DOI: https://doi.org/10.31073/mivg202301-355
Available at (PDF): http://mivg.iwpim.com.ua/index.php/mivg/article/view/355

UDC 631.6: 631.432

THE NECESSITY, SCIENTIFIC AND PRACTICAL PRINCIPLES OF IMPROVING METHODS OF DRAINAGE SYSTEMS DESIGN AND CALCULATION

A.M. Rokochinskiy[1], Doctor of Technical Sciences, P.P. Volk[2], Doctor of Technical Sciences, L.R. Volk[3], Ph.D.,
[1] National University of Water and Environment Engineering, Rivne, Ukraine;
https://orcid.org/0000-0002-5248-6394; e-mail: a.m.rokochinskiy@nuwm.edu.ua;
[2] National University of Water and Environment Engineering, Rivne, Ukraine;
https://orcid.org/0000-0001-5736-8314; e-mail: p.p.volk@nuwm.edu.ua;
[3] National University of Water and Environment Engineering, Rivne, Ukraine;
https://orcid.org/0000-0003-1033-6715; e-mail: l.r.volk@ukr.net;

Abstract. *The paper presents a new approach to improving the methods of design and calculation of drainage systems and their technical elements in the drainage mode and in the subsoil moistening mode. This was done on the basis of substantiating the connection of all technical elements of the system and taking into account the influence of their work efficiency on the effectiveness of regulating the water regime of drained lands. The existence and structure of the hierarchical and hydraulic relationship between the parameters of soil flow movement, the parameters of the closed collector-drainage network, and the parameters of canals and structures of drainage systems were determined based on the application of the system methodology. A physical model, a structural model, a mathematical model, and a hydraulic model of the drainage system were developed. By using these models, the principles of determining the parameters of the hydraulic characteristics of drainage or water supply (discharge, pressure, velocity etc.) for all elements (drained massif of reclaimed field, collector and drainage network, open canals of the network, main canal, water intake) in the entire range of variation with possible consideration of changes in slopes were obtained. The considered approach will make it possible to evaluate the efficiency of water flow movement simultaneously on every technical element and on the drainage system as their interconnection. In the future, this will make it possible to improve the methods of designing and calculating the technological and structural parameters of drainage systems, and thereby ensure the overall technical, technological, economic, and ecological efficiency of their functioning in accordance with modern conditions and requirements. This is a further improvement of the methods of design and calculation of drainage systems and their technical elements, taking into account the structural, hierarchical, and hydraulic relationship between them in accordance with modern conditions and requirements. This will make it possible to increase the validity and general technical, technological, ecological and economic efficiency of the creation and functioning of drainage systems during the implementation of adaptive measures regarding the changes in climatic conditions and the level of agricultural production in the area of drainage reclamation, for example, in Ukrainian Polissia. It will also provide an opportunity to ensure the necessary level of food security in the region and the country as a whole in the war and post-war periods.*

Key words: *design, construction and operation, drainage system, optimization, ecological and economic principles*

Relevance of research. Among the biggest challenges of our time is the issue of food, water, and environmental security exacerbated by climate change and the harmful consequences of Russian aggression, which already impacted the national and global economies [1–3].

At the same time, the technical condition of the drainage systems (DS) built 40–50 years ago has deteriorated due to wear and tear along with a failure to perform the necessary set of operational measures, which has led to the deformation and silting of the closed collector and drainage network (CCDN), as the main regulatory element of such systems that work in the regime of drainage and subsoil moistening. As a result, there was a deviation of their parameters from the design values, a violation of the regime and operation of the CCDN and all other technical elements of the DS, a decrease in their throughput. The overall efficiency of the functioning of such systems and the productivity of drained lands decreased by 25…50 % compared to the design [4–6], etc.

In agricultural production, land reclamations traditionally play a leading role in ensuring its sustainable development in adverse climatic conditions.

Based on the generalized research of domestic and foreign scientists, specialists of Ukrhydromet, the Institute of Water Problems and Land Reclamation of the National Academy of Agrarian Sciences, Odesa State Ecological University, as well as the results of authors' own research, an assessment of the current state of weather and climate conditions in the Polissia zone of Ukraine, their changes and impact on the yield of cultivated crops, soil fertility and moisture availability, operating conditions of water and reclamation facilities, and the natural and reclamation state of drained lands was carried out [7–9].

At the existing speed and levels of changes in weather and climate conditions, we should expect a deterioration of natural and reclamation conditions in general both in the Polissia zone and in Ukraine as a whole. This will inevitably affect the functioning of water and reclamation objects and complexes as a result of changes in the ecological and economic resources, which determines the need to develop adaptive regime-technological and technical measures for the management of these objects on the basis of relevant research, complex scientific sectoral, state, and interstate programs.

Based on the results of the analysis and generalization of the content of programmatic international and national documents (IPCC and Working Group II) regarding the necessity and general recommendations for the development of adaptive measures related to climate change, the results of research and the general assessment of domestic and foreign scientists and specialists, the general recommendations for the development of adaptive operational, construction and design measures that have their own clear goals and are closely interconnected have been considered [10–12].

