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PROTECTION OF TERRITORIES FROM WATERLOGGING IN THE ZONE OF THE NORTH CRIMEAN CANAL OF KHERSON REGION AND WAYS TO IMPROVE IT

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Abstract. *he system of protecting territories from the harmful effects of water using vertical drainage in the zone of the North Crimean Canal of the Kherson region was considered and the proposals for its improvement by creating additional horizontal drainage systems with gravity drainage were substantiated. Field drainage studies were carried out at 8 research and production sites with a total area of 4763 hectares and a term of operation of 48–55 years and more. The conducted studies included surveying the drainage in the areas, measuring the drainage flow and the depth of groundwater levels, and determining work efficiency. The research covered the settlements: Chornyanka, Nova Mayachka, Stara Mayachka, Podo-Kalynivka, Tarasivka, Velyki Kopani, Kalanchak, and Skadovsk, for the protection of which 119 water intake wells with a depth of 26–70 m were installed. It is shown that vertical drainage is effective during the whole operation and periods of selective work when the groundwater levels were at depths of 2–3 m and 1–2 m, respectively. To ensure reliable protection of territories from waterlogging and flooding in current conditions due to the impossibility and economic impracticability of restoring the operation of all existing vertical drainage wells, it is proposed to supplement the existing protection systems based on it with systems of closed horizontal drainage of the gravity type with low-sloping and non-sloping drainage. The area of additional horizontal drainage is about 40 thousand hectares, the estimated length of the collector and drainage network is 456 km, and the depth of laying drains and collectors is 2.5–11.0 m.*

Keywords**:** *vertical drainage, efficiency of horizontal drainage, gravity drainage*

Formulation of the question. Vertical drainage is a relatively new and rather complex type of reclamation system that is used to protect territories from waterlogging, built in a relatively short time, and required forced drainage based on electrification and automation [2; 8; 10; 15; 16; 25; 28]. Therefore, the territory belongs to the flooded area if the depth of the groundwater level exceeds the critical limit, which is defined as 1.5–2.0 m [10; 22].

Vertical drainage is used to protect territories from waterlogging in the area of irrigation, drainage, and Dnieper reservoirs [1; 10; 15; 16; 19; 20; 25–27]. In the irrigation zone, the total area of territories covered by vertical drainage systems, is 250.000 hectares, on which about 2.000 wells have been built [8; 10; 17; 26; 30–32]. This drainage is widespread in the Kherson region (110.000 hectares), and the number of water-lowering wells is 924, of which 96.000 hectares (557 wells) are on irrigated and adjacent lands, and 14.000 hectares (367 wells) are in 81 settlements [4–7; 10; 26; 39].

The long period of operation, obsolescence, and high energy consumption of vertical drainage systems, as well as the military aggression of the Russian Federation, complicate the effectiveness of its work and lead to the aggravation of the problem of waterlogging of territories on a significant scale, especially in wet and abnormally wet periods, which requires an increase in the overall drainage of territories. Ensuring the efficient operation of drainage in

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these conditions requires the development and application of additional measures, first of all, the addition of horizontal drainage systems with gravity drainage.

The purpose of the work is to justify the reliable protection of territories from waterlogging in the zone of the North Crimean Canal based on increasing the drainage capacity of vertical drainage systems by installing horizontal drainage with gravity drainage.

