Construction of closed horizontal drainage on irrigated lands and determination of its parameters

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Abstract. The article describes the construction technology of closed horizontal drainage in irrigated areas, presents the results of theoretical studies to determine the depth of drainage, the width of the drainage trench, the diameter of the drainage pipe, the thickness of the filter material, the distance between the drains and the drainage module. According to the results of theoretical studies, the average drainage depth is 1.5 *m*, the width of the drainage trench is 0.3 *m*, the diameter of the drainage pipe is 0.1 *m*, the thickness of the filtration material is 0.1 *m*. The distance between the drains is 150 *m* with the drainage module 0.1 *l/s*, the distance between drains is 180 *m* with a drain module of 0.12 *l/s,* and the distance between drains is 210 *m* with a drain module of 0.14 *l/s*.

1 Introduction

Drainage has great importance in improving the condition (amelioration) of lands. Scientists of the former Central Asian Research Institute of Irrigation (at present - the Scientific Research Institute of Irrigation and Water Problems of the Ministry of Water Resources of the Republic of Uzbekistan) V.Dukhovny, Yu.Pulatov, V.Berdyansky, A.Mirsagatov, A.Abrorkhadzhaev, E.Tomin, A.Abirov, and others, who were engaged in land amelioration activities during the 1960-1988 years, made a huge contribution to the construction of open and closed horizontal drainages in Central Asia.

According to the recommendations of the scientists mentioned above, 30 percent of irrigated land should be open, and 70 percent should be installed as closed. However, due to the lack of scientifically-importance technology for the construction of closed horizontal drainage, scientists' recommendations are not being followed. The drains built in 1966 using as the world's first drainage machine designed are still in usage today.

In our country, 39 thousand *km* of closed horizontal drainage have been built, of which 70 *percent* are out of order, and other remaining 30 *percent* are being operated with very low efficiency. One of the main reasons for this is increasing the groundwater level. During the operation of imported drainage machines, drains are laid to a depth of 3.0 *m*. At present, the groundwater level has risen to a depth of 1.5 *m* from the earth's surface.

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Therefore, in places, open drainages are built, and due to a decrease in the area for agricultural crops, the land-use coefficient is being decreased. According to preliminary calculations, currently, open drainages occupy an area of 250 thousand *hectares*. Long-term observations show that drainages fail because the groundwater level is almost equal to the water level in the reservoirs into which they are removed.

2 Methods

There are two solutions to this problem:

- the first - choosing other deeper reservoirs, where groundwater can easily flow out, but this solution requires more expenses.
- the second - improving the design of machines for the construction of drainage and build drainage to a depth of 1.5 *m*.

The research aims to determine the parameters of closed horizontal drainage in irrigated areas (diameter of the drainage pipe, filtration material and its thickness, installation depth, and distance between drains).

The horizontal drainage structure is shown in Figure 1. It consists of a drainage pipe 3 installed at a certain depth, a filtration material 4 wrapped around it, holes 5 for water entering the drainage pipe, inspection wells 2 installed at regular intervals (100 or 400 *m*), and a cover 1 of the inspection well.

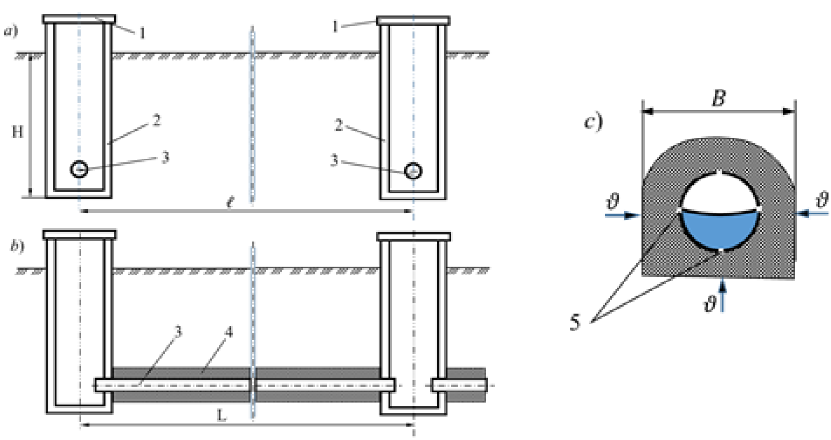

Fig. 1. Closed drainage design: *a* is cross-section; *b* is longitudinal section; *c* is drain pipe and the filter wrapped around it.

Construction technology of horizontal drainage. A drainage trench is dug with an appropriate slope and a drainage pipe and its filtration material installed on it. In this case, the length of the drainage can be 400...1200 *m*. The soil from the drainage trench is filled up and compacted. Inspection wells installed at certain intervals (100 or 400 *m*).

