Effect of levee foundation coefficient of consolidation on the extent of the saturated zone after 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. It occurs 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. Figure 1 shows a slope failure due to rapid drawdown.

An important assumption of undrained rapid drawdown analysis is that seepage is at a steady-state prior to drawdown. However, as shown in Figure 2 this assumption may be incorrect for levees, because storm surge or flooding usually occurs for short durations compared to earth dams.

Figure 1. Lower Quail Canal – California Aqueduct (photo by L. Harder, CA DWR ca. 1999)

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 recession after a storm surge or significant flood.

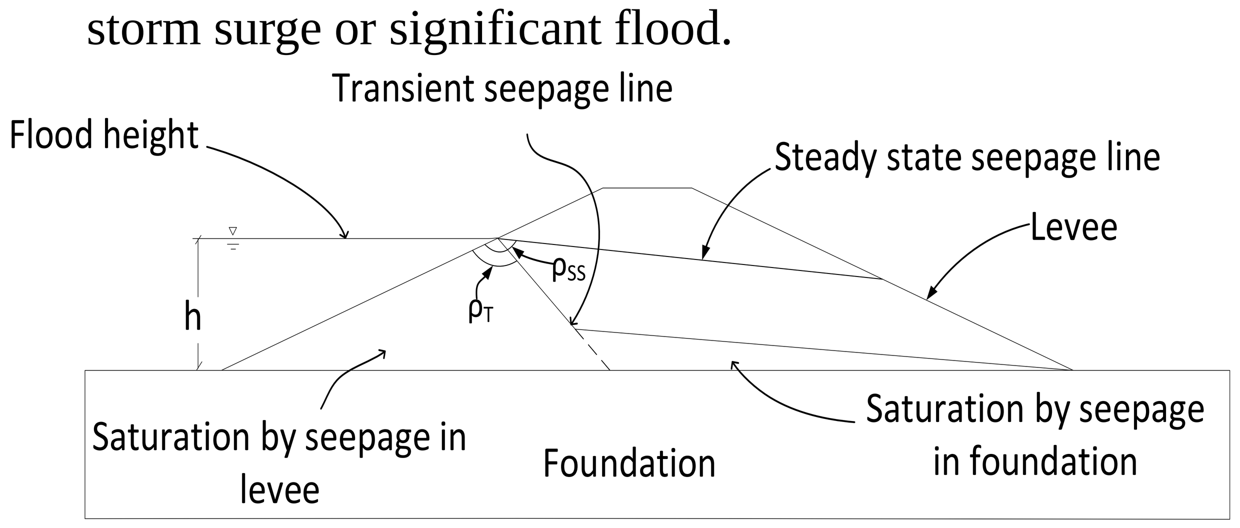
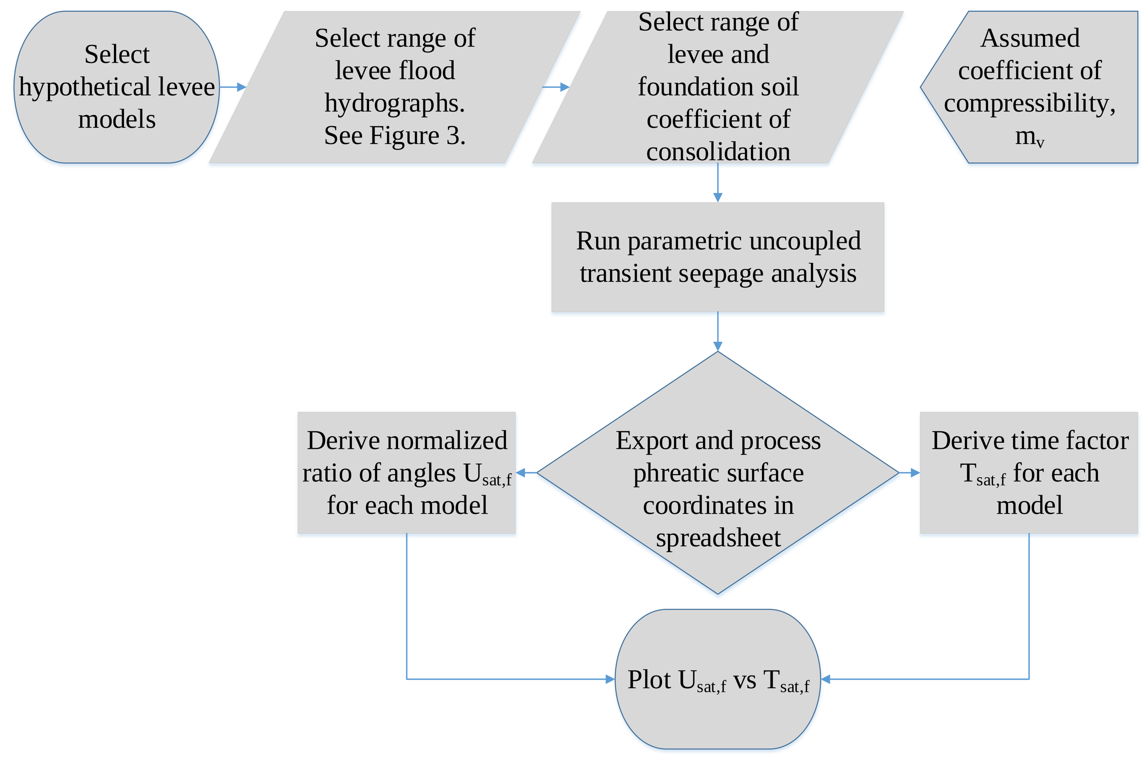