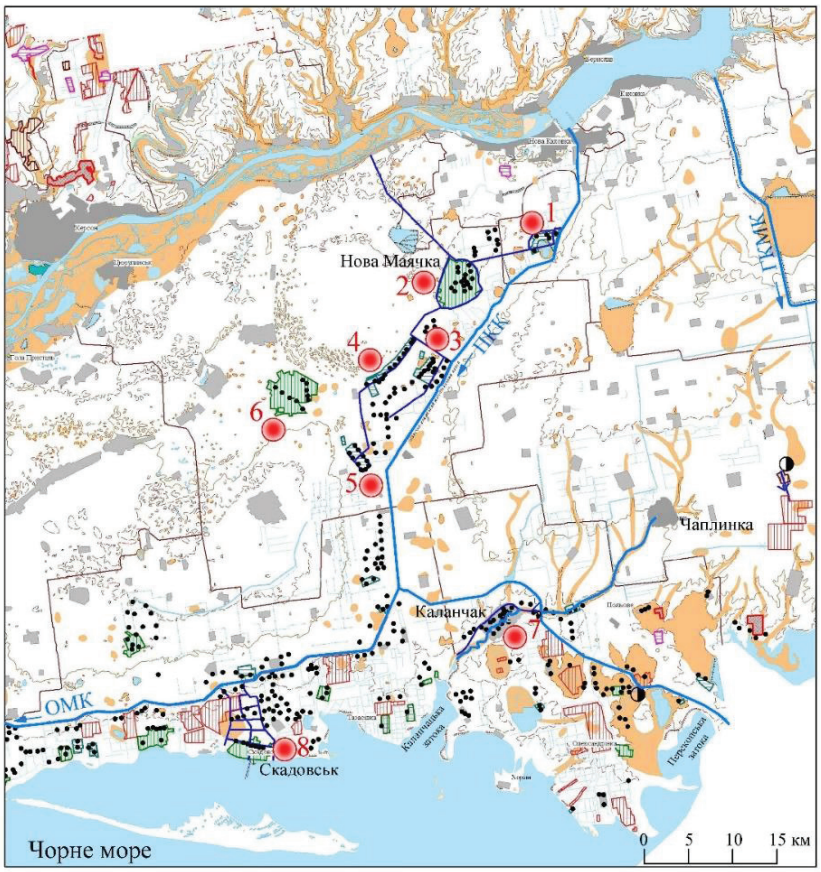
Research methodology. Field studies of the work of vertical drainage were carried out at objects located in the zone of the North Crimean Canal (NCC) within the Kherson region [3; 11; 12; 21; 29; 30; 32; 34; 36–38]. The research covered systems in the settlements of Chornyanka, Nova Mayachka, Stara Mayachka, Podo-Kalynivka, Tarasivka, Velyki Kopani, Kalanchak, and Skadovsk (Fig. 1).

Field studies of the work of vertical drainage included examination of drainage systems, measurement of drainage flow, and depths of groundwater levels through observation and specially drilled wells. The survey was conducted using the materials of design, construction, and operating organizations and the results of published manuscripts.

Measurements of drainage flow and groundwater levels were carried out by traditional methods [10; 22]. According to the survey results, drainage operation conditions, drainage runoff flow rates, depth of groundwater levels in various conditions, data on drainage efficiency, and operating conditions were determined.

The area of vertical drainage covered by research is 4.763 hectares, with 3.455 hectares in the Lower Dnieper basin and 1.308 hectares in the Black Sea. The water receivers of the drainage runoff are the North Crimean Canal and the Black Sea.

The characteristic of the studied drainage systems. The research was carried out on the drainage system in Chernyanka village, which contains 32 wells, and the vertical drainage system in Nova Mayachka town, which consists of 20 water-lowering wells, mostly 23 m deep,



Symbols:

-1; -2; -3; -4; -5; -6;

Fig. 1. Scheme of the vertical drainage in the zone of NCC:
1 – irrigation canal; 2 – horizontal drainage systems; 3 – vertical drainage well;
4 – horizontals of the area; 5 – vertical drainage systems; 6 – areas of drainage studies № 1–8

550 mm in diameter, and 500–1000 m apart. The total flow rate is 910 l/s. Drainage water is pumped into the North Crimean Canal or used for irrigation. The system has been operating for over 55 years.

The system in Stara Mayachka village and the surrounding areas contains 16 wells that situated in two lines. In the first line, which is located at a distance of 550–800 m from the NCC, there are 6 wells, the distance between which is 600–1100 m. In the second line, at a distance of 2100–2400 m from the NCC, there are 8 wells, the distance between which is 300–500 m. The distance between the two line is about 1.500 m. The depth of the wells is 70 m.

