage of excessively moistened lands, it is necessary first of all to find out the type of water supply of the territory, which is determined by the main source of soil over-moistening. It depends on climatic, geological, hydrogeological, hydrological, soil, and other conditions of the melioration object. Figure 1 shows satellite images of the experimental site.

The field stage of the survey was carried out by deciphering the map-version by the ground method, according to the contours where soil sections were done. Primary soil diagnosis is carried out according to the morphological structure of the profile [21], followed by clarification of the genetic status of soils based on the results of the analysis [22]. For the analysis of soil chemical composition, analytical methods described in detail in the manual on general soil analysis [23,24] were used.

When carrying out field topographic and geodetic work on an experimental site, typical flat depression prevails, which is flat in places with heights from 115 to 135 m. Orographic depressions are characteristic of the entire area of the territory - depressions occupied by shallow reservoirs or vast expanses of swamps. With the help of open access to the EOS Crop Monitoring program, geomorphological features of experimental plot relief were visualized (Fig. 1).

A slope map is necessary to determine the most

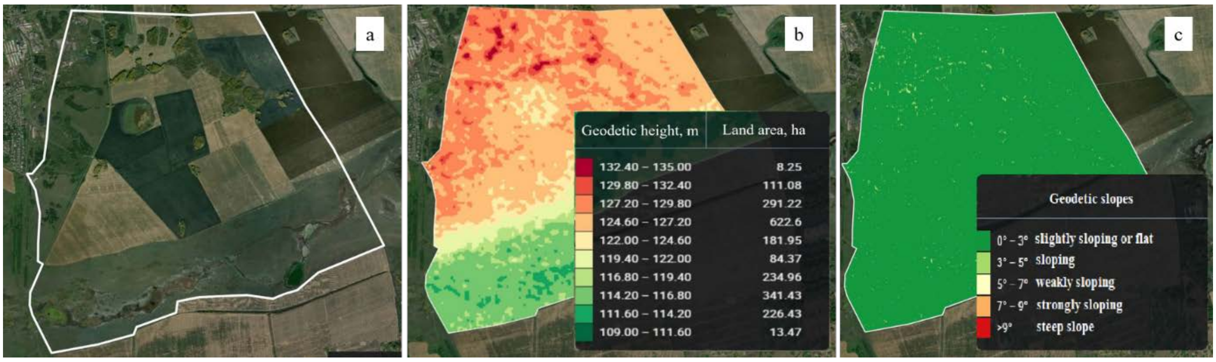

Fig. 1 Satellite images of the experimental site (a - natural background by season; b, c - primary topographic data on height and slopes)

gentle and even sections of the relief. The degree of lowering or raising the terrain is characterized by the angles of inclination of lines or slopes. The degree measure of the angle of inclination characterizes the steepness of the slope of a given line of terrain. According to the field survey, the surface of the territory is rather weakly dissected. The direction of the slopes within the field is heterogeneous. The main slopes towards the center of the site are outlined (values from 0.04 to 1%), which is expressed in increased migration of salt masses to lower areas (Fig. 1-b, c). The coloring scale of the map conveys the angles of inclination: 0°-3°: slightly inclined and flat; 3°-5°: inclined; 5°-7°: slightly sloping; >7°: very sloping and steep. The simplicity of calculation and information content make the surface slope the most used indicator in modeling the processes of redistribution of surface and subsoil runoff, erosion, etc.

A height map is a digital model that displays elevation differences in a field. The model allows the identification of potentially problematic areas, such as flood zones, water-restricted areas, soil erosion areas, etc. The elevation difference is displayed as a difference in shades, from dark green lowlands to dark red uplands. In combination with other data (indicators of the NDVI index, productivity map, etc.), the height map allows for determining the processes of waterlogging, drainage of the site, etc. The hypsometric marks of the site range from 109-132 m (Figure 1-b). The most significant depression in the area is occupied by a swamp with a low, gently sloping coast (122-125 m). A topogeodetic survey of the area was carried out with the required picket density for scales of 1:500 and 1:2000 [18, 21]. At the site of the work site, markers were installed at a distance of 500 m from each other, and excavation was carried out for the best identification on the ground. Upon completion of full-scale topographic and geodetic works on the object, cameral data processing was carried out. The data from the total station (point coordinates) were imported as text lists into the Autocad Civil 3D program. After that, according to these points, a 3D surface was built, and the network of points was thickened to build a relief with contour lines (isolines) (Fig. 2).