The function of control wells is to monitor the operation of the drain and their exploitation when flushing the drain pipe. In this case, of course, the first inspection well should be installed at the beginning/top of the drain. If the water inside the drain pipe is discharged into an open drain, the asbestos pipe is connected to the end of the closed drain pipe, which is diverted to the open drain at a certain distance [4].

3 Results and Discussion

Typically, drainage pipes of different diameters are installed over large areas to transfer water from a small-diameter pipe to a large-diameter pipe (for example, from a 100 *mm* pipe to a 150 *mm* pipe, from a 150 *mm* pipe to a 200 *mm* pipe, from a 200 *mm* pipe to a pipe diameter 250 *mm*, etc.), and the last pipe collects all the water and discharges it into an open drain [1, 2, 6].

The volume of water taken from one hectare can be determined using the following formula:

$$V = 10^4 \cdot h_o \cdot (W_c - W_o),\ m^3 \quad (1)$$

where h_o is a layer of water-saturated soil, *m*; W_c is moisture content of water-saturated soil (W_c = 0.28 ... 0.30); W_o is optimum soil moisture (W_o= 0.10 ... 0.18).

Using the formula (1), we determine the volume of water D (m^3/*ha*) entering the drainage system.

For example, the magnitude of the drainage load with single irrigation of a hectare $D = 10^4 \cdot h_o \cdot (W_c - W_o) = 10^4 \cdot 0.8 \cdot (0.3 - 0.18) = 960\ m^3/ha.$

The drainage module can be determined by the following formula [5]:

$$q = \frac{D}{T_d},\ \frac{m^3}{year \cdot ha} \quad (2)$$

where $T_д$ is the number of days in a year.

Formula (2) can be written as follows:

$$q = \frac{D}{T_d} = \frac{1000 \cdot D}{365 \cdot 24 \cdot 3600} = \frac{D}{86.4 \cdot 365} = \frac{D}{31536},\ \frac{l}{sec \cdot ha} \quad (3)$$

Drainage module for heavy sandy soils:

$$q_{\text{oc}} = \frac{D}{31536} = \frac{3153{,}6}{31536} = 0.10\ l/(sec \cdot ha) = 0.36\ m^3/hour.$$

The drainage module can be expressed as follows:

$$q_{\text{oc}} = \frac{\pi \cdot d_{\text{т}}^2}{4} \cdot n \cdot \vartheta_{\text{oc}}, \quad (4)$$

where $d_{\text{т}}$ is the diameter of the holes on the surface of the drainage pipe, *m*; n is the number of holes in one meter of the drainage pipe, ϑ_{oc} is the groundwater velocity, *m/h*.

From formula (4), $\vartheta_{\text{oc}} = \frac{4 \cdot q_{\text{oc}}}{\pi \cdot d_{\text{т}}^2 \cdot n} = \frac{4 \cdot 0.36}{3.14 \cdot (4 \cdot 10^{-3})^2 \cdot 400} = 75\ m/h = 0{,}02\ m/s.$

If there are four holes in each centimeter of the pipe, then the number of holes in a meter of the drainage pipe is $n = 4 \cdot 100 = 400$ *pcs*.

Consequently, the water velocity in heavy sandy soils is 75 *m/h*, and the distance between drain pipes is ℓ = 150 *m*.

The volume of water for each meter of drainage is:

$$Q_{1m} = 1 \cdot \ell \cdot h_o \cdot (W_c - W_o) = 1 \cdot 150 \cdot 0.8 \cdot (0.30 - 0.18) = 14.4\ m^3/h.$$

If the area of one hectare is 10 thousand m^2 and the drainage pipe collects water at a distance of 150 *m*, then the width *b* of the area can be determined as follows:

10000 = 150 · *b*, and therefore *b* = 66.67 *m*.

If each meter of the drainage pipe receives 14.4 m^3 of water per hour, then the volume of water at a distance of 66.67 *m* will be 14.4 · 66.67 = 960 m^3, which is equal to the volume of water flowing out from one hectare.

Drainage module for sandy soils:

$$q_c = \frac{D}{31536} = \frac{3784{,}32}{31536} = 0{,}12\, l/(sec \cdot ha) = 0{,}432\, m^3/h.$$

$$\vartheta_c = \frac{4 \cdot q_c}{\pi \cdot d_т^2 \cdot n} = \frac{4 \cdot 0{,}432}{3{,}14 \cdot (4 \cdot 10^{-3})^2 \cdot 400} = 90\, m/h = 0{,}025\, m/sec.$$

Therefore, the distance between the drains is ℓ = 180 *m*.

