***Authors Response to Interactive comments on* "Shallow water table effects on water, sediment and pesticide transport in vegetative filter strips: Part A. non-uniform infiltration and soil water redistribution" *by* Rafael Muñoz-Carpena et al.**

RC1- M Vanclooster (Referee)

Thank you very much for the careful review and edits to the initial submission. Below we address the comments raised on the initial submission and we have also revised the manuscript accordingly to accommodate these. Please note that we uploaded the revised manuscript as a supplement to these response comments. [RC1-#: Reviewer 1 comment #; AR-#: Authors response to comment #).

RC1-1: Unclear development of some of the infiltration concepts and underlying equations. Some of the parameters/variables or conceptual explanations in Eqs. (4), (9), (10), (12), (13), (17) and (19) needs reconsiderations. For instance, for Eq. (4) and (9), the authors should clearly explain the significance of f, and why they consider it as z-dependent. In Eq. (10) authors should develop in detail the underlying hypothesis of the linearity of the unsaturated hydraulic conductivity curve, and explain the derivative to z_p in stead of z. Also there is mix up of the signs in Eq. (12) and (19). Finally, it is unclear how the suction head at the infiltration front is evaluated, which in principle should be evaluated using the unsaturated hydraulic properties of the unsaturated soil (and hence between the wetting front and the water table). Detailed concerns have been marked up in the annotated manuscript.

AR-1: Yes, thank you for catching the errors made in the transcription of the equations into the manuscript. Specific details for the revised equations follow:

Eq. 4. Based on Neuman (1997, Eq. 7) the infiltration rate in the soil under Green-Ampt conditions can be approximated the unit gradient saturated flow reduced by an integral term representing flow in the unsaturated domain (ψ is the soil pressure potential ≤ 0) below the wetting front,

$$f = f_p = K_s - \frac{1}{z_F}\int_0^{\psi_i} K(\psi)\mathrm{d}\psi$$

were ψ_i is a sufficiently low unsaturated pressure head (high negative value) at which the unsaturated conductivity K is negligibly small. Assuming negligible soil surface pressure (H_p=0 at z=0), non-uniform soil moisture controlled by equilibrium with the shallow water table, and expressing in terms of soil suction (h= - ψ) Chu (1997, eq. 4, 12) proposed that the integral could be bounded over the soil depth between the water table and the wetting front where limits of integration become h[0, L-z_F],

$$f = f_p = K_s + \frac{1}{z_F}\int_0^{L-z_F} K(h)\mathrm{d}h$$

As suggested, we changed the equation to include z_F in the denominator and no just z (but not L-z_F).

Eq. 9. Yes, changed to z_p and no just z.

Eq. 10. Removed erroneous K_s from denominator. No, there is no need for limiting linear assumptions as the equation is general and applies to any hydraulic characteristics.

Eq. 12-14. Yes, f should be f_p and it is now corrected.

Eq. 16. Yes, changed to z_F.

Eq. 17. This equation was correct based on the Newton-Raphson root-finding method used.

Eq. 19. Redundant with previous equations and removed. Also removed eq. 20 (with reference to Eq. 3).

RC1-2: Authors should also demonstrate the efficiency of the integral formulation of the infiltration problem by comparing it with the reference solution (Richards equation based) on a CPU calculation time basis. Given the fast development of processing capacity in modern computing system, but also progress in solving the non-linear Richards equation (e.g. de Maet et al., 2014), the reference solution of the Richards equation should become strongly competitive with the presented integral infiltration form model on a CPU time basis. Hence, the problems associated with the reference should no longer be a strong issue.

