Structure and Parameter Schematization of the Vadose Zone for Groundwater Recharge Modeling

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Abstract—On the basis of published soil profile data typical retention curves and hydraulic conductivity functions were obtained that depend on soil depth, lithological characters, and different surface landscape conditions. The corresponding average soil hydraulic parameters for M.Th. Van Genuchten equations were estimated. These average soil parameters are suitable for groundwater recharge estimations based on unsaturated flow modeling.

Keywords: vadose zone, hydrophysical parameters, soil water flow, modeling, infiltration groundwater recharge.

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INTRODUCTION

Infiltration groundwater recharge by means of atmospheric precipitation is a complex natural and multi-step process and its direct quantitative estimation is difficult and tricky. Methods for the estimation of the groundwater recharge on the basis of process modeling of transformation of atmospheric moisture on the land surface and the following unsaturated flow in the vadose zone are becoming increasingly widespread in the modern practice of hydrogeological investigations [Pashkovskii, 1985; Grinevskii, Pozdnyakov, 2010]. As groundwater recharge is considered as a part of unique water-balance cycle [Shestakov, Pozdnyakov, 2003] such models, being complex in substance, are used not only in groundwater hydrology but also in allied sciences, such as soil science [Globus, 1987], hydrology [Kuchment, Gelfan, 1993], and other fields. They are also used in developing global weather and climate models of separate regions [Gusev, Nasonova, 2004].

When using such complex models on a regional scale the most important task is parametric security, which can be performed on the basis of the schematization of typical natural conditions and integrating data of real observations. Particularly, this means the schematization of the cross section of an vadose zone and the foundation of the hydrophysical parameters of unsaturated flow determination, which are rather difficult to model processes of groundwater recharge [Badov et al., 1988].

The schematization principles for vadose zone are considered and the opportunity to use the generalized parameters of a unsaturated flow model for estimation of the groundwater recharge is proven in this article on the basis of the generalization of the published data on the structure and hydrophysical characteristics of soil profiles.

THE PRINCIPLES FOR THE ESTIMATION OF INFILTRATION RECHARGE ON THE BASIS OF UNSATURATED FLOW MODELING IN AN VADOSE ZONE

The principal model of infiltration recharge during groundwater formation consists of two interrelated blocks: transformation of precipitation on the land surface and unsaturated flow in the vadose zone.

The first calculated block determines the condition on the upper boundary of the unsaturated flow model, which is the outflow of moisture to the vadose zone formed from atmospheric precipitation taking the temporal variability of its outflow into account, which is determined by weather and climate conditions and also by processes of retention and evaporation of atmospheric moisture by flora, snow accumulation, and snow melt, and surface runoff. The infiltration value is estimated as the moisture discharge that reaches the lower boundary of the unsaturated flow model in the vadose zone where there is a predetermined pressure that is equal to the groundwater depth level (condition of the first class) or a condition of the third class determined lateral flux to the nearest drain or vertical water exchange with a deeper aquifer. Such a model is produced by the equation of one-dimensional vertical saturated-unsaturated flow from land surface to the groundwater level and is performed by
Fig. 1. Changes of the bulk density and water capacity of solids in the vadose zone in dependence on its lithological content and landscape surface according to data: (a) S.F. Fedorov, (b) 1–5 A.I. Subbotin, 6–7 S.A. Verigo and L.A. Razumova, 8–11 A.A. Rode.
the commonly used HYDRUS-1D program code [Simunek et al., 2005]:

$$\frac{\partial \omega}{\partial t} = \frac{\partial}{\partial z} \left( k_w(\omega) \left( \frac{\partial h}{\partial z} + 1 \right) \right) - TR_p(z, t, h),$$  \hspace{1cm} (1)

where $\omega$ is volumetric water content, $\omega_{\min}$ is the residual soil water content, $\omega_{\max}$ is the maximum water capacity, $h$ is the pressure head, $k$ is the filtration coefficient, $TR_p$ is transpiration, and $\alpha$ and $n$ are empiric parameters.

