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Comments on 'Modeling Infiltration during a Steady Rain' by Russell G. Mein and Curtis L. Larson

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The infiltration model presented by *Mein and Larson* [1973] is an elegant extension for steady rainfall of the rather classical Green and Ampt model for infiltration from a ponded surface (curve D in Mein and Larson's paper). Some comments appear in order to clarify how well this elegant approximation does in fact match the soil infiltration pattern predicted by Richards' equation (equation 2 in Mein and Larson's paper).

As the authors have acknowledged, the numerical solution of (2) that they used to make comparisons for evaluating their model was essentially like one developed earlier [*Smith and Woolhiser*, 1971]. In a similar comparison with this numerical model, I used four different soils, representing a range from sand to clay, and produced an evaluation of the proposed model that is somewhat different from that of Mein and Larson.

To simplify for comparison, Mein and Larson's equation 8 can be used with ponded infiltration (Mein and Larson's Figure 1, curve D) to compare the shape of the curves. In Figure 1 (this paper), two examples are shown: one is a

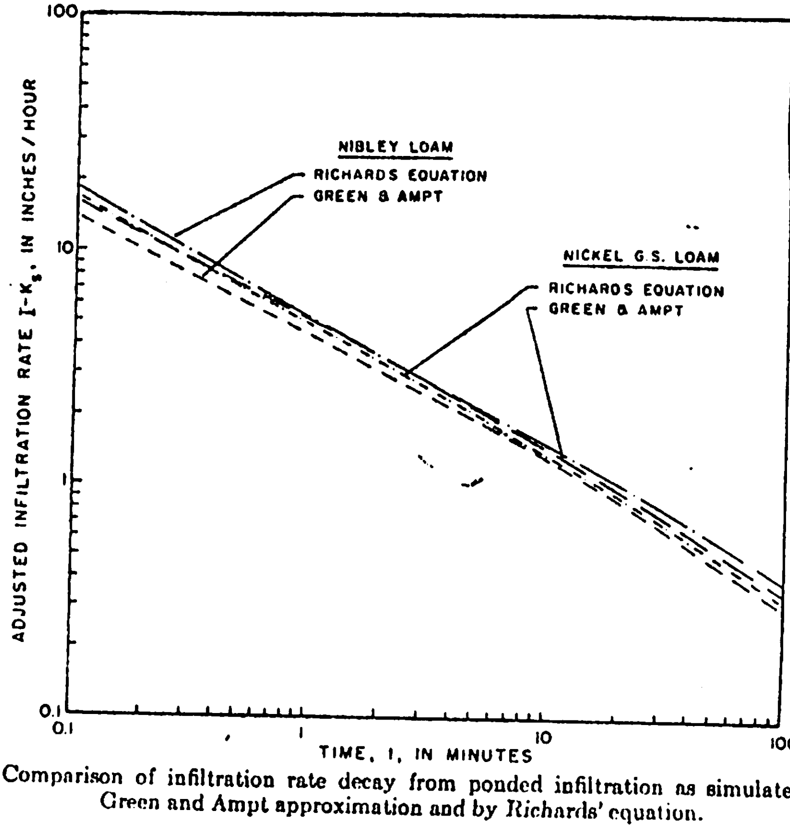

Fig. 1. Comparison of infiltration rate decay from ponded infiltration as simulated by th Green and Ampt approximation and by Richards' equation.

good average fit, and the other is biased. The logarithmic plot somewhat exaggerates the goodness of fit of the model. Two items deserve mention. First, the slope and shape of the decay curve from (8) of Mein and Larson are practically fixed for all soils. Mein and Larson's (8) is the Green and Ampt equation, which may be solved in terms of infiltration rate f_p and time t as follows:

$$\frac{K_s t}{S_{av} M_d} = \frac{K_s}{f_p - K_s} - \ln\left(1 + \frac{K_s}{f_p - K_s}\right) \quad (1)$$

The symbols used by Mein and Larson have been adopted in (1). Here K_s and M_d may be considered variables (measurable directly), whereas S_{av} is a single soil-dependent parameter. Secondly, Mein and Larson used (9) to estimate biased values for S_{av} that were generally lower than a 'best fit' S_{av} for the soils tested. Were there a better procedure for evaluating S_{av}, the Green and Ampt curve would, for most cases, be acceptable. The logarithmic slope of (1) given above is mathematically asymptotic to 0.5 at small times and thus compares to the formula of *Philip* [1957]. The numerical solution of Mein and Larson's (2) predicts this slope to be ≥ 0.55.