The system of vertical drainage in Podo-Kalynivka village contains 11 wells located linearly at a distance of 500–1000 m. The length of the well is 7200 m. The depth of the wells is 65 m. The wellhead is located at a distance of 5400 m from NCC.

The vertical drainage system in Tarasivka village, which is located on a gentle slope within the terrace, is 2–3 km from the highway of NCC. The absolute level of the water in the canal is 14.3 m, and the surface of the land in the village is 11.0 m. The canal bed during the inter-irrigation season provides drainage of the adjacent territories. Vertical drainage in Tarasivka village has an area of 365 hectares. The 10 wells were laid, which are located linearly along the contour of the village, with the exception of the northwestern territory on the rise. The distance between the drains is 500–750 m, and between the drainage lines is 1350 m. The wells work according to the circular cut-off drainage scheme. The depth of the drains is 70 m.

The vertical drainage in Velyki Kopani village is located on the lowest territory of the village in two lines of 5 wells. The distance between the drains is 500–900 m, and between the rows of drains is 1000–1500 m. The depth of the wells is 70 m. In Velyki Kopani village wells are located within the settlement, and in Tarasivka village are outside its borders, along the contour.

There are 19 vertical drainage wells located in Kalanchak town, which are located mostly linearly along both banks of the Kalanchak River. The distance between the drains is 400–1000 m, and between the drain lines is 800–1500 m. The length of the drainage is 5400 m, and the width is 2500 m. The depth of the wells is 42–62 m.

The vertical drainage system in Skadovsk city belongs to the linear type. The drainage is located on the northern outskirts of the city. The distance of the drainage to the sea to the south is about 3000 m, and to the north to the Oleksandrivskyi (Krasnoznamyanskyi) canal is 7000 m. The drainage contains 7 wells, the distance between which is 350–700 m. The total length of the drainage line is 3100 m. The depth of the wells is 48–51 m.

Research results. The results of field studies [3; 9; 11; 12; 21; 28–30; 32–38] show that with practically continuous operation of all existing wells, which was characteristic until 1995, vertical drainage ensured the maintenance of the groundwater level at depths of 2–3 m and there was almost no waterlogging of protected areas. After 1995, in connection with a sharp increase in the price of electricity, a large part of the wells was disconnected, but, as the results of the research showed, with the constant operation of only part of the wells (about 30 %), there was a gradual rise in the level of groundwater to a depth of 1–2 m. Moreover, during this mode of operation in wet periods (1997–1998, 2004–2005), temporary flooding of drainless depressions and long-term waterlogging of lands were observed [3; 11–14; 18; 21; 23; 24; 28–30; 32–38]. Including an additional number of wells in operation helped eliminate flooding, but in general, did not ensure a decrease in groundwater levels to the required depth of 2–3 m (Table 1).

1. Main characteristics and performance indicators of vertical drainage

Name of the settlement	Area, ha	Drainage area, ha	Number of wells, pcs.	Depth of wells, m	Operation of wells, years	Number of wells, pcs.	Depth of groundwater levels, m
Chornyanka	463	180	32	–	50	3	1–2
Nova Mayachka	1984	1248	20	26	55	12	1–2
Stara Mayachka	314	267	10	65	51	4	1–2
Podo-Kalynivka	519	420	11	65	51	3	1,4–3,0
Tarasivka	441	365	10	70	52	2	1–3
Velyki Kopani	1821	975	10	65	51	2	1,5–3,0
Kalanchak	1292	683	19	42–62	48	5	1–2
Skadovsk	1500	625	7	48–51	53	3	1–3
	8334	4763	119	26–70	48–55	34	1–3

Long-term studies have established that with the constant operation of only a part of the existing vertical drainage wells (no more than 30%), a sharp increase in water inflow and rise in groundwater levels are observed, which in wet periods causes the development of flooding and waterlogging process, which cannot be quickly eliminated by including additional wells. In these conditions, in order to ensure effective protection of territories, it is proposed to additionally strengthen the effect of vertical drainage by installing closed horizontal drainage systems with self-flowing, low-sloping, and non-sloping drainage of runoff in the Dnipro River and the Black Sea in the area of the settlements of Korsunka, Oleshky, and Darivka (Fig. 2–5).

