Effect of levee foundation conditions on the saturated zone during flooding for rapid drawdown analysis

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1 Introduction

Rapid drawdown is one of the most important loading conditions for dams and levees when water is lowered at a rate faster than the rate which water pressure dissipates after prolonged impoundment of water for dams, and in the case of levees, prolonged flooding. An important assumption of undrained rapid drawdown analysis is that seepage is at a steady-state prior to drawdown. This conservative approach assumes the worst possible loading condition prior to drawdown for a dam. However, this may be incorrect for levees as shown in Figure 1, as storm surge or flooding usually occurs for short durations compared to earth dams.

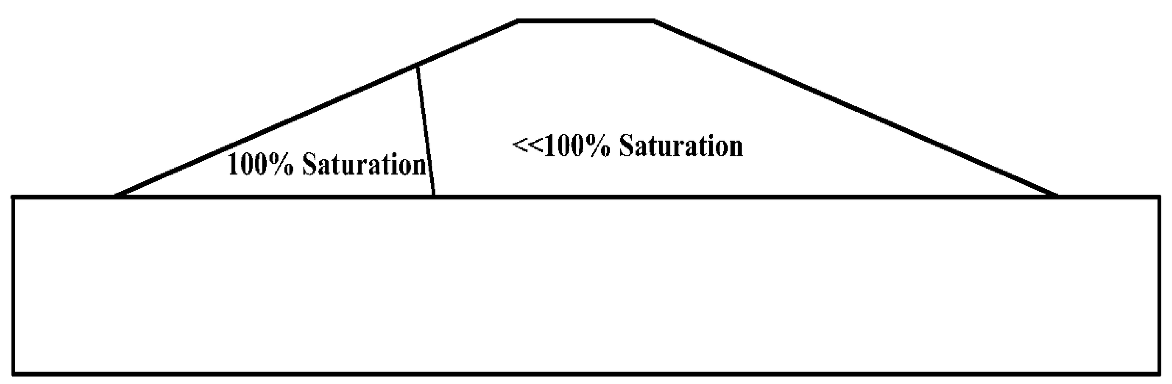

Figure 1. Idealized levee saturation after storm surge

In view of the rapid loading and unloading of levees, pragmatic levee design for rapid drawdown requires an estimate of the extent of the saturation zone of these structures prior to flood recession after a storm surge. Figure 2 shows a slope failure due to drawdown.

Figure 2. Slope failure due to drawdown. (photo by Neil F. Humphrey)

2 Objectives

This study is part of a broader research initiative exploring the extent of the saturation zone in levees due to flooding and builds on the work of Poston et al.(2018) with the final goal to develop charts which can be used to make appropriately conservative assumptions about the saturation zone within levees prior to rapid drawdown.

3 Methodology

1. Select a hypothetical levee model and a range of flood hydrographs which mimic typical floods as shown in Figure 3.
2. Select a range of levee and foundation soil coefficient of consolidation, c_v, values.
3. Then use parametric uncoupled transient seepage analysis to examine the effect of flood stage and the foundation soil's coefficient of consolidation, c_{vf}, on the saturation zone of the levee.
4. After examining the effect of flood stage and c_{vf} on the saturation, derive a standardized equation, and compare it to a standardized ratio of angles, S, between an approximated linear transient seepage line, an approximated linear steady-state seepage line and the downstream face of the levee.

The equation T is a function of levee geometry, levee soil coefficient of consolidation (c_{vs}), foundation soil coefficient of consolidation (c_{vf}), flood time to peak (t_p), flood height (h), base width of levee(L), levee height (H) and average base width of levee (L_{av}) corresponding to the average flood height.