> AR-2: The three arguments in favor of the proposed algorithm for this specific application were: a) speed, b) robustness, and c) physical consistency with the model (VFSMOD) used in the follow up paper that uses (Chu 1978 and Skaggs and Khaleel , 1982) extension of Green-Ampt for unsteady rainfall conditions without the presence of a shallow water table. VFSMOD is used in current long-term pesticide regulatory assessments (30 yr. daily time steps in the USA or 10 yr. daily time steps). Considering ~1/3 to ~2/3 of days with rainfall-runoff, the model would be run between 3000 and 7000 times for a 30 yr. assessment. Even a marginal time improvement can prove advantageous in this type of throughput applications. As suggested by the reviewer, we performed a quick comparison between the CHEMFLO and SWINGO for D=10 h for the cases in Fig. 5, with small speed differences of 1-5 s between both solutions (CPU: 1.6 GHz Intel Core 2 Duo). However, the differences will likely be compounded in the context of the throughput simulations presented above. The results are machine and computer and compiler dependent, and as such an unfair comparison between both types of solutions. CHEMFLO contains a graphical interface, a standard finite differences solution implemented in Java computer language (run in Oracle ® jre-8u144), and is not intended for optimized simulations. SWINGO was implemented in Fortran (Intel ® Fortran Compiler v17.0.4). Admittedly, the differences will likely be smaller with optimized code and new developments of Richards implementations suggested by the reviewer e.g. de Maet et al., 2014). A new discussion at the end of section "3.1 Numerical testing" is now added to the revised manuscript with these considerations and reference.

RC1-3. Finally, there is a set of small editorials that are marked up in the annotated manuscript.

> AR-3: We revised the manuscript and addressed all minor comments following the reviewer's suggestions.

RC2- S. Reichenberger (Referee)
Thank you very much for the careful review and edits to the initial submission. Below we address the main comments raised on the initial submission. Please note that we uploaded the revised manuscript as a supplement to RC1 response comments, with your suggested changes also there. [RC2-#: Reviewer 2 comment #; AR-#: Authors response to comment #).

RC2-1. p2, l. 48: The citation "Ohlingerlow and Schulza" seems misspelled, and the reference does not appear in the reference list. Maybe it should read "Ohliger and Schulz"?

> AR-1. Corrected and reference added: Ohliger R. and R. Schulz. 2010. Water body and riparian buffer strip characteristics in a vineyard area to support aquatic pesticide exposure assessment. Science of The Total Environment 408(22):5405-13. DOI: 10.1016/j.scitotenv.2010.08.025

RC2-2. p. 2, l. 49 and following occasions: The term "bottomland" is not known to me. It seems to be a U.S. expression. Is it synonymous to "floodplain"?

AR-2. Changed to "floodplain"

RC2-3. p. 2, l. 57: "hydric soils": hydromorphic soils? waterlogged soils?

AR-3. Changed to "hydromorphic"

RC2-4. p. 3, l. 92: "soil depth (z) above the WT": In fact, z is just the vertical coordinate, isn't it? Fig. 1 a) and eq. 1 suggest that z is positive downward, but for sake of clarity, it should be stated explicitly whether z is defined as positive downward or positive upward.

AR-4. Yes, corrected as "soil depth (z, [L], positive downwards from the surface)"

RC2-5. p. 3, l. 95: "L is depth to the WT (i.e. the distance from the surface": Maybe this could be rephrased more clearly? The phrase is slightly confusing because L is also used as an integration boundary. Maybe "L is the depth of the permanent water table below the soil surface (z = 0)"?

AR-5. Yes, corrected as "L [L] is the depth of the fixed water table below the soil surface (i.e. the distance from the surface)".

RC2-6. p. 3, l. 97: "Bouwer (1969) expression": I guess it should read "Bouwer's"?

AR-6. Yes, corrected

RC2-7. p. 4, l. 115 and other occasions of "et al.": "Vachaud et al., (1974)": should be "Vachaud et al. (1974)" without the comma

AR-7. Yes, corrected

RC2-8. p. 6, l. 157: "w and b are the width and length of the VFS surface area": Given that VFS length and width are often confused, it should be clearly stated which is the flow direction: Maybe "w and b are the width (VFS dimension perpendicular to the flow) and length (VFS dimension in flow direction) of the VFS surface area"?

AR-8. Yes, corrected as suggested

RC2-9. p. 7, l. 176-178: Can you explain more clearly why the shift time t0 is needed? And what would be the physical interpretation of t0?