In addition, during the period of extreme waterlogging, it is recommended to include

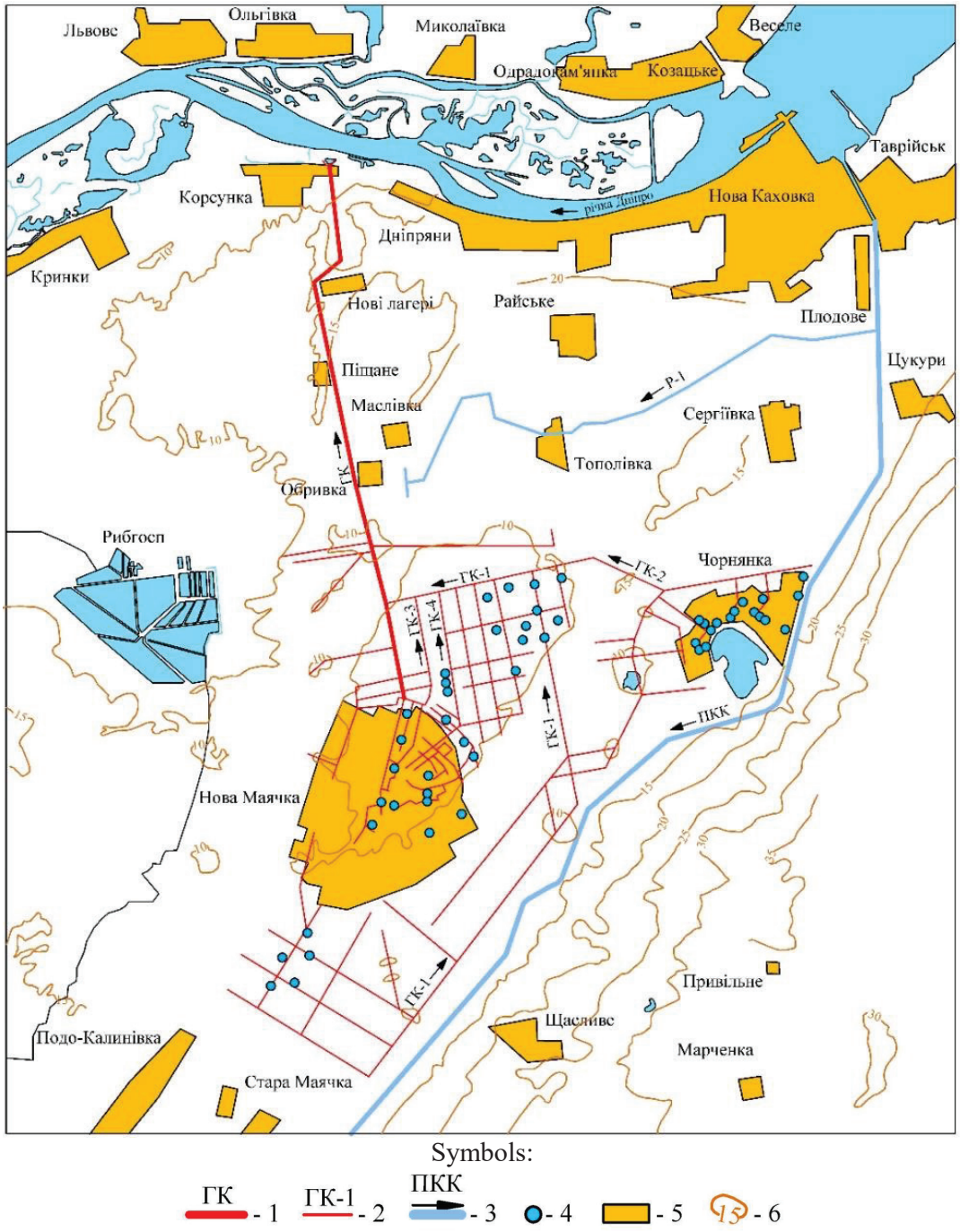


Fig. 2. Scheme of the collector and drainage network in the area of Nova Mayachka village:
1 – main collector; 2 – closed drains; 3 – main canals; 4 –vertical drainage wells; 5 – settlements;
6 – horizontals of the area