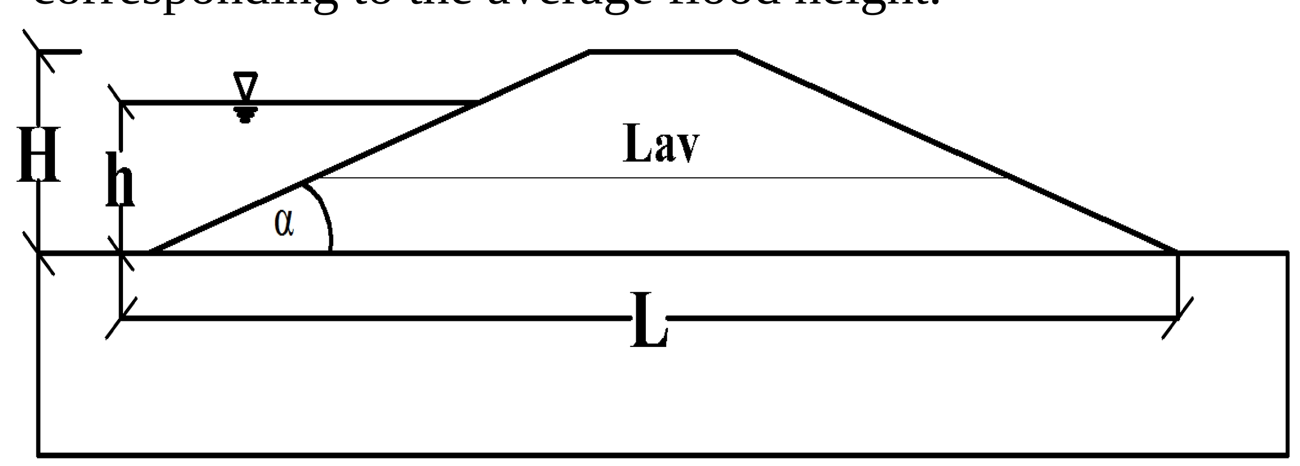

Figure 3. Hypothetical levee model

4 Results and Discussion

For a given flood scenario, the area of saturation under transient conditions generally increases with increasing c_v values (either levee or foundation) along with an increase in angle between the seepage line and waterside slope face. The angle between the seepage line and the downstream face of the levee decreases with increasing saturation zone. Figure 4 shows the extent of levee saturation zone for a range of levee and foundation soil c_v values.

The 100% area of saturation labeled A can be estimated from the charts found in Poston et al.(2018). Parameters for deriving the equation T are shown in Figure 5. The area of saturation labeled B can estimated from the preliminary plots shown in Figure 6.

Results and Discussion contd.