Figure 2. Idealized levee saturation after flood

2 Objectives

As part of a broader research initiative exploring the extent of the saturation zone in levees due to flooding, this poster investigates the influence foundation coefficient of consolidation has on levee through-seepage and develops equations and chart for delineating the saturated zone within levees. A similar study by Poston et al. (2018) considered levees on an impervious foundation.

3 Methodology



The finite element software Slide from Rocscience was used to predict phreatic surface within the levees and the Simple model option was used to define the soil-water characteristic curve and the hydraulic conductivity function of the soil.

4 Results and Discussion

The time factor $T_{sat,f}$ is function of levee geometry (α), levee soil coefficient of consolidation (c_{vs}), foundation soil coefficient of consolidation (c_{vf}), flood time to peak (t_p), flood height (h) and width of levee (L) as shown in Figure 3.

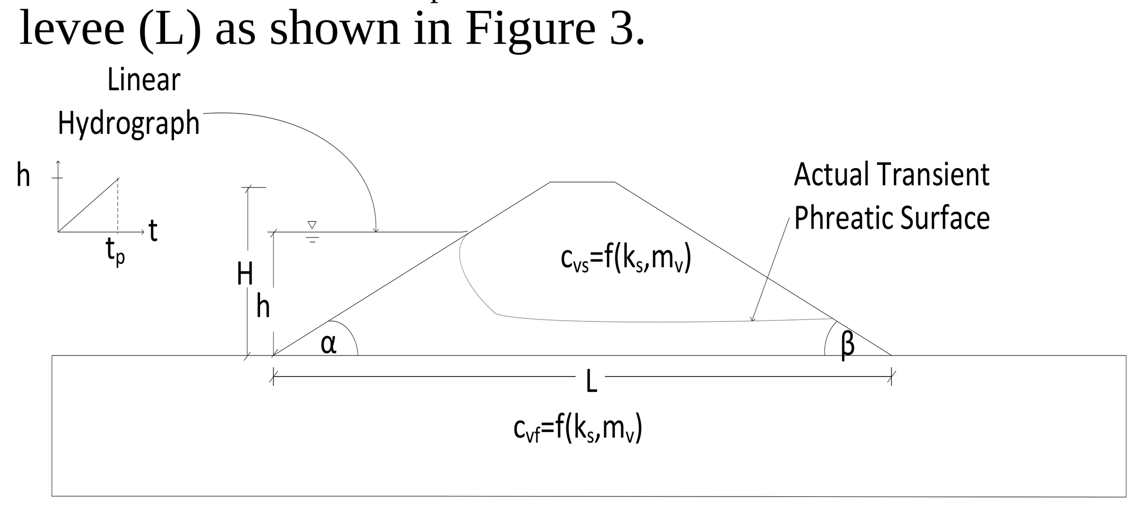


Figure 3. Hypothetical levee model

Figure 4 shows the extent of levee saturation zone for a range of levee and foundation soil c_v values. The saturated zone tends to have an L-shape when a more pervious foundation is considered. The two zones of saturation labeled A and B shown in Figure 5 are due to seepage from the retained water and seepage from foundation into levee respectively. Seepage from the retained water (Zone A) is not significantly affected by the presence of a pervious foundation.