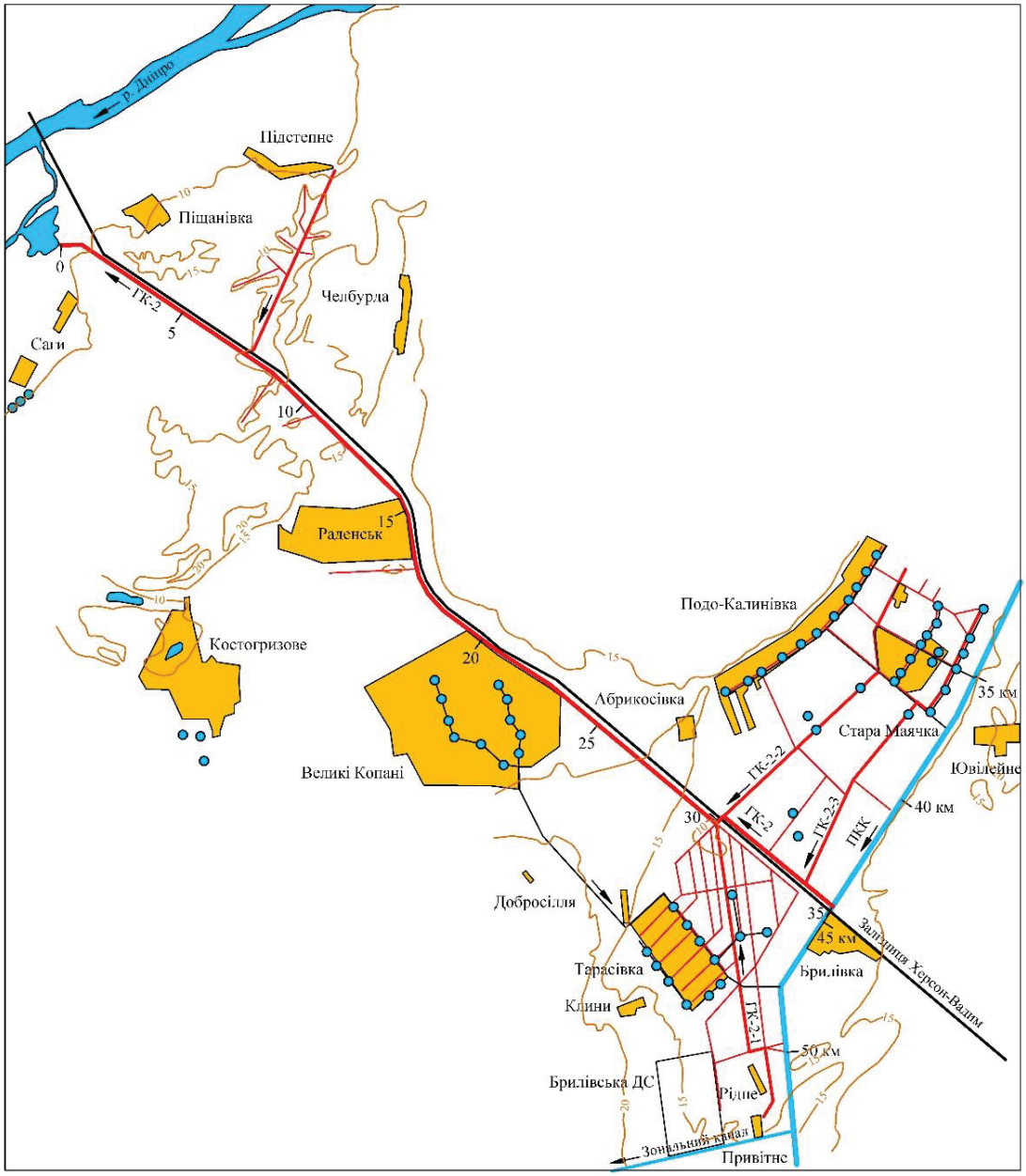


Fig. 3. Scheme of Tarasivka main collector MC-2:
1 – main collector; 2 – closed drains; 3 – main canals (NCC, Zonal); 4 – vertical drainage wells; 5 – settlements; 6 – horizontals of the area; 7 – railway lines

in that operation part of the existing vertical drainage wells that are not constantly in use. The area of land on which horizontal drainage with gravity drainage should be arranged is about 40.000 hectares, and the depth of laying the drains should be 2.5–3.5 m. Drainage water is proposed to be carried out by gravity collectors with a depth of 2.5 to 11.0 m.

The total approximate length of the collector and drainage network reaches 456 km (Table 2).

The closed horizontal drainage is laid from plastic drainage pipes with a diameter of 200 mm, wrapped with fiberglass in two layers. Under laying pipes in one line are formed drains, for two or more lines are formed drains and draining collectors. Drains are connected to the collector using inspection reinforced concrete wells. Wells are also arranged at the bends of drainage lines, before and after highway crossings, after 2.0–2.5 km, etc.