Therefore, the question of changing approaches and developing a number of appropriate measures for the adaptation to climate change aimed at effective regulation of water regime, regulation and accumulation of moisture in soil profile and within the system, the transition from traditional periodic to the implementation and provision of regular moistening of drained lands, improvement of water regulation technologies, types and structures of DS and their technical elements, methods of their design and calculation becomes extremely urgent.

Thus, the improvement of the methods of design and calculation of DS in compliance with modern economic and environmental requirements, the wide use of information and computer technologies is a mandatory condition and an integral component of the successful implementation of adaptive measures and solving the problem of increasing the general technical, technological, economic, ecological efficiency of their creation and functioning [5; 13; 14].

Analysis of the latest studies and publications. Traditionally, issues of substantiation of the type and design of the DS and their constituent technical elements (drainage, collector, canals of the lateral and fencing network, main canal, hydrotechnical structures, etc.) were solved on the basis of the application of ***water balance, hydromechanical, and empirical*** methods. At the same time, each of them has its advantages and disadvantages.

At one time, many well-known domestic and foreign scientists fruitfully dealt with various aspects of the creation and functioning of the DS (V.A. Hurin, P.I. Kovalenko, L.F. Kozhushko, O.Ya. Oliynyk, M.G. Pivovar, V.L. Polyakov, M.I. Romashchenko, O.V. Skrypnyk, V.A. Stashuk, M.M. Tkachuk, M.M. Khlapuk, V.F. Shebeko, A.M. Yangol, A.V. Yatsyk, Engelsmann K., Ernst, Hooghoudt, Kirkham, Kunze G., Ramanauskas, Schilfgoarde, Ylover R. and many others) [15–19].

In order to increase the efficiency of the DS operation with two-way regulation of the water regime of drained lands, in the 70s and 80s of the last century, issues related to the automation of water regulation management and production processes of water distribution on drying and moistening systems were intensively developed by means of hydraulic automation (B.O. Bakhovets, V.D. Dupliak, P.I. Kovalenko, Y.G. Kovalchuk, S.K. Matus, O.M. Naumchuk, V.Y. Pastushenko, O.I. Tyshenko, Y.V. Tkachuk, B.I. Chalyy, M.V. Yatsyk, etc.) [6].

Such developments on the methodology for the creation and functioning of the DS acquired a high scientific level, received comprehensive recognition, were included in the relevant industry standards and were widely implemented in practice. But, as global and domestic practice, accumulated experience, as well as scientific research have shown, unfortunately, these methods do not sufficiently take into account the changing nature of weather and climate conditions, terrain relief, water-physical properties of soils, geological and hydrogeological conditions, etc., by profile and area of the drained massif, common conditions and modes of operation of all the main technical elements and the system as a whole in their interconnection, as well as modern economic and ecological requirements for such objects.

In turn, this requires a change in scientific and methodological approaches to the justification in projects of construction, reconstruction, and modernization of drainage systems of their optimal constructive solutions (type, design, parameters of systems and their constituent technical elements) according to relevant technologies (methods, regimes, schemes) of water regulation depending on multiple variables of natural and climatic, relief, soil, hydrogeological, agrotechnical, and other conditions of the object's functioning in their interrelationship. This will make it possible to create a new generation of DS, which, in accordance with modern conditions and requirements, can regulate not only the water regime of the drained territory, but also accumulate moisture, both in the soil and within the system as a whole.

In this regard, **the purpose** of the research is to further search for new approaches to improving the design and calculation methods of DS and their technical elements that work in the mode of drainage and subsoil moistening, based on the substantiation of the relationship of all technical elements of the system and taking into account the influence of efficiency of their operation on the efficiency of regulating the water regime of drained lands.

Research methods and materials. Modern challenges related to the food, water, and environmental crises, as well as climate change, determine the need to change approaches to the creation and functioning of DS on the basis of the further development of the systematic methodology and the optimization method, as its integral component, the application of system optimization, the essence of which is a finding of intermediate local optima, when each subsequent optimal decision is made taking into account the previous one in the sequence, which corresponds to the hierarchical subordination of all their interconnected heterogeneous elements [13; 14].