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 (ρ_T). The angle between the seepage line and the horizontal bottom of the levee (θ_2) decreases with increasing saturation zone (Figure 5).

Results and Discussion contd.

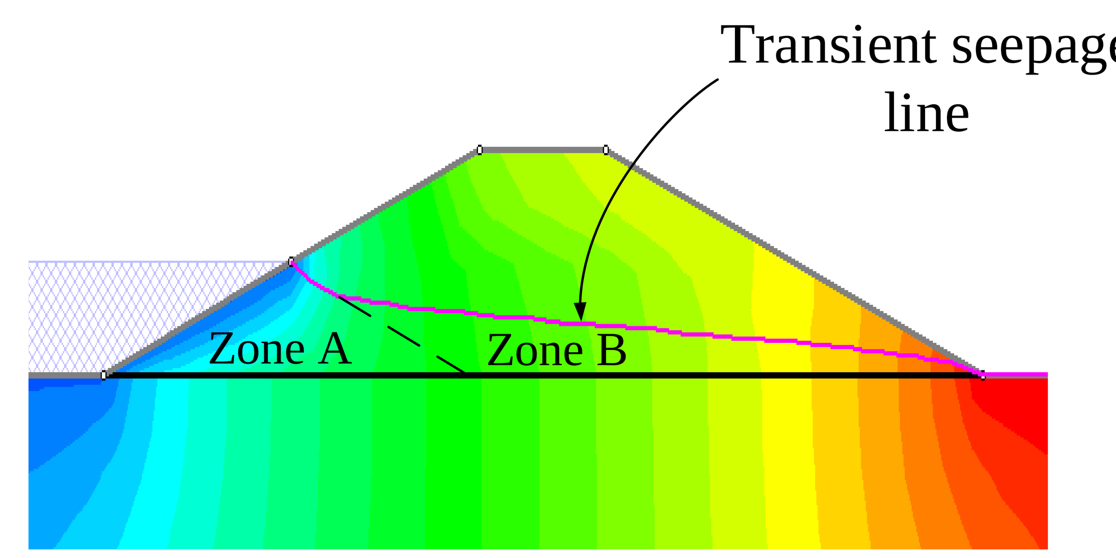


Figure 4. Transient seepage results for silt-like levee on sand-like foundation showing seepage line and total head contours

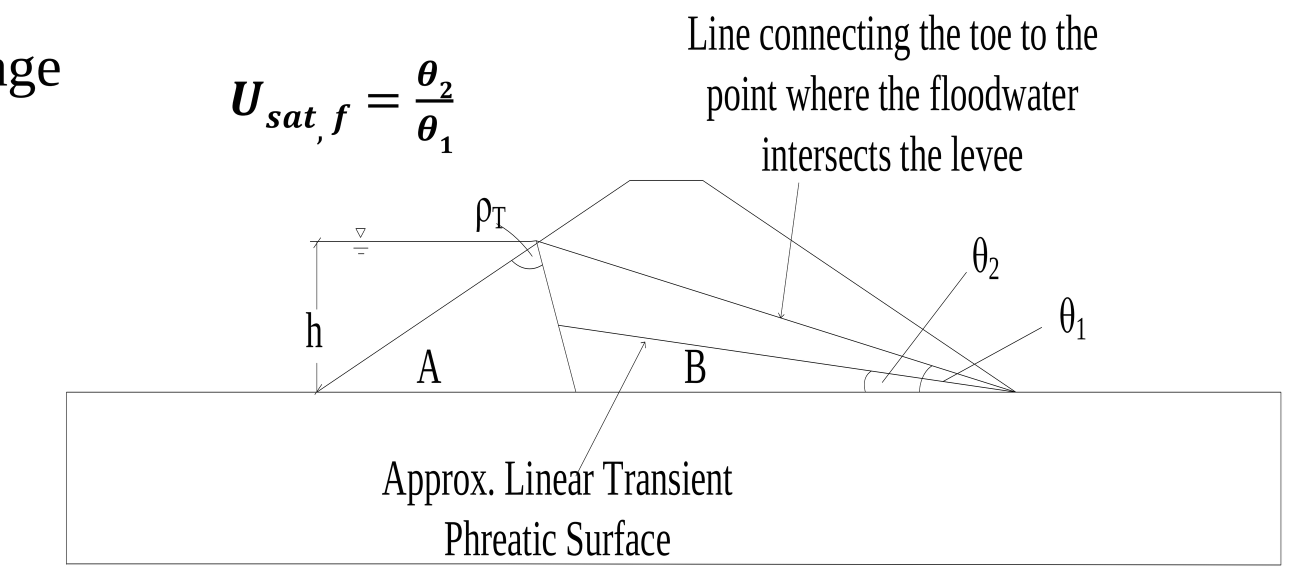


Figure 5. Angles of approximate linear phreatic surfaces (ρ_T after Poston 2018)