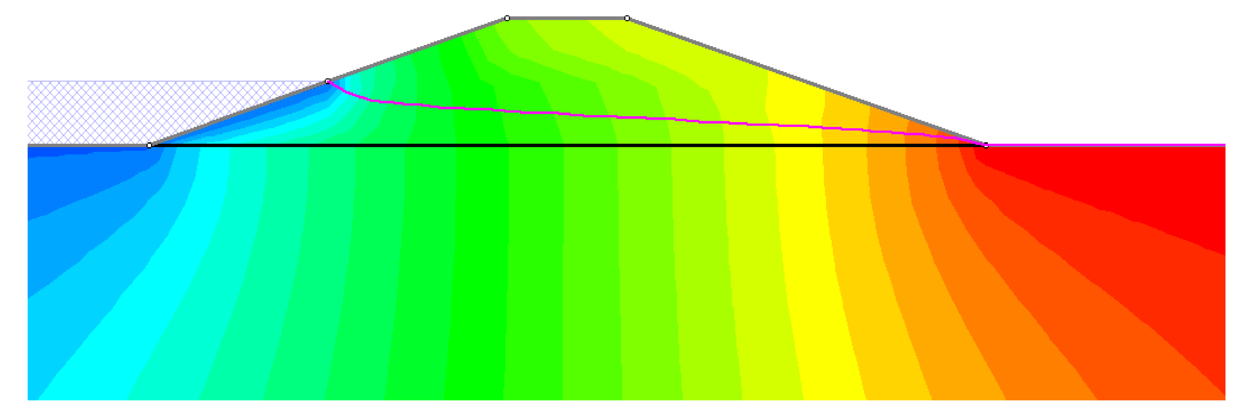

Figure 4a. Transient seepage results for silt-like levee on sand-like foundation

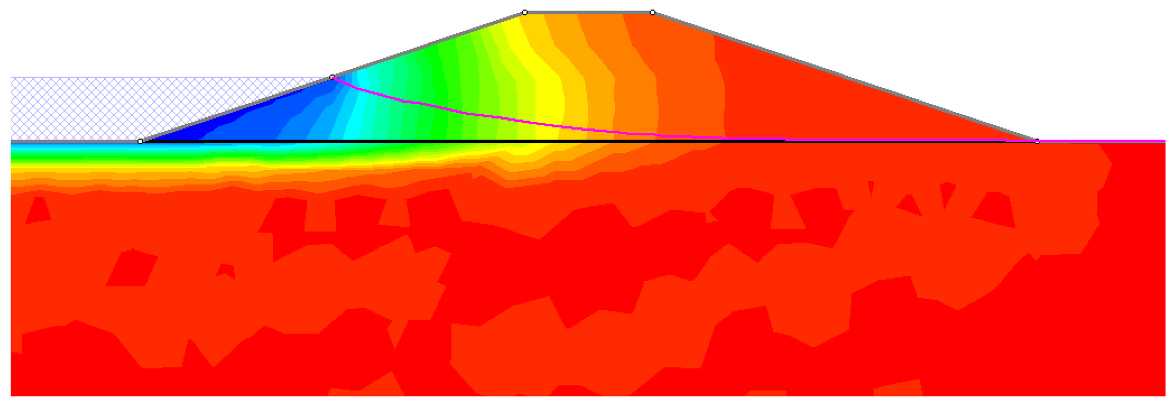

Figure 4b. Transient seepage results for silt-like levee on clay-like foundation

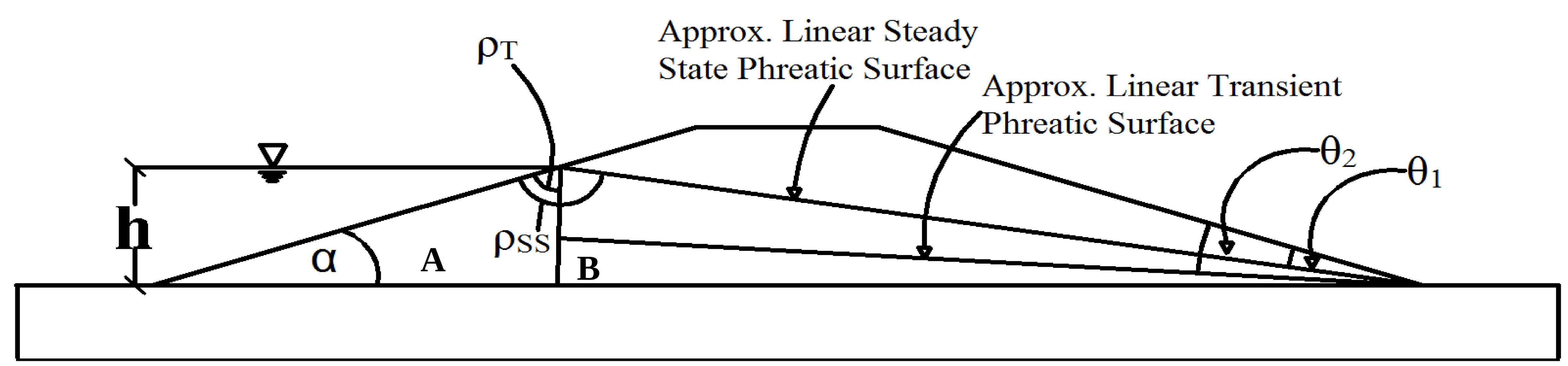

Figure 5. Variables used in deriving standardized equations, T and S

For a given levee soil, levee saturation, S, increases with increasing T as shown below in Figure 6.