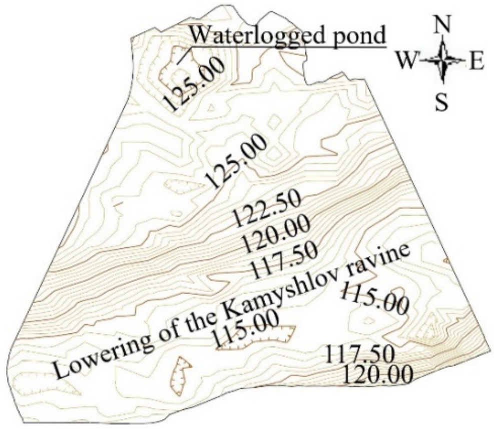

Fig. 2 Topographic and geodetic map of the experimental area

Based on topographic and geodetic data, waterlogged zones of the site were determined to develop measures for draining arable land and draining wastewater into lowland areas. As a result of the work carried out with the help of a total station survey, it was revealed that the site is dominated by a microrelief with fluctuations in relative heights within 4-5 meters. The general slope of the lowering of the site is in the direction of the Kamyshlov Ravine.

The main morphometric indicators, such as depth, length, and width for all reservoirs, were determined during field topographic-geodetic and bathygraphic works. In the course of the research, when determining morphometric characteristics, digital methods were used with a resolution of up to 30 m. The indicators of elongation, average width, and development of the coastline, as well as the volume of water in the reservoir, were determined by calculation (Table 1).

Table 1 Morphometric characteristics of the reservoir

Characteristics	Reservoir sections*****		Total for 2 reservoirs
	Reservoir – 1 (main body of water)	Reservoir -2 (permanently flooded area)	
Length (L), m	59.44	591.85	
Width (H), m	56.76	512.01	
Width av. (H_{av}), m	54.11	376.87	
Elongation index* (C_{el}.)	1.1	1.6	
Coastline length ($L_{c.l.}$), m	216.02	1988.0	
Coastline indentation index** (C_{ind})	2.1	2.4	
Depth*** (h_{max}.), m	1.9	0.48	
Water surface area**** (F), m^2	3216.61	223050.46	226267.07
Estimated volume (V_{cal}), m^3	2037.19	35688.07	37725.26

Note:
** - in terms of elongation, lakes of rounded shape C_{el}.<1.5 are distinguished; lakes close to the round shape Cel. =1.5-3 [25];*
*** - by the degree of development of coastline - slightly indented C_{ind} =1.0-6.0 [26];*
**** - by maximum depth: with a very shallow depth (less than 3.12 m) [27];*
***** - by the area of the water surface, they are divided into small lakes (0.001-0.01 km^2); small (0.01-0.1 km^2); small (0.1-1.0 km^2) [28].*
****** - coordinates: reservoir – 1 N54°53'19.22", E70°29'52.56"; reservoir – 2 N54°53'23.82", E70°29'39.44".*

When determining physical and geographical factors of the environment at the locations of water bodies, the distance from the water body to the sea in the north direction, the nearest distance from the body of water to the sea, the shortest distance from the object to the nearest river were measured using the Google Earth Pro program.

When conducting field studies, ideally, round reservoirs were not recorded. This reservoir in dry years is divided into two smaller ones. In high-water years - the territory is completely flooded and forms a single coastal water area. According to field studies, reservoir-1 was identified as the main reservoir and reservoir-2 in a long-term flooded area. According to the area of the water surface, the reservoirs are small. The values of the maximum length and width vary from 59.44 to 591.85 m and from 56.76 to 512.01 m, respectively. By the values of the coefficient of elongation of reservoirs, they are characterized by a shape - round for reservoir-1 (C_{el}<1.5) and close to round for reservoir-2 (C_{el}=1.5-3.0). The depth ranges from 0.48 to 1.90 m. The water surface area is 3216.61 m^2 for reservoir-1 and 223050.46 m^2 for reservoir-2. The estimated total volume of the reservoir is 37725.26 m^3.

Pumping water from a swampy area. To determine the possible area of irrigation by various irrigation methods for the cultivation of crops and to clarify the water regime and waterlogging of arable lands, the possible volume of water bodies was determined, and experimental hydrological work was carried out using the open drainage method, which involves pumping water from a reservoir in the experimental area. Pumping out was carried out for 2 days on a small pond-1 (installation of a pump, suction and supply flexible pipelines, installation of hydrometric rods, a water meter, etc.).