This study found that Zone A can be estimated from the chart proposed by Poston et al. (2018) which considers levee on impervious foundation shown in Figure 6. The angle ρ_{SS} can be calculated from equations presented in Poston et al. (2018), and subsequently ρ_T can be calculated from T_{sat} and U_{sat}.

On the other hand, Zone B is influenced by the rate of seepage within the foundation and the levee properties. Zone B can estimated from the chart shown in Figure 7. The equation for $U_{sat,f}$ in Figure 7 describes the trendline of data from the parametric analyses. For the same levee soil, the levee approaches steady-state conditions more quickly as c_{vf} increases. The angle θ_2 can be calculated from $T_{sat,f}$ and $U_{sat,f}$. Subsequently, ρ_T and θ_2 can be calculated to delineate the start-of-drawdown phreatic surface. These methods provide a simple means to estimate the saturated zone for RDD analysis of levees.

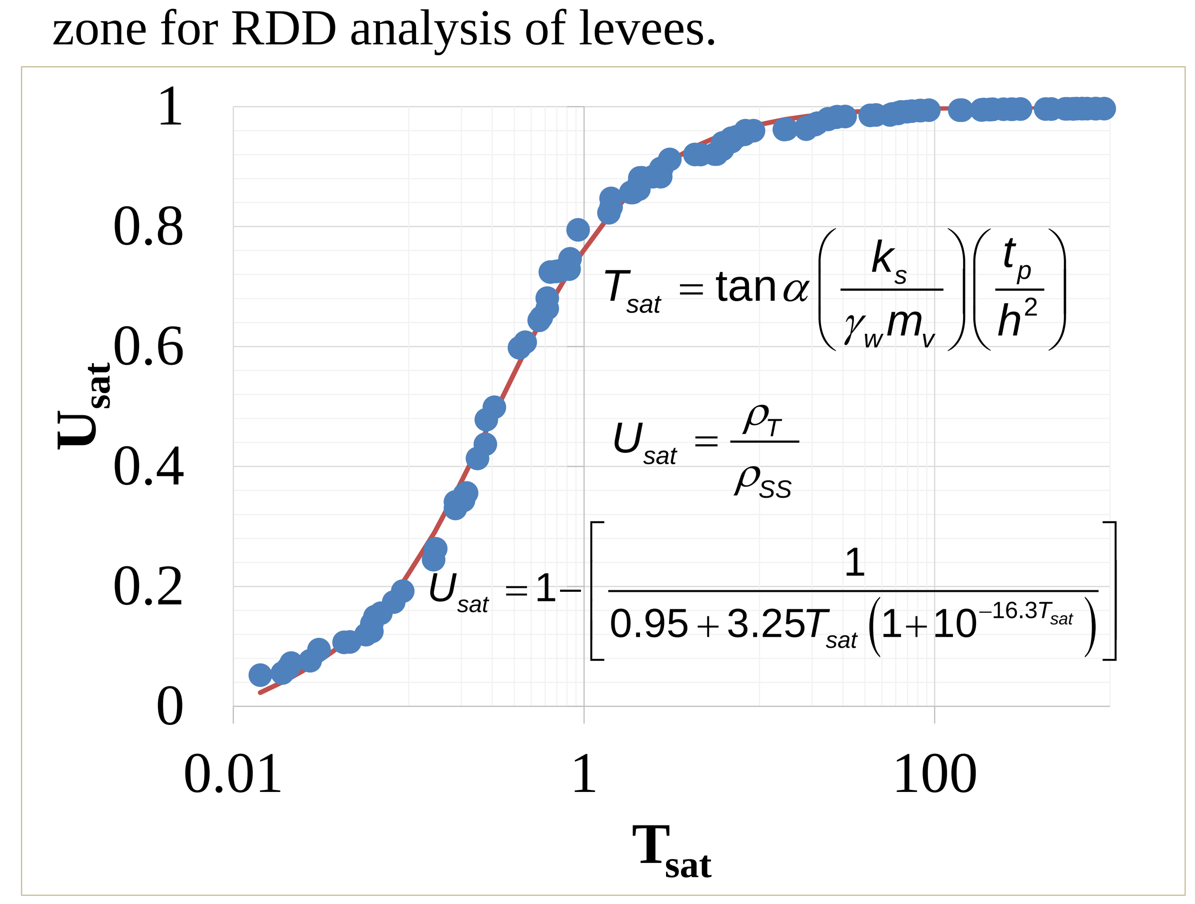


Figure 6. Estimation of levee saturation due to levee seepage types (from Poston et al. 2018)