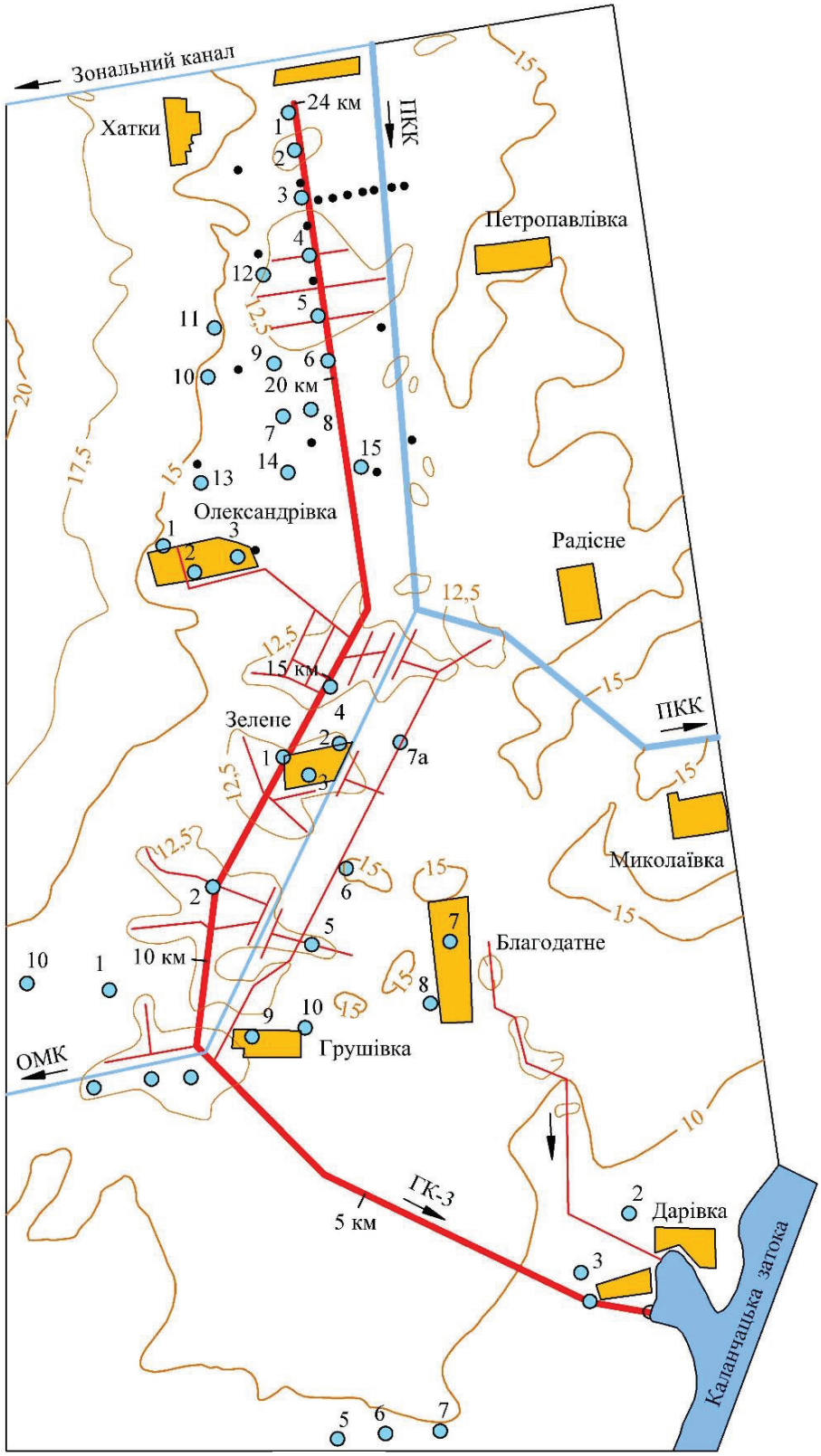


Fig. 4. Scheme of the main collector MC-3:
1 – collector; 2 – closed drains; 3 – main canals (NCC – North Crimea, OMC – Oleksandrivskyi);
4 – vertical drainage wells; 5 – observation wells; 6 – settlements; 7 – horizontals of the area