Drainage module for medium sandy soils

$$q_{us} = \frac{D}{31536} = \frac{4415.04}{31536} = 0.14\, l/(sec \cdot ha) = 0.504\, m^3/h.$$

$$\vartheta_{us} = \frac{4 \cdot q_{us}}{\pi \cdot d_т^2 \cdot n} = \frac{4 \cdot 0.504}{3.14 \cdot (4 \cdot 10^{-3})^2 \cdot 400} = 105\, m/h = 0.029\, m/sec.$$

Therefore, the distance between the drains is ℓ = 210 *m*.

The volume of water flowing through the drain pipe can be determined using the following formula:

$$Q = \frac{\pi \cdot d^2}{4} \cdot \vartheta_q = \frac{\pi \cdot d^2}{4} \cdot \sqrt{2 \cdot g \cdot h} = \frac{3.14 \cdot 0.1^2}{4} \cdot \sqrt{2 \cdot 10 \cdot 0.03} = 0.00785 \cdot 0.632 = 0.006 \frac{m^3}{sec} = = 22\, m^3/h.$$

where *d* is the diameter of the drainage pipe, *m*; ϑ_q is water flow rate in the pipe, *m/s*; *h* is lifting height of the drainage pipe, *m*.

If during every hour 22 m^3 of water passes through the drainage pipe, then 960 m^3 of water from a hectare flows out in 44 *hours*, that is 1.83 *days*.

In this case, the depth of the drainage trench for all drainages was taken equal to H = 1.6 *m,* and its width was B = 0.3 *m*.

Water supplied from the soil's surface for irrigation of crops is absorbed into the soil, flushes out salts from the soil, and the mixture of water and salt enters the drainage pipes. In this case, layers are formed moistened with $h_н$ and saturated with water h_o (Fig. 2).

These heights determined experimentally are h_n= 0.7 *m* and h_o = 0.8 *m* respectively.

The drainage depth *H* can be determined as follows [4]:

$$H = h_n + h_o + d = 0.7 + 0.8 + 0.1 = 1.6\, m.$$

It can be seen from the figure that the groundwater boundary has a curved line; it is located low in places that are close to the drainage pipes and high in the middle of the distance between the drainage pipes.

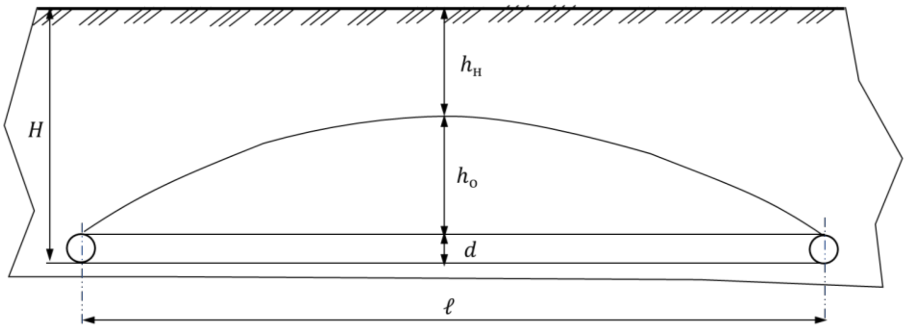

Fig. 2. Curvilinear diagram of the distribution of the wetted and water-saturated layer.

The values of the results obtained from theoretical calculations and experiments are shown in the following table.

Table. Values of the results obtained from theoretical calculations and experiments.

Drainage depth, *m*	Drainage pipe diameter, *m*	Filter thickness, *m*	Moistened soil depth, *m*	Water-saturated soil depth, *m*	Drainage module (flow), q, *l/s·ha**	Water velocity, *m/h* $\vartheta = \frac{4 \cdot q}{\pi \cdot d_т^2 \cdot n}$	Distance between drains, *m* $\ell = 2 \cdot \vartheta \cdot t$
1.6	0.1	0.1	0.7	0.8	0.10	75	150
					0.12	90	180
					0.14	105	210
					0.16	120	240
					0.18	135	270
					0.20	150	300

Drainage modulus values were determined based on the field experience [3].

4 Conclusions

According to practical results obtained through experiments and theoretical calculations, the average drainage depth is 1.6 *m*, the width of the drainage trench is 0.3 *m*, the diameter of the drainage pipe is 0.1 *m*, the thickness of the filter material is 0.1 *m*, the distance between drains is 150 *m* at drainage module 0.10 *l/s*, the distance between drains 180 *m* with drainage module 0.12 *l/s*, the distance between drains 210 *m* with drainage module 0.14 *l/s*, the distance between drains 240 *m* with drainage module 0.16 *l/s*, the distance between drains was 270 *m* with a drainage module of 0.18 *l/s* and the distance between drains was 300 *m* with a drainage module of 0.20 *l/s*.

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