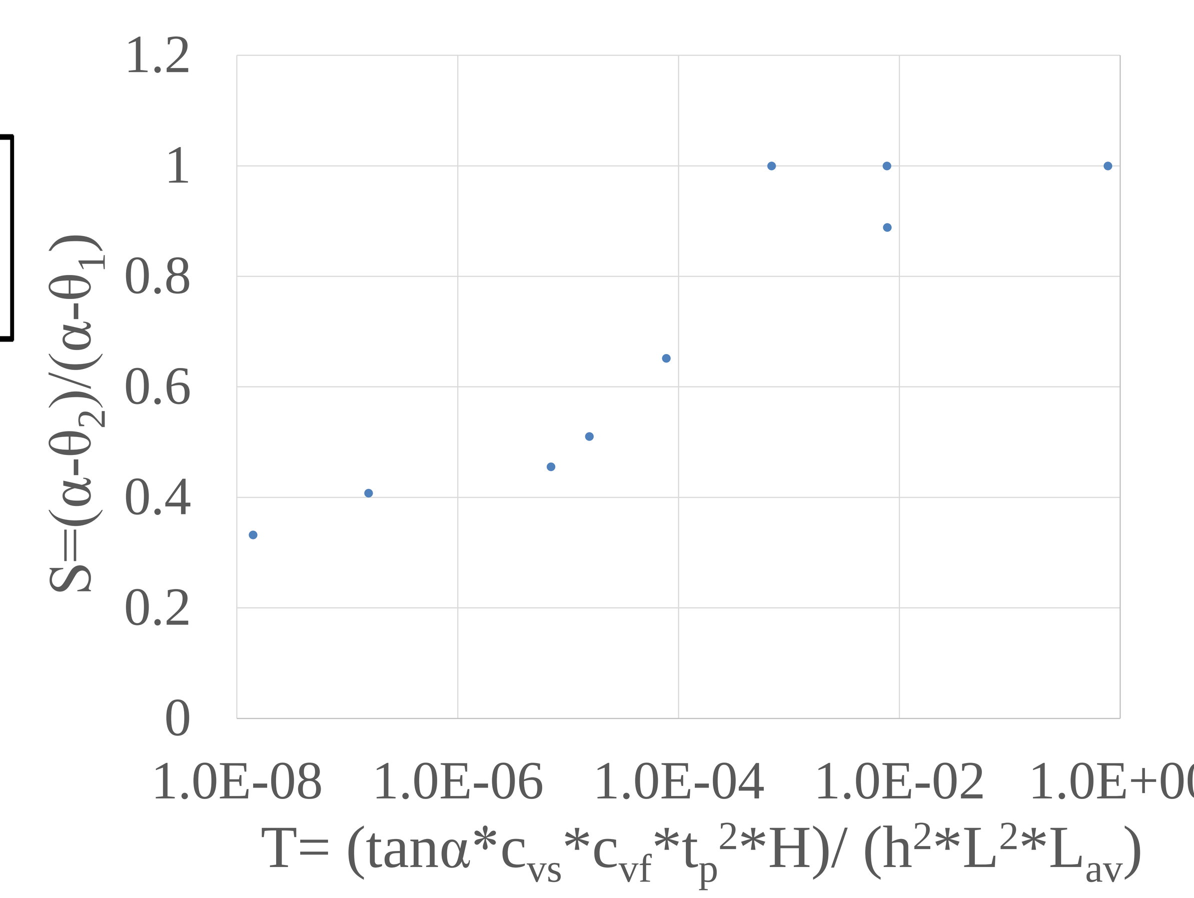

Figure 6a. Plot for T vs S at 50% flood height

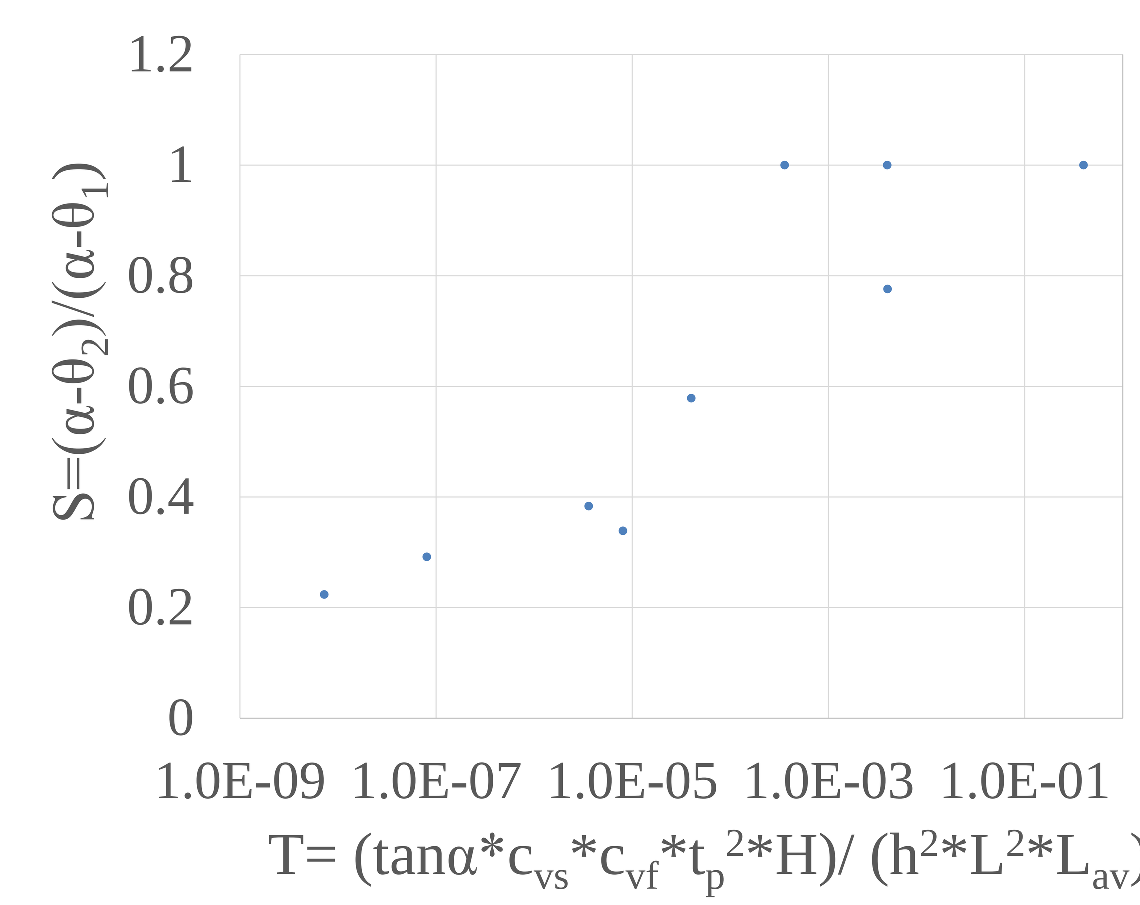

Figure 6b. Plot for T vs S at 75% flood height

5 Future Work

Other factors which will be considered in the development appropriately conservative charts for estimating the extent of levee saturation zone include:
1. Hydrograph shape
2. Initial pressures or saturation
3. Soil water characteristics curve type
4. Hydraulic conductivity function type

6 References

Poston, K., Turkson, P., VandenBerge, D.R (2018). "Parametric Study of Levee Saturation for Undrained Rapid Drawdown Analysis.", *Proceedings of USSD 2018,* (accepted for publication)

VandenBerge,D.R., Duncan, J.M., & Brandon. T. L (2015). "Limitations of Transient Seepage Analysis for Calculating Pore Pressures during External Water Level Changes." *Journal of Geotechnical and Geoenvironmental Engineering*,141(5). doi:10.1061/(asce)gt.1943-5606.0001283

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