According to such principles and scientific and methodical approaches

– general approaches, methods, and models for optimizing technical and technological solutions for water regulation of drained lands on ecological and economic grounds were developed by moving from the established practice of considering land reclamation objects not purely as technical, but as complex natural and technical systems;

– we prove the presence of a structural connection in such a system between disparate elements, which have a type **effect ⇔ mode ⇔ technology ⇔ design**;

– we developed the principles of construction and implementation of complex optimization models for regime-technological and constructive solutions for water regulation of drained lands;

– the criteria of economic and ecological optimization regarding different levels of management decision-making in time are substantiated (1-project, 2-planned operation, 3-operational management);

– we developed a set of predictive and simulation models for prognosis assessment on a long-term basis of variable natural, agricultural, and reclamation conditions of a real object;

– we substantiated a set of adaptive measures, which includes agromelioration (improvement of technologies and means of deep loosening of drained mineral soils) and hydrotechnical (improvement of technologies and regimes of water regulation on drained lands, corresponding types and structures of DS, technologies of their design and calculation methods) and ensures the implementation of reconstruction, modernization, and new construction of DS that meet modern conditions and requirements;

– on the basis of consideration of structural, hierarchical, mathematical models of the object and its management model, the principles of construction and implementation of relevant complex models of system optimization were developed grounding on a sequential justification based on the hierarchical subordination of regime, technological and constructive solutions in their interaction, when each subsequent optimal solution is accepted taking into account the previous one;

– complex models of system optimization were developed and the methods of their implementation were improved according to the relevant criteria and models, which make it possible to justify regime, technological and constructive solutions in projects of construction, operation, reconstruction, and modernization of substations in compliance with modern economic and ecological requirements in their interconnection;

– we improved the technology of designing DS on the basis of system optimization regarding the step-by-step assessment of technical, technological, economic, and environmental parameters of heterogeneous elements and the system as a whole using a multivariate approach and corresponding heterogeneous methods, in contrast to the existing, mostly monovariant, by combining them and sequentially implementing them according to an hierarchical subordination with decision-making according to the relevant basic project procedures. This makes it possible to comprehensively assess and improve the overall efficiency, as well as the technical, technological, economic, environmental, and investment soundness of their projects in accordance with modern conditions and requirements.

Research results and their discussion. Based on and in the development of the main provisions and principles regarding the application of the system methodology and the optimization method during the creation and functioning of water and land reclamation objects (Kovalchuk V.P., Kovalchuk P.I., Lazarchuk M.O., Turchenyuk V.O. etc.) and, based on their various definitions, we established interdependent relationships between disparate elements and such systems' characteristic technological, economic, and ecological features [20–26].

Therefore, according to [27] and other papers, when applying the most modern methodology of the system approach and system analysis to the creation and functioning of water and land reclamation objects, DS are presented as complex natural-technical and ecological-economic systems (CNTEES) in which there is a structural relationship is the form

effect ⇔ mode ⇔ technology ⇔ construction.

This determines the need for more detailed studies of the regularities of interconnected processes of water movement both in the main elements and in the system as a whole.

Therefore, by analogy and in the development of such an approach, it is advisable to single out and consider a technical subsystem of the type *soil flow movement parameters ⇔ CCDN ⇔ parameters of canals and structures of DS*, the elements of which have a structural, hierarchical, and hydraulic relationship (Fig. 1).

At the same time, a specific feature of the DS with two-way regulation of the water regime of drained lands is that the processes of water flow in the elements of the CCDN of the DS during its operation in the mode of drainage and subsoil moistening are similar, but mutually opposite and are implemented using the same CCDN.

Accordingly, the determined connection between the regime of the groundwater level and the CCDN is provided by the transformation of the filtration movement of a relatively uniform and continuous soil flow on the reclaimed field into a heterogeneous structure of a collection of separated water turbulent flows in hierarchically and hydraulically connected pressure drainage pipelines, as constituent elements of the CCDN, canals of the lateral network, main canal and water receivers with different conditions of formation of their gradients of pressures and velocities when operating in the drainage mode and vice versa – when operating in the subsoil moistening mode. This can be reflected by the corresponding subsystem

mode of movement of soil flow ⇔ mode of flow in CCDN ⇔ mode of flow in the canals of the lateral network ⇔ mode of flow in the main canal ⇔ flow mode in the water receiver.

In turn, according to the general theory of the movement of water flow in a pressure pipeline, the efficiency of the flow regime in the CCDN is determined by the parameters of the hydrodynamic structure of the velocity distribution in the cross section of the flow in a separate collector and drainage pipeline, as its main element, which determines the efficiency of each such element and the CCDN in general. At the same time, it is obvious that the efficiency of the CCDN in the pressure mode is determined by the efficiency of the canals of the lateral network, the main canal, and the water receiver, in which the movement of water occurs in an open canal.

According to the construction structure and connections between the elements of a self-flowing DS (see Fig. 1), we developed its physical model (Fig. 2), which works in the mode of drainage and subsoil moistening, for which a patent for a useful model was obtained (No. 147568) [28].