Analysis of the meteorological data of the experimental site (Bulaevo village) shows that the climate of the territory is sharply continental and arid, characterized by a small amount of precipitation (Fig. 3). Summers are hot, and winters are harsh, with little snow. Up to 70% of precipitation occurs during the warm season.

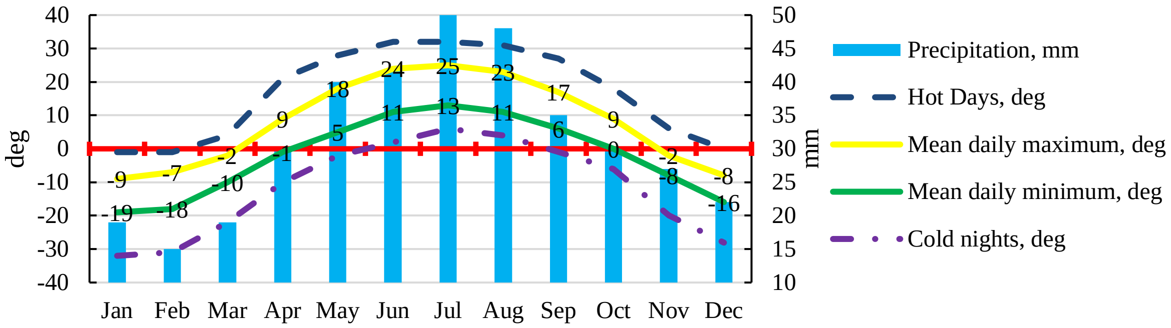

Fig. 3 - Annual average temperature (deg) and total annual precipitation (mm) in Bulaevo (Kazakhstan)

However, even though more than half of the atmospheric precipitation falls in the summer, the summer is dry and hot. Rains often have a torrential character, when more than 100 mm of water can fall during one downpour. Precipitation during the cold period, falling in the form of snow, is only 17-20% of the total annual amount. With this nature of the distribution of precipitation over the seasons of the year, their share in the formation of surface and groundwater turns out to be insignificant. Due to high summer temperatures and a large deficit of humidity, the precipitation of this period is almost completely spent on evaporation. Only winter precipitation, which can accumulate in the form of a more or less massive layer of snow, causes spring floods in rivers and replenishment of groundwater.
The average maximum and minimum temperatures in Bulaevo, calculated for the last years, are shown in Fig. 3. On the flat terrain, the western transport of air masses prevails. Summer cyclones bring moist air masses to the plain. Annual moisture is unstable, and the steppe falls from 300 to 400 mm of precipitation, mainly during the warm season (250-300 mm). Snow during the winter falls up to 45 cm, but it lies unevenly on the plain. Precipitation in the steppes is very low, up to approximately 400 mm/year.

To choose the best way to drain the experimental plot, it is first necessary to find out the reason for the waterlogging of the experimental plot. Therefore, six piezometric observation wells were installed along the perimeter of the site to determine the regimes and dynamics of the groundwater level, determine the drainage of the territory, that is, the effect of groundwater on swamping of the territory, since for research on drainage reclamation, ground pressure waters occurring on the first from the surface of the regional aquiclude. Geodetic referencing of piezometric wells of the experimental area (latitude - N, longitude - E) is given according to the World System of Geodetic Parameters of the Earth (WGS84) (Table 2). The level of groundwater in the wells was recorded with a clapperboard. From observation wells, groundwater samples were taken for chemical analysis.

Table 2 Geodetic referencing of piezometric wells

Well number	Geodetic coordinates		Elevation marks of the borehole, m
	North latitude (N)	longitude east (E)	
Borehole 1	54°53.312'	70°29.314'	126
Borehole 2	54°53.351'	70°29.935'	127
Borehole 3	54°53.464'	70°29.442'	133

The site belongs to the sub-area of distribution of groundwater of the Neogene-Quaternary deposits of the ancient Kamyshlovka valley. Being confined to more or less well-washed deposits of the ancient Kamyshlovka Valley, groundwater has relatively low mineralization and is mostly fresh. The aquifer is represented by sandy loams, loams, less often clayey sands, occurring at a depth of 5-15 m.