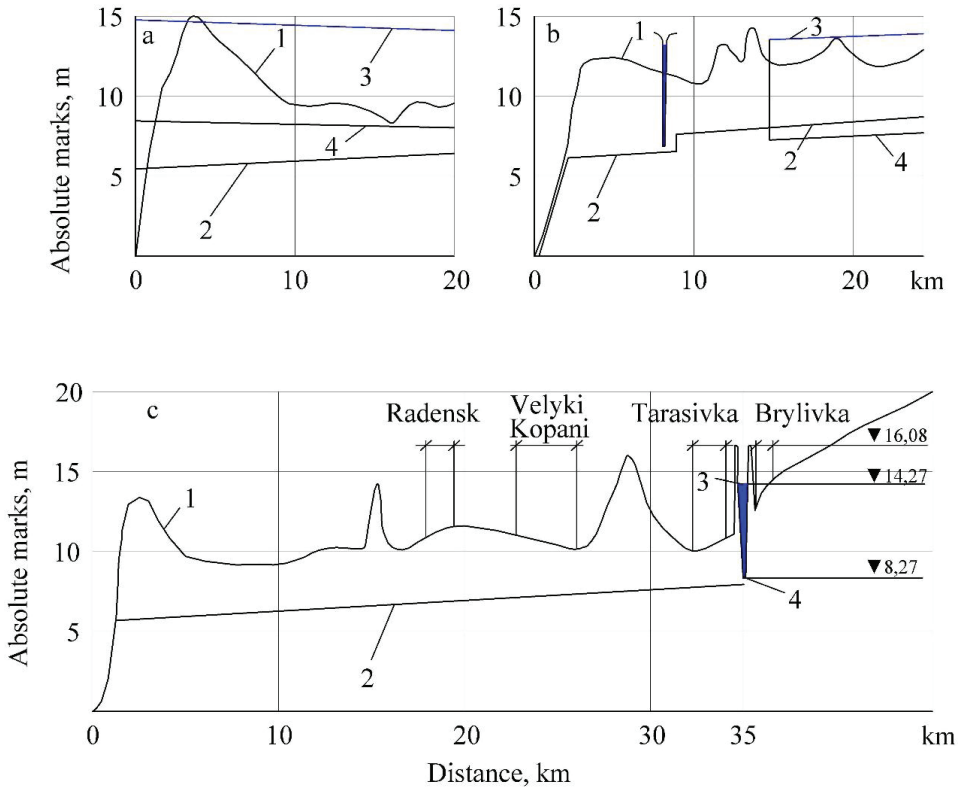


Fig. 5 Longitudinal profiles of the main collectors:
a – Novomayatskyi; b – Tarasivskyi; c – Darivskyi;
1 – the surface of the earth along the route of the collectors; 2 – the bottom of the collector;
3 – the water level in the NCC; 4 – the bottom of the NCC

2. Approximate characteristics of closed horizontal drainage in the zone of NCC

Collectors	Drainage area, thousand ha	Laying depth, m	Drainage length, km	
			main collectors	drains
MC-1	19,6	2,5–11,0	16	183
MC-2	10,0	2,5–9,0	38	135
MC-3	9,6	3,0–6,0	24	60
Total	39,2	2,5–11,0	78	378

Conclusions. Research has established that under the current mode of operation, vertical drainage does not provide reliable and effective protection of territories from the harmful effects of water in the zone of the North Crimean Canal of the Kherson region. Groundwater levels in the areas currently protected by vertical drainage are mainly at depths of 1–2 m, which is subject to waterlogging, and in some wet and extremely wet periods, temporary flooding is observed. To ensure the protection of territories from waterlogging and flooding, it is proposed to strengthen the protective effect of vertical drainage with systems of closed horizontal drainage of the gravity type. The area of such drainage will be about 40,000 hectares, the estimated length of the collector and drainage network is 456 km, and the depth of its laying is 2,5–11,0 m.

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ЗАХИСТ ТЕРИТОРІЙ ВІД ПІДТОПЛЕННЯ В ЗОНІ ПІВНІЧНО-КРИМСЬКОГО КАНАЛУ ХЕРСОНСЬКОЇ ОБЛАСТІ ТА ШЛЯХИ ЙОГО УДОСКОНАЛЕННЯ