The advantage of the proposed scheme is that it reflects the principles of determining the parameters of the hydraulic characteristics of drainage or water supply (discharge, pressure, velocity, etc.) simultaneously for all elements

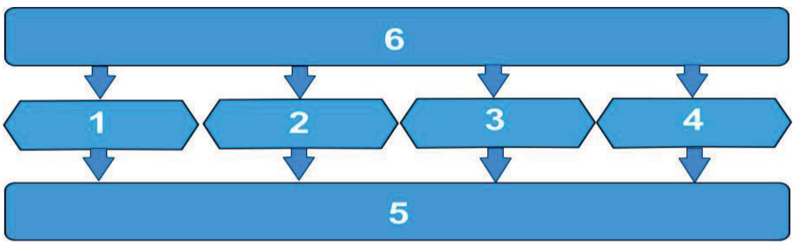

Fig. 1. Structure diagram of DS:
1 – collector and drainage network on the reclaimed field; 2 – lateral canal network; 3 – main canal; 4 – water receiver; 5 – facilities and means of drainage automation; 6 – facilities and means of water supply automation

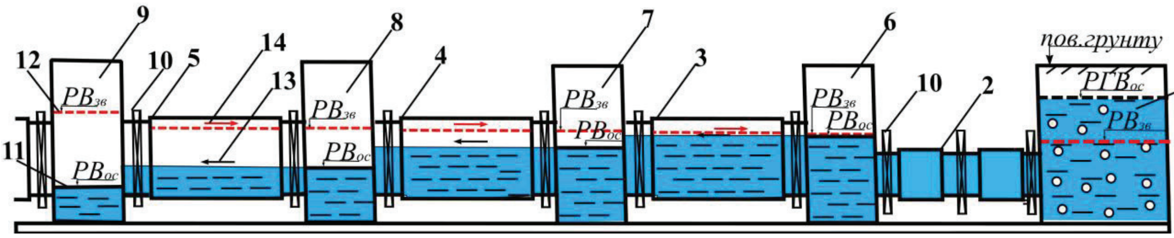

Fig. 2. Structural diagram of the interconnection of the main technical elements of the DS: 1 – an element of the reclaimed field; 2 – CCDN; 3 – an element of open canals of the lateral network; 4 – the main canal element; 5 – a water receiver element; 6 – the tank that displays the water level in the CCDN, lateral network (7), main canal (8), water receiver (9); 10 – capacity regulators; 11, 12 – water levels during system operation, respectively, in drying and moistening modes (12); 13, 14 – directions of water movement through system elements when working in the drying and moistening mode, respectively

of the DS (drained massif of the reclaimed field, collector and drainage network, open canals of the lateral network, main canal, water receiver) in almost the entire range of their variation with the possible consideration of changes in slopes.

Accordingly, by introducing the necessary notation, the functional relationship between its components can, in the general case, be represented as a complex function that does not have an explicit solution

$$y_i = f_1\left(f_2\left(f_3\left(x_i\right)\right)\right),\ i=\overline{1,n_i}, \qquad (1)$$

where f_1 is the function that depends on the parameters of the movement of soil flow R_i, $i=\overline{1,n_i}$; f_2 is the function that depends on the parameters of the CCDN FS_i, $i=\overline{1,n_i}$; f_3 is the function of arguments x_i, which depends on the parameters of canals and facilities K_i, $i=\overline{1,n_i}$; i is the set $\{i\}$, $i=\overline{1,n_i}$ of possible options for the implementation of appropriate technical and technological solutions for water regulation of drained lands in the appropriate natural, agricultural, and land reclamation conditions of a real object.

The listed functions f_1 ... f_3 are functions of complex interconnected arguments, i. e.

$f_3\left(x_i\right)$ – as a function that depends on the parameters of canals and facilities;

$f_2\left(f_3\left(x_i\right)\right)$ – as a function that depends on the parameters of the closed collector and drainage network;

$f_1\left(f_2\left(f_3\left(x_i\right)\right)\right)$ – as a function that depends on the parameters of the movement of soil flow.

Then, the search for the parameters of the components of the composite function (1) and, first of all, the parameters of water regulation technologies and the type and design of technical elements related to them, depending on the created mode of flow movement, can be formally carried out from the expression (1) through the corresponding inverse functions.

Namely:

– regarding the parameters of canals and facilities FK_i, $i=\overline{1,n_i}$

$$f_3\left(x_i\right) = f_2^{-1}\left(f_1^{-1}\left(y_i\right)\right),\ i=\overline{1,n_i}; \qquad (2)$$

– regarding the parameters of the closed collector and drainage network FS_i, $i=\overline{1,n_i}$

$$f_2\left(f_3\left(x_i\right)\right) = f_1^{-1}\left(y_i\right),\ i=\overline{1,n_i}; \qquad (3)$$

– regarding the parameters of soil flow movement FR_i, $i=\overline{1,n_i}$

$$x_i = f_3^{-1}\left(f_2^{-1}\left(f_1^{-1}\left(y_i\right)\right)\right),\ i=\overline{1,n_i}. \qquad (4)$$

The implementation of complex functions (1) – (4) should be based on the studies of the regularities of interconnected processes of water movement in all the constituent elements (subsystems) of the DS as CNTEES, which are different by their nature.

In this setting, models (1) – (4), which are presented in a general implicit form, cannot be sufficiently adequately expressed analytically and have no practical solution. But they make it possible to theoretically substantiate the possibility of setting a problem at least on an empirical or even on a much more objective empirical-functional level of determining the dependence between them.