The conducted studies are based on the results of the analysis of thematic maps, informational, analytical material, Landsat 8 satellite images, and field research data.

4. RESULTS

Northern Kazakhstan is distinguished by the type of soil and high complexity of soil surface, which is associated with both latitudinal zonings, varying degrees of aridity of certain parts of bioclimatic zones, and a variety of lithological and geomorphological conditions. The study area is completely included in the forest-steppe zone. It is subdivided into the forest-steppe subzone, where the forests are not inferior in the area to the steppe areas, and the split forest-steppe subzone, where open steppe spaces predominate.

The soil surface of the study area is mainly represented by ordinary chernozems. Meadow-chernozem soils are quite common. They are found in places with a close occurrence (3.5-6 m) of groundwater and excessive surface moisture (depressions between crests, depressions, terraces of rivers and lakes).

Among the ordinary chernozems, the most widespread is the solonetzic genera, which are most often found in combination with solonetzes, and the ordinary genera, occupying drained and poorly drained territories.

In the transitional part from the split forest-steppe to the steppe zone, chernozems with a pronounced tongue-like humus horizons are often found. These soils are characterized by heterogeneity of color already in the upper horizon, their small thickness, effervescence only along rock folds, and low water-physical properties. The thickness of the humus horizon in chernozems reaches 80 cm or more, but in most cases, they are of medium thickness. According to the granulometric composition, the genera of ordinary and alkaline soils are medium and light loamy, while the genera of carbonate soils are predominantly heavy loamy [29].

In terms of hydrogeology, the experimental site is located in the Ishim-Irtysh interfluve and is covered with a continuous cover of deluvial-proluvial sandy-loamy deposits up to 20-35 m thick. The soil granulometric composition has a great influence on soil formation and soil agricultural properties. The following depends on it: processes of movement, transformation, and accumulation of substances; soil physical, physico-mechanical, and water properties, such as porosity, moisture capacity, water permeability, water-carrying capacity, structure, air, and thermal conditions. The volumetric weight ranges from 1.28-1.49 t/m^3 (Table 3). The humus content in arable soils varied from

4.73% to 5.35 % (average), and waterlogged soils had significantly lower humus content, ranging from 1.65% to 4.01% (low and very low). Similar patterns were observed in the levels of hydrolyzable nitrogen, mobile P_2O_5, and exchangeable K_2O.

By the data collected from the research plots, the total amount of absorbed bases was found to range from 31.8 to 40.0 mg-eq/100 g of soil. Among the absorbed bases, calcium comprises 60.8-77.0%. An increase in the number of cations in waterlogged soils is often associated with solonetzic soil. In such cases, there is also an increase in the Na+ cation content in the soil's absorption complex compared to arable lands.

Table 3 Changes in the physicochemical and agrochemical properties of soils of experimental plots

Soil analyzes	Arable land			Waterlogged soils		
	Selection horizon, cm					
	0-20	21-37	38-70	0-19	20-50	51-95
Bulk density*, t/m^3	1.28	1.36	1.46	1.38	1.43	1.49
Humus**, %	5.35	4.93	4.73	3.7	1.64	0.72
Hydrolyzable N, mg/kg	44.8	36.4	30.8	33.6	14.0	14.0
Mobile P_2O_5, mg/kg	25.0	23.0	18.0	25.0	12.0	14.0
Exchangeable K_2O, мг/кг	810	550	280	580	220	230
SAC, mg-eq/100 g	33.5	31.8	32.5	34.6	39.8	40.0
Ca in SAC, %	77.0	76.4	71.6	70.3	71.0	60.8
Mg*** in SAC, %	22.2	23.4	27.4	27.2	23.6	31.0
Na**** in SAC, %	0.7	0.1	0.8	2.3	5.2	8.1

Note:
** - by the assessment of soil density: arable land is compacted - 1.2-1.3t/m^3; typical values for subsurface horizons are -1.4-1.6 t/m^3 [30];*
*** - refined gradations of humus concentration in the horizons of soil profile: very low, up to 2.0%; low 2.1-4.0%; average 4.1-6.0% [31];*
***** - the upper limit of the allowable content of exchangeable Mg^{2+} for low-humus soils is up to 30% of SAC [32].*
***** - gradation according to exchangeable Na^+ for low-humus soils: weakly solonetsous - 5-10% of SAC [33]*

