READ-ME: FLOW CHART

Goal of Flow Chart:

- To display and connect equations that relate the backscatter, the complex plane-wave reflection coefficient, the impedance and the porosity of the soil in order to calculate the porosity and density of the soil in-situ. The theory used is the Effective Density Fluid Model (EDFM), which uses all parts of the fluid model and substitutes the density for a density that relies on the effective density.
- The flow chart does not show the future flow of the code that will be written, just how the equations relate to each other and where all the values come from.

Flow Chart Key: (Also on flow chart)

- Yellow are properties of the Side Scan sonar
- Green are adjustments made within the Side Scan Sonar Software (these could also be from the code that interprets the Side Scan data
- Orange are calculated values/ parameters
- Grey are main equations with unsolved variables (ie porosity)
- Blue are water properties/properties from the field
- Purple are values that we are trying to get to and may need to be iterated
- Red are values that can be found in the lab
- White are notes, assumptions, and values to be determined

Flow:

The general flow of the chart follows the energy of the signal. The energy starts at the side-scan sonar and then loses energy as it travels through the water. Then this “incident energy” is distributed through scattering due to roughness, scattering due to sediment volume, and bottom loss. At the end of the flow chart, the scattered cross section is added up and compared with the bottom loss and incident energy to check the theory. If the incident angle, θ_i = scattered angle, θ_s; and azimuth, $\phi_s = \pi$, then the flow calculates the monostatic cross section (the backscatter). If the receiver of the signal is not in the same location as the output of the signal, then other angles should be used accordingly.

Outside of this main flow, there are two sections. The one in the bottom left calculates the effective density used in place of the sediment mass density within the Fluid Model. The section in the bottom right describes the connection between the reflection coefficient, the impedance, and the index of impedance, which can be used to estimate a value for the porosity and the density of the soil.

The variables that will need to be iterated are:

- Porosity, β
- Reflection Coefficient, $R(\theta)$*
- Speed of Sound in sediment
- Complex wave number in sediment (related to the speed of sound through the angular frequency)
- Density of soil (within bottom right section-- initially use the effective density)

*theta is assumed to always equal the incident angle, making $R(\theta)$ constant throughout the calculations.

Assumptions/notes:

- The slow wave and shear wave of the Biot model do not appear in the EDFM model, they are assumed to be not of interest.
- There is a thin layer of varying density on the surface of the seafloor [See Lyons and Orsi 1998]. This is not taken into account.
- The waves are modeled as plane waves, which discounts certain properties. Spherical wave attributes have been accounted for within the EDFM model in past work [See Camin and Isakson 2006]

Future work/edits for code:

- Ui (the incident energy) needs to be put in dB in order for the units to match with the bistatic scattering cross section.
- The flow chart does not display how porosity and the Reflection Coefficient are found through the iteration, rather just how the equations are formed and relate to the different variables. I am thinking that the iteration display would need to be a separate flow chart with the variables condensed and taken from the flow chart above.

Notation notes:

- I am assuming sediment mass density = bulk density from what I have read in Jackson's paper's and from the textbook. Jackson uses a ratio of [sediment mass density/ pore fluid mass density] in all of his equations for the FM. Williams says in his paper "all EDFM calculations were carried out by using the FM formulas, but replacing the FM density by the effective density. Thus, the only difference between the FM and EDFM calculations is the density they use." So, I am assuming from this that Williams replaces the "sediment mass density" with the effective density from the fluid model within the ratio, not just replaces the ratio in total with the effective density.But this is overall a confusing point in the paper because Williams does not acknowledge that there is a ratio at all

References:

[1] K. L. Williams, "An Effective Density Fluid for Acoustic Propagation in Sediments Derived From Biot Theory," The Journal of the Acoustical Society of America , pp. 2276-2281, 2001.

[2] K. L. Williams and D. R. Jackson, "Bistatic bottom scattering: Model, experiments, model/ data comparison," The Journal of the Acoustical Society of America , pp. 169-181, 1998.

[3] L. M. Brekhovskikh and O. A. Godin, Acoustics of Layered Media I, Moscow,: Springer-Verlag, 1990.

[4] B. Yavari and A. Bedford, "Comparison of Numerical Calculations of Two Biot Coefficients with Analytical Solutions," The Journal of the Acoustical Society of America, pp. 985-990, 1991.

[5] D. R. Jackson, D. P. Winebrenner and A. Ishimaru, "Applicaiton of the Compostie Roughness Model to High-frequency Bottom Backscattering," The Journal of hte Acoustical Society of America, pp. 1410-1422, 1986.

[6] A. P. Lyons and T. H. Orsi, "The Effect of a Layer of Varying Density on High-frequency Reflection, Forward Loss, and Backscatter," IEEE Journal of Ocean Engineering, pp. 411-422, 1998.