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Анотація. *Розглянуто системи захисту територій від шкідливої дії вод за допомогою вертикального дренажу в зоні Північно-Кримського каналу Херсонської області та обґрунтовано пропозиції щодо їх удосконалення шляхом створення додаткових систем горизонтального дренажу з самопливним водовідведенням. Натурні дослідження дренажу проводили на 8 дослідно-виробничих ділянках загальною площею 4763 га і терміном експлуатації 48–55 років і більше. Проведені дослідження містили обстеження дренажу на ділянках, вимірювання дренажного стоку та глибин залягання рівнів ґрунтових вод, визначення ефективності роботи. Дослідження охопили населені пункти: Чорнянка, Нова Маячка, Стара Маячка, Подо-Калинівка, Тарасівка, Великі Копані, Каланчак та Скадовськ, для захисту яких облаштовано 119 водозабірних свердловин глибиною 26–70 м. Показано ефективну роботу вертикального дренажу у період його повноцінної роботи та недостатню у періоди вибіркової роботи, коли рівні ґрунтових вод знаходились на глибинах 2–3 м і 1–2 м відповідно. Для забезпечення надійного захисту територій від підтоплення та затоплення в сучасних умовах у зв'язку з неможливістю та економічною недоцільністю відновлення роботи всіх наявних свердловин вертикального дренажу запропоновано існуючі системи захисту на його основі доповнити системами закритого горизонтального дренажу самопливного типу з малопохиловим та безпохиловим водовідведенням стоку. Площа додаткового горизонтального дренажу становить близько 40 тис. га, орієнтовна довжина колекторно-дренажної мережі – 456 км, глибина закладання дрен та колекторів – 2,5–11,0 м.*
Ключові слова: *вертикальний дренаж, ефективність роботи горизонтальний дренаж, самопливне водовідведення*