Based on the structural model of the DS (see Fig. 1) and the established nature of the connections between its system elements in general according to mathematical models (1) – (4), the integral amount of water during the operation of the DS in the mode of water removal (drainage -) or subsoil moistening (water supply +) ($\pm W_S$) in time (T) and space (F), in the general case can be determined as

$$\pm W_S = \int_0^T \int_0^F w_i \cdot \left(T, F\right)\ dt\ df,\ i=\overline{1,n_i}, \qquad (5)$$

where w_i is the integral amount of water during water removal or water supply, which passes through each DS's technical element in the set $\{i\}$, $i=\overline{1,n_i}$; T is the period of system's operation; F is the area of the system as a whole.

Then, the volume of water for DS during drainage or water supply, taking into account the necessary and technically possible amount of it, can be generally defined as

$$\pm W_S = \Delta_s \left(\hat{q}_s \cdot T \cdot F_s \right), \quad (6)$$

where Δ_s is the coefficient of imperfection of the system as a whole in relation to the ratio of the required and possible amount of drainage or water supply by it; $\hat{q}_s$ is the time- and space-weighted average value of the drainage or water supply module within the system and the period of the object's operation.

The coefficient Δ_s of imperfection of the system as a whole regarding the ratio W_{sf} of possible (actual) and the ratio W_{st} of necessary (calculated) drainage or water supply by it can be represented a dependency

$$\Delta_s = \frac{W_{sf}}{W_{st}} = \frac{\sum_{i=1}^{n_i} W_{if}}{\hat{u}_S \cdot T \sum_{i=1}^{n_i} f_i \cdot F_s}, \quad (7)$$

where $\hat{u}_S$ is the average value of the velocity of water flows movement in the system, m/s; f_i is the share of the DS area that is served by a certain technical element: the collector and drainage network of the set $\{kd\}$, $kd=\overline{1,n_{kd}}$, lateral canals network of the set $\{b\}$, $b=\overline{1,n_b}$; main canal of the set $\{m_k\}$, $m_k=\overline{1,n_{m_k}}$; water receiver (υ).

Accordingly, for any technical element of DS (see Fig. 1)

$$\pm W_i = \sum_{m_i=1}^{n_{m_i}} \Delta_{n_{i-1}} \left(\overline{q}_i \cdot T_i \cdot f_i \cdot F_s \right), \quad (8)$$

where $\pm W_i$ is the volume of water that is diverted or supplied to the DS by any of its technical elements; m_i is the number of constituent elements of the i-th technical element of the DS; $\Delta_{n_{i-1}}$ is the coefficient of imperfection of the technical elements of the DS when the efficiency of each subsequent element is determined by the previous one; q_i is the calculated module of drainage flow or water supply in relation to the corresponding mode of operation of the i-th technical element of the DS, l/s·ha; T_i is the period of operation of the technical element on the system.

The efficiency of the system is determined by the corresponding efficiency of each of its elements, the nature of the complex relationships between which is similar to the models (1) – (4):

$$\Delta_s = f_n \left(f_{n-1} \left(\sum_{i=1}^{n_i} \Delta_{n_{i-1}} \right) \right). \quad (9)$$

That is, the efficiency of each subsequent element of the system is determined by the corresponding efficiency of the previous one and vice versa.

In turn, by the analogy with the formula (7), the coefficient of imperfection $\Delta_{n_{i-1}}$ of the system's element is the ratio of the possible (actual) volume of water W_{if} and the necessary (calculated) volume of water W_{if}, which is drained or supplied to the DS by any of its technical elements:

$$\Delta_{n_{i-1}} \left(W_i \right) = \frac{W_{if}}{W_{it}}. \quad (10)$$

Then, applying the equations of the statistical theory of determining the influence of each operating factor on the initial parameter, the following equation can be obtained:

$$\Delta_{n_{i-1}} \left(W_i \right) = \frac{W_{it} - \sqrt{\sum_{j=1}^{z} \left(\Delta x_j \frac{\partial y}{\partial x_j} \right)^2}}{W_{it}}, \quad (11)$$

where x_j is the main j-th operating factor (average speed in the element of the system; the area of any technical element of the system; time, etc.); z is the number of active factors in the equation of the initial parameter; Δx_j is the absolute change of values of j-th factor of the initial parameter.

Since the movement of water in the self-flowing DS during its operation in the drying and moistening mode is caused by the presence of the necessary pressure gradient due to the difference in levels (see Fig. 2), the hydraulic model of the system and any of its technical elements in general can be represented as: (12) – for the system; (13) – for its technical elements:

$$\pm W_s = \Delta_s \hat{u}_S T \sum_{i=1}^{n_i} \omega_i; \quad (12)$$

$$\pm W_i = \sum_{m_i=1}^{n_{mi}} \Delta_{n_{i-1}} u_i \omega_i \cdot T_i \quad i=\overline{1,n_i}, \quad (13)$$

where ω_i is the area of a technical element of the system, m; u_i is the average speed of water flow in the technical element, m/s; l_i is the parameter of the system's element (canal bed or pipeline), from which water is drained at a certain stage i during the estimated time period T, m.