Equations (1a) and (1b) in the unsaturated flow model are a numerical approximation (in this record according to M.T. van Genuchten [van Genuchten, 1980]) of the dependences of suction pressure from moisture (the main hydrophysical character is MHC) and the unsaturated soil hydraulic conductivity from moisture (hydraulic conductivity curve). The variables that are entered into these equations are the parameters of the unsaturated flow model and the practical implications of the experimental determination of MHC curves and hydraulic conductivity [Badov et al., 1988] and also the variability of hydrophysical soil parameters in the cross section of the vadose zone determine the problems of parametric securing of the calculation model.

Thus, the purpose of this investigation is the substantiation of the calculated parameters of the unsaturated flow model depending on the structure and soil properties of the soil continuum and vadose zone and also the opportunity to use them to estimate the groundwater recharge.

**SCHEMATIZATION OF VADOSE ZONE STRUCTURE**

The zone capacity of incomplete water saturation is determined by the depth of occurrence of the groundwater level (GWL). For processes of infiltration recharge the main component is the surface of the vadose zone with a capacity on average of not more than 5–6 m, where the volume water content is changed considerably and the formation of upward and downward fluxes of moisture takes place. At greater depths of the vadose zone (according to the deep occurrence of the GWL) a transit unsaturated flow is formed where the downward flow (infiltration) is practically unchanged [Pashkovskii, 1985].

The most dynamic moisture mode is formed in the soil zone to a depth of 0.6 m (in black soils to 1 m), where in any lithological composition of soils its properties, such as density, porosity, and others, are changed to a greater degree due to the influence of the flora root system and also the activities of living organisms (Fig. 1). It is noteworthy that soil properties depend upon the landscape (Fig. 1, A [Fedorov, 1977]) at this depth, they are less dense on the land surface in the forest and have a higher water capacity than in the conditions of a field landscape. Below, along the cross section of the vadose zone the soil parameters become more homogeneous and typical of the lithological composition and almost do not depend upon the flora developed on the land surface. These trends are seen in

![Suction pressure vs. Moisture content](image-url)
Thus, an vadose zone cross section can be schematized by three model intervals. The maximum variability of hydrophysical properties is characteristic for soil horizons of the A type (grass sod, soil covering, and humus horizons) and the E type (A2) and for standing soil with a depth of up to 0.2 m. Then, with a depth on average of up to 0.6 m, the trend towards a density increase and soil water capacity parameter decrease is preserved but it is less intensive. Illuvial soil horizons of the B and B1 type are equal to this interval. Soil hydrophysical properties of the vadose zone are almost unchanged and fit a deposit lithological composition at a depth of more than 0.6 m, which is fitted to the B2 horizon and spreads to the parent rocks (C). Thus the first two layers refer to soil horizons; their hydrophysical properties, besides mechanical composition (soil type), may depend upon the landscape pattern and flora on the land surface. The thickness of the first layer (A horizon) in chernozem soil cross section should be increased up to 0.6 m and the illuvial horizon interval should be from 0.6 to 1 m (Fig. 1B).

The hydrophysical parameters are taken on average to the depth of the three selected model layers, as a special model test showed that the small-sized internal heterogeneity of the vadose zone, especially at a greater depth, is almost not shown in the resulting values of the infiltration recharge [Pashkovskii, 1985].

PARAMETER SUBSTANTIATION OF UNSATURATED FLOW FOR TYPICAL CROSS SECTIONS OF AN VADOSE ZONE

Because of the difficulty of making experimental estimates of MHC parameters, their calculation is possible on the basis of so-called pedotransfer functions (PTF) in whose regression equations combining the equilibrium pressure and moisture values with the main physical properties of soils are the most widespread [Globus, 1987] and which are obtained as the result of the generalization of laboratory research. Depending on which set of characteristics of the soil are used in PTF, the uniqueness of the MHC parametric characteristic can be different [Chanzy, 2008].