The arable land is characterized by the granulometric composition, which consists of heavy loam and medium loam. The amount of "physical clay" is unevenly distributed throughout the soil profile, with 58.9% found on the upper horizon and decreasing to 38.5% on the lower horizons (Fig. 4). Arable lands are generally composed of sandy particles that range in size from 0.25 to 0.005 mm, which make up 29.5-43.9% of the soil. The next most common fractions are silty particles, which are smaller than 0.001 mm and makeup 17.5-33.3% of the soil, followed by sandy particles ranging from 0.005 to 0.001 mm, which make up 27.1-9.9% of the soil. Waterlogged soils are characterized as heavy loamy (57.7%) and light loamy (62.4%) textures in the lower portion of the soil profile. These soils contain a silt fraction ranging from 34.6% to 38.2%, while the proportion of sand fraction decreases to 24.1%.

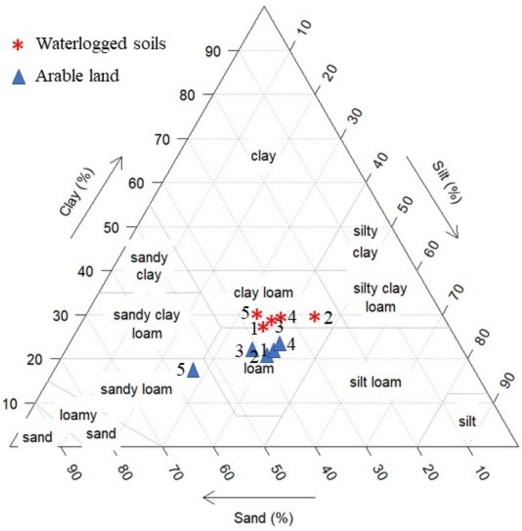

Fig. 4 Differences in granulometric composition between waterlogged soils and arable land
(Horizon soils: 1-A; 2-AB; 3-B; 4-BC; 5-C)

The installation of piezometric observation wells along the entire perimeter of the study area made it possible to identify the effect of groundwater on the waterlogging of the territory. In the experimental area, there is unsatisfactory natural drainage, which creates such a regime of groundwater in which evaporation is the main factor in their consumption and movement of water-soluble salts into the upper soil horizons. The level of occurrence of groundwater in the experimental area is not opened at a depth of 2-3 m.

The heterogeneity of the lithological composition of water-bearing rocks and their frequent change along stretching are not favorable for the formation of the sustained aquifer. The latter occurs only in the form of specific localized lenses. The assessment of water's qualitative composition is assessed according to the following indicators: mineralization, the ionic composition of water, the toxicity of specific ions, etc.

The total mineralization of water is a parameter that reflects the concentration of substances dissolved in a liquid (mainly inorganic salts) (Table 4). The primary assessment of water is carried out according to the total concentration of salts dissolved in it. According to the qualitative composition, surface waters from the pond are fresh, and the total salinity was 0.435-0.806 g/l, which allows the use of the water supply (Table 4). According to hydrochemical composition, they are different: in

Table 4 Hydrochemical composition of water samples, $\frac{g}{mg-eq}/l$

Sampling date D/M/Y	Sampling place	Anions				Cations			Σsalts*, g/l	Kurlov formula [34]	pH**
		CO_3^{2-}	HCO_3^-	Cl^-	SO_4^{2-}	Ca^{2+}	Mg^{2+}	Na^++K^+			
13.06.22	Pond-1 (main, N54°53'19.22", E70°29'52.56")	Not found	$\frac{0.260}{4.24}$	$\frac{0.031}{0.88}$	$\frac{0.034}{0.72}$	$\frac{0.032}{1.60}$	$\frac{0.022}{1.80}$	$\frac{0.056}{2.44}$	0.435	$\frac{HCO_3^-\ 72.6\ Cl^-\ 15.1\ SO_4^{2-}\ 12.3}{(Na^++K^+)41.8\ Mg^{2+}30.8\ Ca^{2+}27.4}$	7.6
13.06.22	Pond-2 (permanently flooded, N54°53'23.82", E70°29'39.44")	Not found	$\frac{0.420}{6.96}$	$\frac{0.058}{1.68}$	$\frac{0.111}{2.32}$	$\frac{0.160}{8.00}$	$\frac{0.012}{1.00}$	$\frac{0.045}{1.96}$	0.806	$\frac{HCO_3^-\ 63.5\ SO_4^{2-}\ 21.2\ Cl^-\ 15.3}{Ca^{2+}73.0\ (Na^++K^+)17.9\ Mg^{2+}9.1}$	7.9
14.06.22	Big Salt lake (lake of the Kamyshlov ravine, N54°51'2.84", E70°20'31.16")	Not found	$\frac{0.420}{6.88}$	$\frac{0.710}{20.00}$	$\frac{2.400}{50.00}$	$\frac{0.232}{11.60}$	$\frac{0.012}{1.00}$	$\frac{1.480}{64.28}$	5.254	$\frac{SO_4^{2-}65.0\ Cl^-\ 26.0\ HCO_3^-8.9}{(Na^++K^+)83.6\ Ca^{2+}15.1\ Mg^{2+}1.3}$	8.4