Conclusions. Thus, the considered issues cause the need for further improvement of the design and calculation methods of DS and their technical elements, taking into account the structural, hierarchical, and hydraulic relationship between them in accordance with modern conditions and requirements, which, in particular, is reflected in the adopted "Irrigation and Drainage Strategy in Ukraine on the period until 2030" [29].

This will make it possible to increase the validity and general technical, technological, and ecological-economic efficiency of the creation and functioning of the DS during the implementation of adaptive measures to the climatic conditions change and the level of agricultural production in the zone of drainage land reclamation, primarily in the Ukrainian Polissia, to ensure the necessary level of food security in the region and the country in general, in the war and post-war periods.

References

1. Kovalenko P., Rokochinskiy A., Jeznach J., Volk P., Koptyuk R. & Prykhodko N. (2019). Evaluation of climate change in Polissia region and ways of adaptation to it. *Journal of Water and Land Development*. Vol. 41. Iss. 1. P. 72–82. DOI: 10.2478/jwld-2019-0030

2. Ukrinform. (2022). URL: https://www.ukrinform.ua/rubric-world/3610439-klimaticna-transformaciauskladnuetsa-agresieu-rf-proti-ukraini-duda.html

3. Gai-Nyzhnyk P.P., Krasnodemska I.Y., Figurny Yu.S., Chirkov O.A. & Chupriy L.V. (2018). Rosiyska ahresiya proty Ukrayiny: pravda i vyhadky, prychyny i naslidky – [Russian aggression against Ukraine: truth and fiction, causes and consequences]. Kyiv : MP Lesya, 2018. 435 p. [in Ukrainian]

4. Hadzalo Ya.M., Stashuk V.A. & Rokochynsky A.M. (2017). Melioratsiia ta oblashtuvannia Ukrainskoho Polissia – [Reclamation and arrangement of Ukrainian Polissya]. Vol. 1. Kherson : OLDI-PLIUS. [in Ukrainian]

5. Stashuk V.A., Rokochynskyi A.M. & Volk, P.P. (2021). Naukovo-metodychni rekomendatsiyi shchodo stvorennya ta funktsionuvannya drenazhnykh system u zminnykh suchasnykh umovakh – [Scientific and methodological recommendations for the creation and functioning of drainage systems in changing modern conditions]. Rivne : NUVHP. URL: http://ep3.nuwm.edu.ua/id/eprint/21450 [in Ukrainian]

6. Volk L.R., Bezusiak O.V. & Volk, P.P. (2021). Udoskonalennya rozmiriv zamknutoyi kolektorno-drenazhnoyi merezhi vodovidvidnykh system – [Improving the dimensioning of closed collecting and drainage network of drainage systems]. *Melioratsiia i vodne hospodarstvo*. Vol. 1. P. 98–106. DOI: 10.31073/mivg202101-269 [in Ukrainian]

7. Romaschenko M., Gusev Yu., Shatkovskyi A., Saidak R., Yatsyuk M., Shevchenko A. & Matiash T. (2020). Vplyv zminy klimatu na vodni resursy ta sil's'kohospodars'ke vyrobnytstvo – [Impact of climate change on water resources and agricultural production]. *Melioratsiya ta upravlinnya vodnymy resursamy*. Vol. (1). P. 5–22. DOI: 10.31073/mivg202001-235 [in Ukrainian]

8. Rokochynskyi A., Turchenyuk V., Volk P., Koptyuk R. & Prykhodko N. (2021). Obgruntuvannya neobkhidnosti pidvyshchennya adaptatsiynoho potentsialu meliorovanykh zemel hidromelioratyvnykh system u zminnykh klimatychnykh umovakh – [Justification of the need to increase the adaptation potential of reclaimed lands of hydromelioration systems in changing climatic conditions]. *Visnyk LNAU. Seriia "Arkhitektura i silskohospodarske budivnytstvo"*. Vol. 22. P. 144–149. [in Ukrainian]

9. Rokochynskyi A., Mazhayskiy Y., Volk P., Yeznah J., Volchak A., Meshyk A., Chernikova, O. & Prykhodko N. (2021) Necessity and ways to increase adaptive potential of dried land in changeable climatic conditions. *Engineering for rural development* : 20th International Scientific Conference Proceedings. Vol. 20. P. 63–73. DOI: 10.22616/ERDev.2021.20.TF015

10. Climate Change and Land. An IPCC Special Report on climate change, desertification, land degradation, sustainable land management, food security, and greenhouse gas fluxes in terrestrial ecosystems (IPCC). URL: https://www.ipcc.ch/reports/ (accessed 29.04.2020).