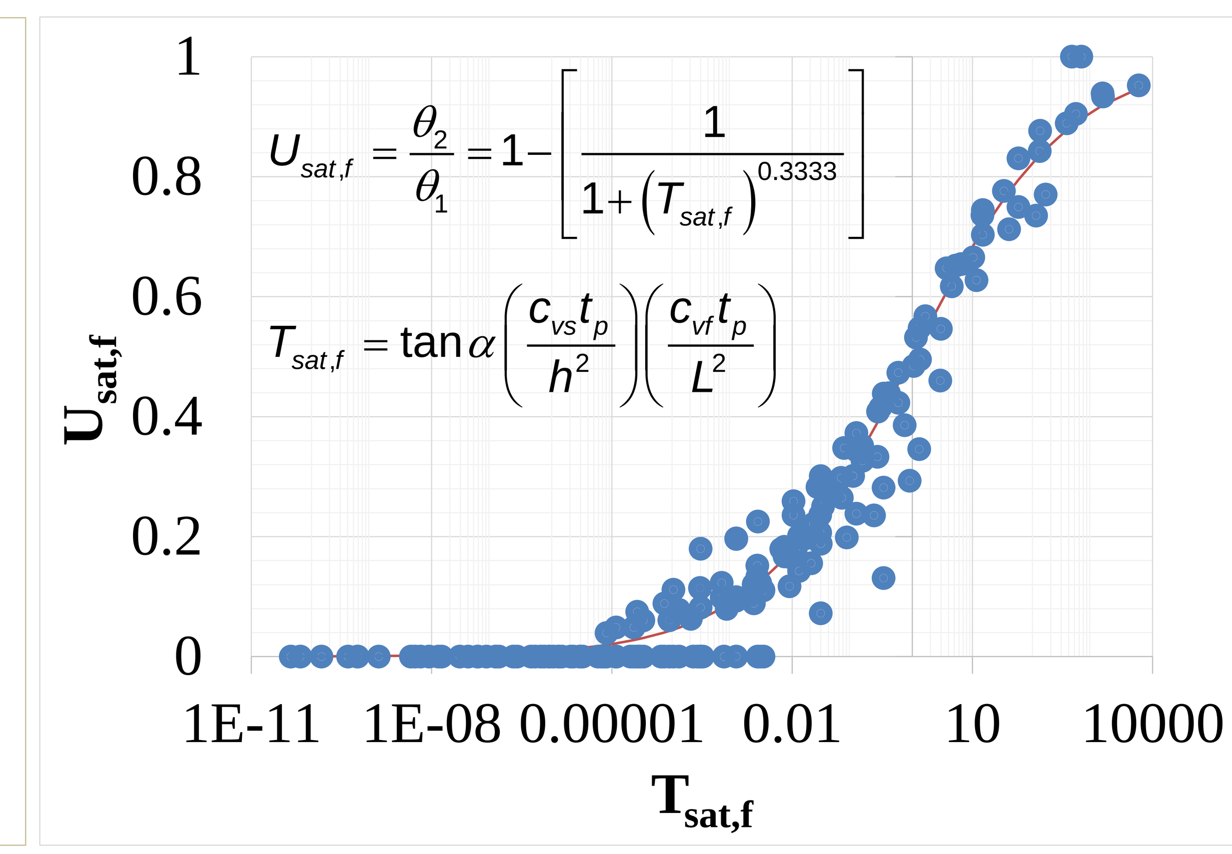


Figure 7. Estimation of levee saturation due to foundation seepage types

5 Conclusions

Levee foundation conditions have the largest impact on through-seepage when $c_{vf} > c_{vs}$. For this reason, cases where the levee has a higher c_v than the foundation may be analyzed for RDD by assuming an impervious foundation.

Future considerations for this study include:

1. Hydrograph shape
2. Soil water characteristics curve type
3. Hydraulic conductivity function type

6 References

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

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