<table>
<thead>
<tr>
<th>Cross section type</th>
<th>Number of occurrences</th>
<th>Minimum moisture, $\omega_{\text{min}}$</th>
<th>Maximum moisture, $\omega_{\text{max}}$</th>
<th>$\alpha$, 1/m</th>
<th>$n$</th>
<th>$k$, m per day</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>A horizon, 0–0.2 m</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Loam soils/forest</td>
<td>3</td>
<td>0.037</td>
<td>30.4</td>
<td>0.571</td>
<td>8.4</td>
<td>2.84</td>
</tr>
<tr>
<td>Loam soils/farm field</td>
<td>7</td>
<td>0.060</td>
<td>29.2</td>
<td>0.472</td>
<td>19.5</td>
<td>1.51</td>
</tr>
<tr>
<td>Loam soils/meadow</td>
<td>19</td>
<td>0.054</td>
<td>27.0</td>
<td>0.529</td>
<td>6.4</td>
<td>1.58</td>
</tr>
<tr>
<td>Sandy–loam/forest</td>
<td>14</td>
<td>0.038</td>
<td>15.7</td>
<td>0.532</td>
<td>7.0</td>
<td>0.90</td>
</tr>
<tr>
<td>Sandy–loam/farm field</td>
<td>7</td>
<td>0.044</td>
<td>15.4</td>
<td>0.514</td>
<td>5.6</td>
<td>0.80</td>
</tr>
<tr>
<td>Sandy–loam/meadow</td>
<td>5</td>
<td>0.042</td>
<td>38.4</td>
<td>0.494</td>
<td>8.2</td>
<td>0.72</td>
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<tr>
<td>Sandy/forest</td>
<td>9</td>
<td>0.029</td>
<td>24.3</td>
<td>0.482</td>
<td>17.6</td>
<td>0.34</td>
</tr>
<tr>
<td>Sandy/farm field</td>
<td>3</td>
<td>0.028</td>
<td>7.7</td>
<td>0.364</td>
<td>7.4</td>
<td>0.22</td>
</tr>
<tr>
<td>Sandy/meadow</td>
<td>6</td>
<td>0.030</td>
<td>31.8</td>
<td>0.413</td>
<td>11.9</td>
<td>0.55</td>
</tr>
<tr>
<td><strong>B horizon, 0.2–0.6 m</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Loam soils</td>
<td>30</td>
<td>0.055</td>
<td>17.6</td>
<td>0.427</td>
<td>6.8</td>
<td>0.60</td>
</tr>
<tr>
<td>Sandy–loam</td>
<td>32</td>
<td>0.038</td>
<td>20.8</td>
<td>0.412</td>
<td>13.3</td>
<td>0.90</td>
</tr>
<tr>
<td>Sandy</td>
<td>17</td>
<td>0.022</td>
<td>11.1</td>
<td>0.366</td>
<td>14.0</td>
<td>1.25</td>
</tr>
<tr>
<td><strong>C horizon, more than 0.6 m</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Clays</td>
<td>–</td>
<td>0.057</td>
<td>–</td>
<td>0.380</td>
<td>–</td>
<td>0.74</td>
</tr>
<tr>
<td>Loam soils</td>
<td>48</td>
<td>0.052</td>
<td>19.2</td>
<td>0.383</td>
<td>7.9</td>
<td>0.49</td>
</tr>
<tr>
<td>Sandy–loam</td>
<td>28</td>
<td>0.034</td>
<td>7.5</td>
<td>0.379</td>
<td>10.9</td>
<td>1.39</td>
</tr>
<tr>
<td>Sandy</td>
<td>18</td>
<td>0.018</td>
<td>28.8</td>
<td>0.370</td>
<td>8.8</td>
<td>2.06</td>
</tr>
</tbody>
</table>

* Filtration coefficient of medium value and variation are calculated on the assumption of the logarithmic normal law of partition.
The Rosetta Program code (ver 1.1) [Schaap, 2003] using the database of the US service soil science (USDA) is widely used for practical estimation of MHC parameters based on PTF. In this code MHC parameter calculation occurs at the real relative content of the sandy, silt, and clay fraction, soil bulk density and specific moisture values (field capacity and wilting point) responding to a suction pressure of 33 and 1500 kPa.

