Appendix A. MARSH 98: Marsh Plain Evolution Modeling

1.0 INTRODUCTION

The FORTRAN program "MARSH98" estimates the long term sedimentation of constructed and natural marshes and marsh plains. The program, proprietary to PWA, utilizes Krone's approach of marsh plain modeling.

2.0 BACKGROUND

According to Krone, the elevation of a marsh plain rises at rates that depend on the (1) availability of suspended sediment and (2) depth and periods of inundation by high tides (Krone, 1987). When the level of an evolving marsh surface is low with respect to the tidal range, sedimentation rates may be high if the suspended sediment supply is ample. However, as the marsh surface aggrades through the tidal range, the frequency and duration of flooding by high tides is diminished so that the rate of sediment accumulation declines.

As laid out by Krone (Krone, 1987), MARSH 98 calculates the amount of suspended sediment that deposits during each period of tidal inundation and sums that amount of deposition over the period of record.

3.0 METHODS

MARSH 98 is based on methods devised by Professor R.B. Krone of UC Davis and reported in his 1987 paper (Krone, 1987). The algorithm is centered around the mass balance of suspended sediment throughout the water column. The equation for this balance is:

On the flood tide when $\frac{d\eta}{dt} \geq 0$,

$$(\eta - z)\frac{dC}{dt} = -V_s C + (C_o - C)\frac{d\eta}{dt}$$

On the ebb tide when $\frac{d\eta}{dt} < 0$,

$$(\eta - z)\frac{dC}{dt} = -V_s C$$

where:

η = Water surface elevation,
z = Marsh plain elevation,
C = Suspended sediment concentration,
t = Time,
V_s = Settling velocity, and
C_o = Ambient suspended sediment concentration of flood laden waters.

The major underlying assumption with the mass balance equation is that all material that settles to the bed becomes permanent marsh plain material and is not scoured by ebb currents, large waves, or storm conditions. The settling velocity for suspended particles has the following relationship:

$$V_s = KC^{4/3}$$

where:

V_s = Settling velocity,
K = A constant (0.00011 when units are S.I. Metric), and
C = Suspended sediment concentration.

Accumulation of material on the bed is determined by the following equation:

$$\Delta z = \frac{\int_t V_s C dt}{C_d}$$

where:

Δz = Change in bed elevation,
V_s = Settling velocity,
C = Suspended sediment concentration, and
C_d = Dry density of inorganic material in the deposit.

On the flood tide, the storage of suspended sediment in the water column is affected by (1) re-supply from the sediment laden flood waters (inflow), and (2) deposition to the marsh surface (outflow)— the suspended sediment concentration is affected by both of these processes. On the ebb tide, the storage is affected by (1) ebb waters that remove sediment (outflow), and (2)

deposition on the marsh surface (outflow)— the suspended sediment concentration is only affected by the depositional process. MARSH 98 can perform the mass balance when the marsh surface is subtidal (always submerged) or intertidal (submerged only part of the time) and can transition between the two states.

Using a series of successively correcting and approximating half- and full-step advances, the algorithm moves the solution forward through time. The technique is very similar to how a second order Runge-Kutta ODE integrator would integrate the equations and advance the solution in time. The exact numerical recipe is laid out by Krone in his 1987 paper.

4.0 REFERENCES

Krone, R.B. "A Method for Simulating Historic Marsh Elevations." *Coastal Sediments '87. Proceedings of the Specialty Conference on Quantitative Approaches to Coastal Sediment Processes*. New Orleans, LA. May 12-14. 1987. 316-323.

Krone, R.B. "Simulation of Marsh Growth Under Rising Sea Levels." *Hydraulics and Hydrology in the Small Computer Age. Proceedings of the Specialty Conference, Hydraulics Division, ASCE*. Lake Buena Vista, FL. August 12-17. 1985. 106-115.

R.B. Krone & Associates. *Tidal Marsh Restoration at Bel Marin Keys*. Prepared for California Quartet, Ltd. January 17, 1996.