A separate issue is the simulation of the amount of infiltration prior to runoff, or what is in effect the time to runoff t_p on a plot (Mein and Larson's Figures 5 and 6) of infiltration rate versus time. Mein and Larson's (6) may be rewritten as

$$F_s = S_{av} M_d [I/K_s - 1]^{-1} \quad (2)$$

Numerical simulation of Mein and Larson's (2) for the four soils used here indicated that the exponent value in equation 2 (this paper) is consistently less than 1 (absolute value). Part of the difference in these results and those of the authors involves the depth increment size in the finite difference approximation of Mein and Larson's (2). In an earlier work, *Mein and Larson* [1971] reported that a minimum increment size $\Delta Z = 0.20$ cm was used. My work indicates a significant change in results for F_s, since ΔZ is successively halved; I have used minimum $\Delta Z = 0.05$ cm.

Figure 2 (this paper) indicates the quality of overall prediction using the Mein and Larson model. Predictions were generally more similar to the 'worst fit.' It is notable that the shape of these decay curves is acceptable overall; the prediction of F_s is the more serious failing. It would have been more instructive for Mein and Larson to have shown the results of Figures 7 and 10 in this type of direct comparison.

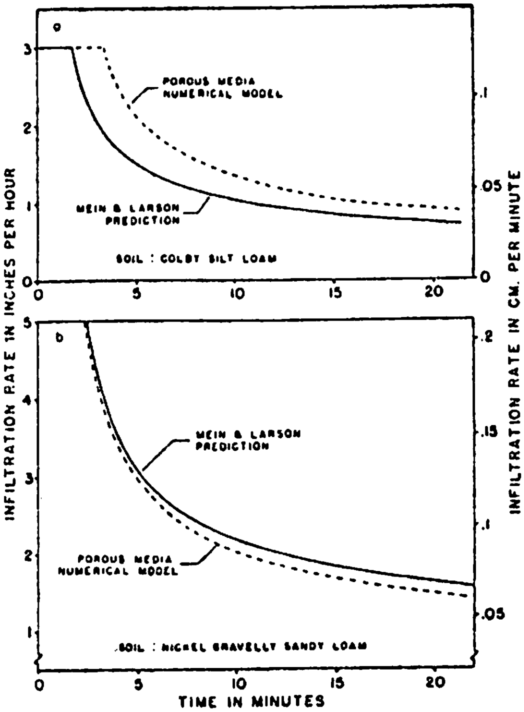

Fig. 2. Comparative accuracy of the Mein and Larson simplified infiltration model (equation 9): (*a*) 'worst' fit and (*b*) 'best' fit.

In summary, exception should be taken to the authors' claim in their last paragraph that this model 'represents the actual infiltration process.' What this model actually does is to represent the approximation from which the Green and Ampt model is derived. The comments presented here are intended to emphasize the often rather serious limitations in predictability resulting from this approximate concept of the infiltration process. By using the same numerical solution of Richards' equation (Mein and Larson's equation 2), a model has been developed that does in fact very closely represent, if not the infiltration process, the performance of Richards' equation 2 under variable soil moisture M_d and patterns of rainfall rate I for a wide range of soil types [*Smith*, 1972]. The important comparison between this model and that of Mein and Larson, however, is that, to achieve such generality, three additional parameters (two additional parameters if the logarithmic slope of Figure 1 is taken as being constant) were employed. Even given the problems described here, one must congratulate the authors for constructing such an elegant approximation that simulated infiltration as closely as was shown by using a single parameter S_{av}.

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