

DETERMINATION OF THE EFFECTIVE LENGTH OF COLLECTING DRAINAGE PIPELINES

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In modern agriculture, hydroameliorative systems play a crucial role in enhancing the efficiency of agricultural land use. One of the key components of these systems is the collecting drainage pipelines, which ensure effective drainage, necessary for improving soil conditions and reducing the risk of flooding areas [1, 2].

The intensity of groundwater drainage from a site is usually expressed through the drainage runoff modulus q_m (l/(s·ha)) or, in the case of infiltration feeding, through its intensity ε (m/day), which refers to the water flow rate coming from a unit area of the free flow surface. The relationship between q_m and ε is given by the following equation [3]:

$$\varepsilon = \frac{q_m}{116}. \quad (1)$$

Using formula (1), the minimum allowable water flow rate, which should be supplied to a unit length of drainage pipe to ensure the calculated conditions for lowering the groundwater level and the necessary moisture regime in the soil, can be determined by the following relationship:

$$q_{\min} = \left(\frac{dQ}{dx} \right)_{\min} = q_m E = 116 \varepsilon E, \quad (2)$$

where E is the distance between drainage pipelines, m.

As shown in many studies [4, 5], a system of two differential equations has been used to describe the fluid motion in perforated drainage pipelines. This system consists of the equation of fluid motion with variable flow rate (3) and the modified filtration equation (4):

$$\frac{dh}{dx} + \frac{2}{g} V \frac{dV}{dx} + \frac{\lambda_{col}}{2gD} V^2 = 0 \quad (3)$$

$$q = \frac{dQ}{dx} = \frac{d(V\Omega)}{dx} = \frac{k_f(H-h)}{\bar{F}} = k_f \frac{z}{\bar{F}}, \quad (4)$$

where H is the depth of immersion of the pipeline axis from the groundwater level; h is the piezometric head in the pipe; $z=H-h$ is a pressure drop varying along the length, under the influence of which liquid flows from the environment into the pipeline; Q , V , D , Ω is accordingly, the flow rate, average velocity, diameter, and cross-sectional

area of the flow at a distance x from the beginning of the pipe; \bar{F} is dimensionless drainage resistance (its determination represents a separate filtration problem [6]); k_f is the filtration coefficient of soil around the pipe; λ_{dis} is the hydraulic friction factor of the distribution drainage pipeline; g is the acceleration of gravity.

By introducing new variables

$$\bar{V} = \frac{V}{\sqrt{gz_{fin}}}, \quad \bar{x} = \frac{k_f x}{\Omega \bar{F}} \sqrt{\frac{z_{fin}}{g}}, \quad \bar{z} = \frac{z}{z_{fin}}, \quad (5)$$

and neglecting the second term in equation (1) due to its negligible effect [7], the following differential equation is obtained:

$$\bar{z} d\bar{z} = \zeta_{l_{col}} A_{col} \bar{V}^2 d\bar{V} \quad (6)$$

where $\zeta_{l_{col}} = \lambda_{col} \frac{l}{D}$ is the coefficient of resistance of the collecting drainage pipeline;

$A = \frac{\Omega \bar{F}}{2k_f l} \sqrt{\frac{g}{z_{fin}}}$ – is the generalized parameter of the collecting drain, which takes into

account its structural and filtration characteristics.

The concept of the effective length of collecting drainage pipelines (l_{ef}) should be introduced for further analysis. The effective length refers to the length of the drainage pipeline at which the minimum allowable flow rate is maintained. To enable the analytical determination of the effective length of these pipes, it is necessary to express the minimum allowable variation in the relative velocity of the part of the fluid flow (5) in new dimensionless variables (3), which may enter the collector per unit of its relative length:

$$\bar{q}_{min} = \left(\frac{d\bar{Q}}{d\bar{x}} \right)_{min} = \left(\frac{d\bar{V}}{d\bar{x}} \right)_{min} = \bar{z}_{in.ef} \quad (7)$$

where $\bar{Q} = \frac{Q}{\Omega \sqrt{gz_{fin}}} = \bar{V}$ is the relative flow rate of the fluid, which numerically equals

the relative velocity in an arbitrary cross-section of the drain; $\bar{z}_{in.ef}$ is the minimum allowable (effective) value of the relative head difference in the initial cross-section of the pipe, which ensures the required intensity of groundwater level reduction. It can be determined using a relationship analogous to (7):

$$\bar{z}_{in.ef} = \frac{1}{\left[1 + \frac{1}{4A_{ef} \bar{V}_{fin.\infty}} \right]^3}. \quad (8)$$

From this, the effective value of the generalized parameter A_{ef} will be:

$$A_{ef} = \frac{1}{4\bar{V}_{fin.\infty}} \left(\frac{1}{\sqrt[3]{\bar{z}_{in.ef}}} - 1 \right). \quad (9)$$

The value of A_{ef} , at which the required relative velocity $\bar{V}_{fin.\infty}$ in the final cross-section of the real collecting pipeline is ensured for a given value, is recommended to be determined using the graph provided in the work [8].

From (9), the effective length of the collecting drainage pipeline (l_{ef} , m) will be:

$$l_{ef} = \sqrt[3]{\frac{3g\pi^2 \bar{F}^2 D^5}{2\lambda_{col} k_f^2 z_{fin}}} \left(\sqrt[3]{\frac{k_f z_{fin}}{q_m \bar{F} E}} - 1 \right). \quad (10)$$

The obtained calculation formulas allow determining the effective length of collecting drainage pipelines. They are quite simple and convenient to use. The proposed calculation method will be useful when designing real collecting drainage pipelines, as it will help reduce construction costs and ensure optimal operating conditions for reclamation systems.

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