The validity of the PTF implemented in the Rosetta program code was analyzed on the basis of laboratory determinations of the dependence of the suction pressure on moisture made by the student M. Shirnin under the guidance of the author. For this purpose two soil monoliths with natural structure with size of 30 × 30 cm from depths of 0.5 and 1 m were selected on the territory of the Zvenigorod training base of the Moscow State University geology department, on the first terrace of the flood plain of the Moskva River set by upper quaternary alluvial deposits [Field method..., 2000], on the edge of the forest massif. The granulometric content and hydrophysical properties of sample soils was tested in the laboratory of soil science of the geology department of Moscow State University (Table 1).

At the same time, the value of the field capacity (FC) is found by using the Michurin formula [Rode, 1965]:

\[ FC = 1.35BD/D(1 – BD/D) \]

and the wilting point is obtained using the empirical equation [Cambell, 1985]:

\[ WP = 1.5396(FC)^2 + 0.0967FC – 0.0044. \]

Experimental determination of the suction pressure dependence on moisture for the examined samples that are hard sandy loam (according to the classification of V.V. Ohotin) was made on a capillarimeter [Badov, Kiselev, 1987] in the laboratory of VNII VODGEO (All-Union Research Studies Institute of Water Supply) under the leadership of A.A. Kiselev. Good agreement of the MHC calculated curve to the experimental points (Fig. 2) is reached only with maximum set of hydrophysical characteristics of the sample, with indices of granulometric content, density, field capacity, and wilting point.

It is necessary to estimate the opportunity to use typical MHC parameters in respect to detailed intervals of the soil cross section and vadose zone for the main types of soils, landscapes, and flora on the land surface in investigations. In principle such an opportu-
ity is due to the soil’s genetic differences, which is not in the form of its MHC, as a rule, and this very situation is the basis for creating national banks of soil hydrophysical information [Globus, 1987]. The extremely similar variability patterns of soil hydrophysical properties with the depth of the genetic types of soils (Figs. 1A, 1B) is explained by this fact and it allows us to weigh the respective insignificant variations of MHC parameters within the selected intervals of vadose zones that are similar with the mechanical (lithological) compositions of deposits.

The considerable spatial variability of soil hydrophysical characteristics on local areas has been noted in a number of studies [Globus, 1987]. At the same time, however, this brings up the question: to what degree is the statistical variability of MHC parameters significant from the point of view of the total flow through the unsaturated zone, which determines the value of the groundwater infiltration recharge?

Thus, it is necessary to solve two problems to prove the parameters of the unsaturated flow model. First, we should substantiate typical MHC curves and estimate variation of its parameters with respect to the accepted schematization of vadose zone cross sections, and second, we should analyze to what extent dispersion of the values of MHC parameters in the unsaturated flow model appear in the calculated values of groundwater recharge.

The first problem is solved on the basis of an analysis of releases, among which the fully characterized mechanical composition and hydrophysical properties of soil cross sections were selected. This allowed the calculation of MHC parameters on the basis of pedotransfer functions. About 30 soil cross sections were used in total for the nonchernozem belt of Russia, for which there are interval indices of the granulometric contents, typical moisture values and soil bulk density in the depth of the soil cross sections with sizes from 0.1 to 0.3–0.5 m [Rode, 1965; Subbotin, 1966; Verigo, Razumova, 1973; Gusev and others, 2008]. For these,
the calculated intervals parameters were obtained via
the accepted schematization of the vadose zone cross
section using the Rosetta program and MHC and
hydraulic conductivity curves were calculated in
accord with approximation by equations (1a) and (1b).