11. United Nations. FCCC. (1992). United Nations framework convention on climate change. INFORMAL. 84 GE.05-62220 (E) 200705. URL: https://unfccc.int/resource/docs/convkp/conveng.pdf

12. United Nations. (1998). nited Nations framework convention on climate change. Kyoto Protocol, Kyoto. URL: https://unfccc.int/resource/docs/convkp/kpeng.pdf

13. Rokochynskyi A.M. & Volk P.P. (2020). Teoretychni aspekty systemnoyi optymizatsiyi stvorennya ta funktsionuvannya drenazhnykh system na ekoloho-ekonomichnykh zasadakh – [Theoretical aspects of system optimization of the creation and functioning of drainage systems on ecological and economic grounds]. *Visnyk NUVHP. Seriia "Tekhnichni nauky"*. Vol. 3 (90). P. 3–21. [in Ukrainian]

14. Rokochynskyi A.M. & Volk P.P. (2021). Modeli systemnoyi optymizatsiyi dlya stvorennya y funktsionuvannya drenazhnykh system u suchasnykh umovakh – [System optimization models for the creation and functioning of drainage systems in modern conditions]. *Melioratsiia i vodne hospodarstvo*. Vol. 1. P. 75–86. [in Ukrainian]

15. Khlapuk M.M. & Tyshenko O.I. (2003). Pidvyshchennia efektyvnosti i nadiinosti osushuvalno-zvolozhuvalnykh system – [Improving the efficiency and reliability of dehumidification and humidification systems]. *Bulletin of the Engineering Academy of Ukraine*. Vol. 2. P. 57–65. [in Ukrainian]

16. Kovalenko P.I., Yatsyk M.V. & Poliakov V.P. (1996). Upravlinnia volohozabezpechenistiu silskohospodarskykh kultur na meliorovanykh zemliakh z urakhuvanniam dynamiky faktoriv zovnishnoho seredovyshcha – [Management of moisture supply of agricultural crops on reclaimed lands taking into account the dynamics of environmental factors]. *Land reclamation and water management*. Vol. 82. P. 3–12. [in Ukrainian]

17. Oleinyk A.Ya.(1981). Heohydrodynamyka drenazhu – [Geohydrodynamics of drainage]. Kyiv : Naukova dumka. [in Ukrainian]

18. Oleinyk A.Ya. & Poliakov V.L. (1987). Drenazh pereuvlazhnennykh zemel – [Drainage of waterlogged lands.]. Kyiv : Naukova dumka. [in Ukrainian]

19. Kozhushko L.F. (2001). Udoskonalennia drenazhnykh system – [Improvement of drainage systems] : monohrafiia. Rivne : Vydavnytstvo RDTU. 279 p. [in Ukrainian]

20. Kovalchuk P.Y. & Ostapchyk V.P. (1982). Opredelenye modelei urozhaia v zavysymosty ot dynamyky vodosnabzhenyia rastenyi – [Determination of yield patterns depending on the dynamics of plant water supply]. *Melyoratsyia y vodnoe hospodarstvo*. Vol. 55. P. 3–5. [in Ukrainian]

21. Kovalchuk P.I. & Mykhalska T.O. (1994). Systemne modeliuvannia dlia otsinky efektyvnosti resursozberihaiuchykh tekhnolohii upravlin nia polyvamy – [System modeling to evaluate the efficiency of resource-saving irrigation management technologies]. *Melioratsiia i vodne hospodarstvo*. Vol. 81. P. 30–35. [in Ukrainian]

22. Kovalchuk P.I. & Chystokletova, V.O. (1994). Optymizatsiia vodokorystuvannia na osnovi vyznachennia rozrakhunkovoi zabezpechenosti zroshuvalnykh norm – [Optimization of water use on the basis of determining the estimated security of irrigation norms]. *Melioratsiia i vodne hospodarstvo*. Vol. 81. P. 39–42. [in Ukrainian]

23. Lazarchuk M.O., Cherenkov A.V. & Rokochynskyi A.M. (2009). Optymizatsiia rozrakhunku osushuvalnykh system ta upravlinnia nymy – [Optimization of drainage systems calculation and management]. Rivne : NUVHP. [in Ukrainian]

24. Rokochynsky A.M., Cherenkov A.V., Muranov V.H. & Volk P.P. (2013). Naukovometodychni rekomendatsii do obgruntuvannia optymalnykh parametriv silskohospodarskoho drenazhu na osushuvanykh zemliakh za ekonomichnymy ta ekolohichnymy vymohamy – [Scientific and methodological recommendations for the substantiation of optimal parameters of agricultural drainage on drained lands according to economic and ecological requirements.]. Rivne : NUVHP. [in Ukrainian]

25. Turcheniuk V.O. & Rokochynskyi A.M. (2020). Systemna optymizatsiia vodo- ta enerhokorystuvannia na ekolohoekonomichnykh zasadakh na rysovykh zroshuvalnykh systemakh – [System optimization of water and energy use on the basis ecological and economic principles in rice irrigation systems] / A.M. Rokochynskyi (Ed.). Rivne : NUVHP. [in Ukrainian]