Note:
** - by classification of natural waters, they are classified as fresh - 0.5-1.0 g / l; strongly brackish - 3.5-10.0 g/l [35]*
*** - by classification of natural waters by pH value: weakly alkaline 7.1−8.2; alkaline 8.3−10.3 [36].*

the reservoir - 1 - bicarbonate-sodium; in reservoir-2 - bicarbonate-calcium with high sulfate concentration. By qualitative composition from the relict lakes of the Kamyshlov ravine - Big Salt Lake - salinity was 5.254 g/l (medium brackish).

By chemical composition - sulfate-sodium, with high chloride concentration. According to the assessment of alkalinity (according to the values of hydrogen index (pH), surface waters of reservoirs - 1 and 2 - are neutral, and those from Big Salt Lake are slightly alkaline. The analysis of the hydrochemical regime of the forming surface waters (covering the waterlogged pilot area) indicates that these waters can be used for irrigation. The use of drainage systems makes it possible to regulate the soil water-salt regime and creates an additional volume of water suitable for irrigation.

5. DISCUSSION

In the conditions of Northern Kazakhstan, the main factor influencing the swamping of arable lands is the infiltration of water in the spring in the absence of a water drainage network on hydro-reclamation systems of water drainage systems.

The drainage system at hydro-reclamation facilities, as a rule, consists of primary drains (systematic drainage), drainage collectors, and various collectors. The effectiveness of water regime management is predetermined by the rate of groundwater withdrawal and the size of the creation of reserve tanks to receive seepage water during peak periods (Fig. 5). To clarify the water regime and waterlogging of arable lands. Experimental hydrological work was carried out using the open drainage method [37], which involves pumping water from the reservoir in the experimental area. Pumping out was carried out for 2 days with necessary technological operations (installation of pump, suction and supply flexible pipelines, installation of hydrometric rods, water meter, etc.).

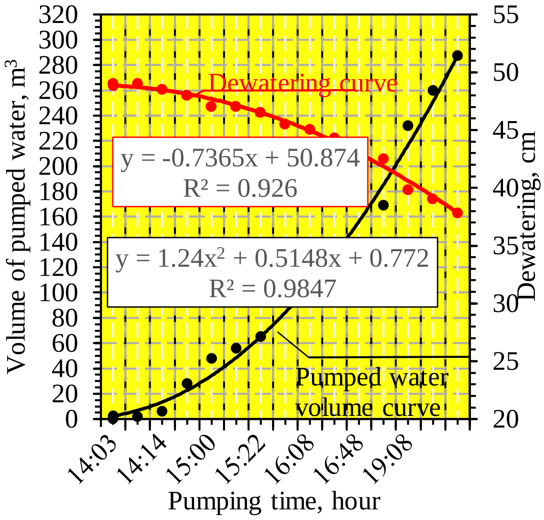

Fig. 5 - Graph of dewatering of water from pond-1 on the experimental site

According to experimental studies, it was found that with a volume of pumped water of 260 m^3 with a pumping duration of 7 hours, the level of the water table of the reservoir decreases by 10 cm (Fig. 5). An increase in the level of the water table according to the marks within 2 days was not observed. Thus, in spring and summer, the total volume of the water bodies is replenished due to atmospheric precipitation, while the inflow of groundwater remains minimal. The permissible level of groundwater rise in the experimental area was:

$$L = 170 + 8 * 2.6\ deg \pm 15 = 190.8 \pm 15\ cm \qquad (1)$$

Thus, in the experimental area, the permissible level of groundwater rise must be set at least at a level of 190.8 ± 15 cm from the daylight surface. The permissible critical depth of groundwater level is provided by drainage determined based on experimental data, taking into account the salinity of groundwater, irrigation regime, quality of irrigation water, and natural and climatic conditions of the drained area. According to the calculation of the drainage flow module for the experimental site, the estimated volume of water for reservoirs 1 and 2 in 2022 was 37725.26 m^3. Drainage area (accepted water surface area) - 226267.07 m^2.