Analysis of MHC calculated curves characterizing
more than 200 intervals of soil cross sections showed
that within every soil horizon (A, B, C) apart from the
genetic type of soil they are grouped by their mechan-
ical (lithological) compositions. Thus, four main types
of cross section are classified according to the percent-
age of clay particles in the soil interval in accord with
the classification of dispersive soil of V.V. Ohotin:
sandy (less than 6%), sandy–loam (6–15%), loamy
(15–30%) and clayey (more than 30%).

The character of the MHC curves was analyzed
taking the landscape conditions on the surface into
account, which distinguish closed (with forest cover
and silva) and open (field) types of landscape; for the
last one soil cross sections of perennial grasses (onward
meadow) and croplands (onward farm field) were con-
sidered separately.

As according to the current ideas, the hydrophysi-
cal characteristics of a soil have a distribution that is
close to normal apart from the coefficient of filtration
(unsaturated hydraulic conductivity), which is classi-
fied as logarithmically normal [Globus, 1987]. Every
interval of an vadose zone cross section can be charac-
terized by medium MHC parameter values in accor-
dance with the lithological type of the cross section
(Table 2). The average values and analysis of the
proper generalized MHC curves and hydraulic con-
ductivity for the upper interval (A horizon) show that
here the unsaturated flow parameters depends not
only on the lithological content of a soil but also on the
type of landscape conditions on the surface (Fig. 3),
which is similar to the variability of the main hydro-
physical characteristics with depth, as discussed above
(Fig. 1A). From the MHC curve analysis it can be seen
that the role of landscape conditions on the surface is
caused mainly by the characteristic quantities of soil
moisture and filtration coefficient values (Figs. 3A,
3B). At the same time, the curve form itself is deter-
mined by the coefficient values α and n of Van Genu-
huten equations (1a) and (1b) and depend on the soil
lithology, what can be seen in diagrams of relative val-
ues (Figs. 3B and 3G). The least significant influence

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**Fig. 5.** Calculated differentiated (a) and generalized (b) MHC and hydraulic conductivity curves for the second horizon of the
vadose zone depending on the soil lithology and landscape conditions on the surface.
of landscape conditions on the surface is caused by the loamy content of the A horizon.

The most conserved MHC parameters with minimum values of the variation coefficient \( (Kv) \) are the values of maximum moisture and the \( n \) parameter; the maximum variability occurs for values of the filtration coefficient (Table 2). Analysis of the variation of the \( \alpha \) and \( n \) parameters that determine the form of the MHC curves and unsaturated hydraulic conductivity shows that the \( \alpha \) value is more stable in the sandy soils of the A horizon and the \( n \) value is more stable in loamy soils (Fig. 4). The decrease of the \( \alpha \) coefficient and the increase of the \( n \) parameter, which determine the soil content from loamy to sandy soil, are clearly seen.

The influence of landscape conditions on the surface is shown more weakly (Fig. 5A) for the second examined interval of the soil cross section, which is equal to the illuvial B horizon. This can be caused by the genetic formation of the illuvial soil horizon by means of salt and the finest fraction washout from the upper layer, which causes its relative hydrophysical homogeneity. In terms of the MHC curves for the B horizon, it seems that its hydrophysical characteristics should be examined irrespective of landscape conditions on the surface and that the average MHC should be used in the calculation of the unsaturated flow in different lithological variations. For reference, the points of the MHC experimental curve for the sample of sandy—loam soil selected at the Zvenigorod site from a depth of 0.5 m (Table 1) which correspond to the calculated average curve for deposits of this type are also shown in Fig. 5B.

For the B horizon as for the A horizon the \( n \) parameter and maximum water capacity have the minimum variation range and the maximum variation occurred for the value of the filtration coefficient (Table 2). However, in contrast to the A horizon \( \alpha \) and \( n \) parameter values increase from loamy deposits to sandy ones, and the variation range of the \( \alpha \) coefficient is rather high (Fig. 4).