26. Stashuk V.A., Vozhehova R.A., Dudchenko V.V., Rokochyskyi A.M. & Morozov V.V. (2020). Pidvyshchennia efektyvnosti funktsionuvannia rysovykh zroshuvalnykh system Ukrainy – [Improving the efficiency of rice irrigation systems in Ukraine] : naukovo-metodychni rekomendatsii. Rivne : NUVHP. [in Ukrainian]

27. Rokochynskyi A.M. (2010). Naukovi ta praktychni aspekty optymizatsii vodorehuliuvannia osushuvanykh zemel na ekoloho-ekonomichnykh zasadakh – [Scientific and practical aspects of optimization of water regulation of drained lands on ecological and economic principles] / M.I. Romashchenko (Ed.). Rivne : NUVHP. [in Ukrainian]

28. Rokochynskyi A.M. & Volk P.P. (2021). Prystriy dlya vyznachennya parametriv hidravlichnykh kharakterystyk vodovidvedennya abo vodopodachi drenazhnoyi systemy v laboratornykh umovakh – [A device for determining the parameters of the hydraulic characteristics of drainage or water supply of the drainage system in laboratory conditions]. Patent of Ukraine. № 150069. [in Ukrainian]

29. Stratehiia zroshennia ta drenazhu v Ukraini na period do 2030 roku – [Irrigation and drainage strategy in Ukraine until 2030] : skhvaleno rozporiadzhenniam Kabinetu Ministriv Ukrainy № 688. (2019, August 14). *Uriadovyi kurier*. No. 170. URL: https://zakon.rada.gov.ua/laws/show/688-2019-%D1%80 [in Ukrainian]

УДК 631.6: 631.432

НЕОБХІДНІСТЬ ТА НАУКОВО-ПРАКТИЧНІ ЗАСАДИ УДОСКОНАЛЕННЯ МЕТОДІВ ПРОЕКТУВАННЯ І РОЗРАХУНКУ ДРЕНАЖНИХ СИСТЕМ

А.М. Рокочинський[1], докт. техн. наук, П.П. Волк[2], докт. техн. наук, Л.Р. Волк[3], канд. техн. наук

[1] Національний Університет Водного Господарства та Природокористування, Рівне, Україна; https://orcid.org/0000-0002-5248-6394; e-mail: a.m.rokochinskiy@nuwm.edu.ua;
[2] Національний Університет Водного Господарства та Природокористування, Рівне, Україна; https://orcid.org/0000-0001-5736-8314; e-mail: p.p.volk@nuwm.edu.ua;
[3] Національний Університет Водного Господарства та Природокористування, Рівне, Україна; https://orcid.org/0000-0003-1033-6715; e-mail: l.r.volk@ukr.net;

Анотація. *Розглянуто новий підхід до удосконалення методів проектування і розрахунку дренажних систем та їх технічних елементів, які працюють в режимі осушення та підґрунтового зволоження, на основі обґрунтування взаємозв'язку всіх складових технічних елементів системи та врахування впливу ефективності їх роботи на ефективність регулювання водного режиму осушуваних земель. На основі застосування системної методології визначено наявність та структуру ієрархічного та гідравлічного взаємозв'язку між параметрами руху ґрунтового потоку, закритої колекторно-дренажної мережі й параметрами каналів та споруд дренажних систем. Розроблено фізичну, структурну, математичну та гідравлічну модель дренажної системи, за якими розроблено принципи визначення параметрів гідравлічних характеристик водовідведення або водоподачі (витрата, напір, швидкість тощо) одночасно по всіх її елементах (осушуваного масиву меліорованого поля, колекторно-дренажної мережі, відкритих каналів бокової мережі, магістрального каналу, водоприймача) практично у всьому діапазоні їхнього варіювання з можливим урахуванням зміни ухилів. Розглянутий підхід дасть змогу оцінити ефективність руху водного потоку одночасно по всіх технічних елементах й дренажної системи в цілому у їх взаємозв'язку та в подальшому удосконалити методи проектування й розрахунку її технологічних та конструктивних параметрів й, тим самим, забезпечити загальну технічну, технологічну, економічну і екологічну ефективність їх функціонування відповідно до сучасних умов та вимог. Подальше удосконалення методів проектування й розрахунку ДС та їх технічних елементів з урахуванням структурного, ієрархічного і гідравлічного взаємозв'язку між ними відповідно до сучасних умов та вимог, дасть змогу підвищити обґрунтованість і загальну технічну, технологічну та еколого-економічну ефективність створення й функціонування ДС при реалізації адаптивних заходів щодо зміни кліматичних умов та рівень аграрного виробництва у зоні осушувальних меліорацій, насамперед в Українському Поліссі, забезпечити необхідний рівень продовольчої безпеки в регіоні та країні в цілому у воєнний й повоєнний періоди.*

Ключові слова: *проєктування, створення та функціонування, дренажна система, оптимізація, еколого-економічні засади*