$$\Delta W_{gr}^{calc} = 37725.26\ m^3/22.626707\ ha = 1667.29\ m^3/ha \quad (2)$$

When calculating the module of drainage flow, the period of the growing season of crops (90-120 days) was adopted:

$$q_{др} = 1667.29\ m^3/\ ha/86.4*120\ day. = 0.16\ l/s*ha \quad (3)$$

Approximate values of drainage flow modulus are 0.15 l/s*ha for heavy soils, 0.20 l/s*ha for medium soils, 0.25 l/s*ha for light soils, and lowland bogs 0.7-0.9 l/s*ha [38]. With the removal of surface runoff by closed collectors and with an intensive inflow of groundwater, it can reach 1.1-2.0 or more l / s per 1 ha. For the experimental plot, the drainage runoff module is 0.16 l/s*ha since the soils are classified as heavy loams in terms of granulometric composition. The amplitude of the rise in water level in the reservoir is predetermined by climatic factors and the intensity of evaporation. The minimum values of volume refer to dry years when the volume of natural precipitation decreases.

At the present stage of exploitation of arable lands in Northern Kazakhstan, the problem of waterlogging can be solved by lowering the level of groundwater and using surface waters formed in the process of swamping for irrigation. The choice of methods for the rational use of these surface waters for irrigation, management of soil ameliorative regime, and obtaining high yields depends on natural conditions, economic situation, the technical level of irrigation and drainage systems, and characteristics of agricultural technology. Therefore, the creation of highly efficient hydro-amelioration (drainage) systems that provide water diversion and prevent waterlogging is the main task, which will significantly reduce and sometimes eliminate the processes of waterlogging of arable lands in Northern Kazakhstan.

It should also be noted that the current ecological and amelioration situation on the arable lands of Northern Kazakhstan poses some new complex tasks: first of all, regulation of amelioration (water-salt and nutrition) regime, optimization of drainage technology parameters, taking into account soil and climatic conditions. Maintaining a favorable ecological and amelioration regime provides the necessary conditions for forming favorable soil processes in the root zone.

Thus, in the conditions of Northern Kazakhstan, the main factor influencing the swamping of arable lands is flood (infiltration) water in the spring in the absence of a water drainage network on hydro-reclamation systems. The drainage system at hydro-reclamation facilities, as a rule, consists of primary drains (systematic drainage), drainage collectors, and collectors of various orders. The effectiveness of water regime management is predetermined by the rate of groundwater withdrawal and the size of the creation of reserve tanks to receive seepage water during peak periods. According to the results of the forecast of the water regime, the values of ascending and descending velocities of moisture movement in the aeration zone and the intensity of infiltration nutrition should be determined. Based on all the data, reclamation regimes are justified, and the load on the drainage and drainage flow module is calculated.

As mentioned above, the climatic and morphological conditions of the experimental site make it possible to use the water resources of the wetland for irrigation. Therefore, to determine the possible area of irrigation by various irrigation methods for the cultivation of crops and to clarify the water regime and waterlogging of arable lands, the possible volume of water bodies and experimental hydrological work was carried out using the method of open drainage, which provide the pumping of water from the reservoir in the experimental area.

6. CONCLUSIONS

The conducted studies have shown the possibility of diverting water into the underlying Kamyshlovskiy ravine by pumping water out with pumps and creating a drainage outlet network. The mineralization of surface water makes it possible to use it for irrigation, which will increase the possibility of farming in this economy and increase the yield of cultivated crops. Based on the results of the study, it can be concluded that in the study area, in conditions of northern Kazakhstan, drainage reclamation was carried out. Therefore, research work to develop effective measures to solve the problem of swamping arable lands, taking into account environmental consequences, should be continued. The future direction of research is the use of the research results in other regions of Kazakhstan with the same problems of waterlogging.

7. ACKNOWLEDGEMENTS

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