There is no sense in analyzing the influence of the landscape conditions at the land surface on the form of MHC curves and hydraulic conductivity for the parent rocks of the vadose zone (C horizon), where soil hydrophysical characteristics of soil are much less changeable with depth (Fig. 1). For this cross section interval (depth more than 0.6 m) the simple differentiation of curves in accordance with the lithological content of deposits occurred, which helps to characterize them by their generalized parameters (Table 2, Fig. 6). Despite the depth of the analyzed soil cross sections was less than 1.5 m, obtained regularities can be considered as typical for the deeper intervals of the cross sections of vadose zones, to the GWL depth. As deposits that should be considered as clays according to the accepted typification are not described in our data, the MHC parameters for this type of cross section were synthesized using the pedotransfer functions of the Rosetta code for a 0.45 clay particle content ratio and a density of 1.8 g/sm\(^3\).

The MHC and hydraulic conductivity calculated curves for the lower interval of the vadose zone cross section (C horizon) reflect the contrast between the differences in the lithological contents of soil (Fig. 6). This is explained by the fact that at this depth the soil of the vadose zone are almost unchanged by the processes of soil formation, root systems of plants, and the activities of living organisms therefore soil have “normal” hydrophysical properties (density, total porosity, water capacity, etc.) that are typical for their lithological (granulometric) contents. Similar types of calculated curves for this interval and typical curves of the proper lithology from the database of the Soil Science Institute of the USA (USDA) are shown [Schaap et al., 2001] in Fig. 6.
The points of the MHC experimental curve for the sample of sandy–loam soil from the Zvenigorod site at a depth of 1.0 m (Table 1) are shown in Fig. 6 for comparison. The experimental points correspond to the range of possible variation in the averaged sandy–loam deposit curve, although they approach the curve for loams when the pressure value is much higher.

The variations of the unsaturated flow parameters for this interval of the vadose zone cross section are found in Table 2 and Fig. 4. The $n$ parameter and maximum water capacity of soil also have their minimum range of variability here.

Thus, as the result of the generalized MHC curves and the hydraulic conductivity of the lithological types of soils (Fig. 7), their parameters and the limit of variation of the averaged values were calculated (Table 2). At the same time, it was found that the type of landscape condition on the surface has special influence on the form of the MHC curves of the upper soil interval (A horizon). In general, as the result of analysis of generalized MHC curves and hydraulic conductivity (Fig. 7), their differences for one-type soil lithology contents that depended on the examined intervals of vadose zone cross sections were found. These differences are more important with high moisture.

However, as our analysis showed, the values of the variation coefficient that were obtained using the average parameters of the van Genuchten equation were very significant in many cases (Table 2). At the same time, this brings up questions of how the variation of MHC parameters affect the results of the modeled values of groundwater recharge and how the average values of parameters obtained by modeling should be legally used. To determine this, a series of model calculations was performed in which the same interface conditions of the unsaturated flow model (1) were used, which were introduced using the three schematized horizons of the vadose zone with the estimated value of the long-term average annual infiltration recharge (outflow through the lower boundary of the model).

In these calculations, the daily average values of moisture entry at the ground surface and the values of potential evapotranspiration from the modeling of precipitation transformation on the land surface from the SurfBal program [Grinevskii, Pozdnyakov, 2010] using long-term daily meteorological ranges of the Mosalk City weather station (Kaluga region) were used at the upper boundary. The constant GWL at a depth of 6 m was used at the lower boundary. In the modeling process conducted with daily time steps the calculated unsaturated flow parameters for every cross...
section horizon within estimated variation of values (Table 2) with the average parameters at other horizons were consecutively changed. For the upper A horizon variations of parameters were considered not only depending on the lithological content of the deposits but also the type of landscape conditions on the surface.