AR-9. As proposed by Main and Larson (1973), t_o is the graphical translation needed to ensure the intersection at $t=t_p$ of the two expressions of F, where $F=i.t$ for $t < t_p$ (a straight line) and Green-Ampt curve for $t > t_p$. Without this translation, the Green-Ampt curve would start at the origin and the line and curve would not intersect. The sentence is clarified as "Next to ensure that F_p (Eq. 3) and $F=i\cdot t_p$ match at the intersection of the two curves on $t=t_p$ (Fig. 2b), an abscissa translation (shift time, t_o) is applied to F_p (Mein and Larson, 1973)."

RC2-10. p. 10, l. 255: "predicative": predictive?

AR-10. Yes, corrected as suggested

RC2-11. Figure 6: "Comparison of the simplified and RE results against Vachaud et al. . . . ": I can see no results of simulations solving the Richards equation in this graph. There are two curves, but I suppose they belong to two SWINGO calculations with different conductivity functions?

AR-11. Yes, lines were not showing and are now added back in the revised manuscript.

RC2-12. Figure 8: In the lateral drainage case (panels e-h) there is no infiltration at all in region I. That means that that lateral drainage was zero, doesn't it? Can you give the settings of S0, Ksh and b in the figure caption?

AR-12. In Region I, when L $<h_b$ then z_w=0, so the soil is saturated from the beginning since the water table is in the capillary fringe and the hydraulic gradient in the Bousinesq approximation is ~0. Eq. 8 and Fig. 1b were edited to reflect this. Values of S_o=0.02, b=1m and K_{sh}= K_s (from Table 1 soils) were added to the figure caption.

RC3- Anonymous (Referee)

Thank you very much for the encouraging comments and careful review of the manuscript. Below we address the specific comments raised on the initial submission. Please note that we uploaded the revised manuscript as a supplement to RC1 response comments, with your suggested changes also there. [RC3-#: Reviewer 3 comment #; AR-#: Authors response to comment #).

RC3-1. The research in this specific manuscript, "Part A", is not specific to VFSs, other than the notion the riparian buffers in particular are likely to often be affected by a shallow water table that can impact infiltration. This paper has greater applicability beyond just VFS modeling, and has great value to hydrologic modeling in general. I would suggest that the authors consider modifying the title, abstract, and certain aspects of the introduction and conclusion to emphasize the broader relevance of this work as a step forward in improving the science of hydrologic modeling in general, beyond the simulation of filter strip processes.

AR-1. Thank you! We have added this suggestion to the introduction and conclusions. "As SWINGO was accurate, fast, and robust when analyzing a variety of conditions, it is appropriate to couple with currently available hydrological models to gauge the influence of the presence of WTs on other landscape processes beyond the simulation of filter strips. The proposed integral equation has broader relevance as a step forward in improving the science of hydrologic modeling in general in many other settings, to study shallow water table effects on surface runoff, infiltration, flooding, transport, ecological and land use processes."

RC3-2. Figure 3: The symbology for the different soils and model simulations are a bit difficult to discern. Some improvement in differentiation would be helpful.

AR-2. Symbols represent Richards eq. (RE) and lines the proposed model, where the different types of each represent the 4 soil types compared. We the revised the figure caption to clarify this.

RC3-3. Figure 4: Silty loam and sandy loam line symbols could be more distinct.

AR-3. We originally used a different color and longer dashes for SandyLoam, but this might not be clear when printing in black and white. We now changed the line types to improve contrast and redid the legend to clarify this.

RC3-4. Figure 6: The caption says that RE simulations are shown on this figure, however, it appears that both model simulations shown in the figure are the new "simplified" method.

AR-4. Yes, RE lines were not showing and are now added back in the revised manuscript.

RC3-5. Figure7: "i" in the figures should be defined in the figure caption as the other variables are.

AR-5. Yes, added to the caption as suggested.

RC3-6. Figure 9: It is not immediately clear what the different line symbology in this figure is meant to represent.

AR-6. The lines describe the trends in change of cumulative infiltration with water table depth for the same rainfall rate (i). We added definitions for K_s, D, h_b and i to the Figure caption.