The modeling results show that the variations of the calculated unsaturated flow parameters at rather average values have a small impact on the total values of long-term average annual groundwater recharge; in most cases this is up to 5 mm per year (less than 5–10%) (Table 3). This supports the usage of the average parameters of MHC curves and hydraulic conductivity

**Table 3. Results of modeling of infiltration recharge for the variation of the calculated parameters of unsaturated flow in the vadose zone**

<table>
<thead>
<tr>
<th>Landscape type</th>
<th>Solid type (soil)</th>
<th>Cross section horizon</th>
<th>Calculated infiltration, mm per year, at the parameters values of unsaturated flow</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Average</td>
</tr>
<tr>
<td>Forest</td>
<td>Loams</td>
<td>A</td>
<td>69</td>
</tr>
<tr>
<td></td>
<td></td>
<td>B</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>C</td>
<td></td>
</tr>
<tr>
<td>Forest</td>
<td>Loamy sands</td>
<td>A</td>
<td>113</td>
</tr>
<tr>
<td></td>
<td></td>
<td>B</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>C</td>
<td></td>
</tr>
<tr>
<td>Forest</td>
<td>Sands</td>
<td>A</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>B</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>C</td>
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</tr>
<tr>
<td>Meadow</td>
<td>Loams</td>
<td>A</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td></td>
<td>B</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>C</td>
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</tr>
<tr>
<td>Meadow</td>
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<td>44</td>
</tr>
<tr>
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<td>102</td>
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<td></td>
<td></td>
<td>C</td>
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<tr>
<td>Ploughed field</td>
<td>Loams</td>
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<td>62</td>
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<tr>
<td></td>
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<td></td>
<td></td>
<td>C</td>
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<td>82</td>
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in the unsaturated flow model for calculation of the groundwater recharge according to the accepted schematization of the vadose zone cross section and the lithological contents of solids.

CONCLUSIONS

1. On the basis of the analysis of the variability of the hydrophysical contents of the soil covering and underlying bedding rocks, the depth of the vadose zone cross section was schematized for three calculated intervals corresponding to the main genetic soil A, B and C horizons.

2. The quantitative research on the hydrophysical parameters of unsaturated flow for soil cross sections versus the lithological contents of deposits shows that MHC curves and hydraulic conductivity almost do not depend on the genetic type of soil but to a greater degree are defined by the lithological content of soil materials. At the same time, for the upper interval of the cross section (A horizon) the calculated parameters of unsaturated flow also depend on the type of the landscape conditions on the land surface by means of processes of decompaction and transformation of the soil material. This is due to the agricultural tillage and the activities of the root systems of plants and living organisms. Thus, the character of MHC curves and hydraulic conductivity for the upper soil interval differs from the character dependences for the proper lithologic type of solids. For deeper intervals of vadose zone cross sections, the landscape conditions and plant characteristics almost have no impact on unsaturated flow parameters and the form of MHC curves. Hydraulic conductivity is defined only by the lithological contents of deposits.

3. The average values of the calculated parameters of an unsaturated flow model that characterizes the main intervals of the vadose zone cross section according to the type of lithological contents of deposits were proven and the scale of their variation was estimated. This result was based on the data from different soil cross sections on the parameter values of unsaturated flow, which are suitable for the approximation of MHC curves and hydraulic conductivity using the van Genulthen equations. The results of test modeling of infiltration recharge show that variability of the calculated parameters of unsaturated flow in the range of its possible variation has almost no impact on the final values of long-term average annual infiltration. This allows us to use the unsaturated flow model parameters characterizing the main intervals of the vadose zone cross section and lithological content of solids to simulate processes of the formation of the groundwater recharge.

4. Schematization vadose zone structure and the parameters of unsaturated flow was conducted on the basis of an analysis of soil cross sections typical of Nonchernozem belts of Russia where meadow soil with the different degree of greenness and grey forest soil are widespread [Soil and geological ..., 1984]. We can suppose that these patterns are found for other regions in general; however, because of the low number of analyzed cross sections of other soil types, this factor should be determined in the future.

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