**Plan for Adding Wave Stretching to HydroDyn**

**Introduction**

This document outlines the plan to add wave stretching into HydroDyn. Wave stretching is an extension to the strip-theory solution, for both strip-theory-only and hybrid models (the potential-flow solution is unaffected by wave stretching). Wave stretching allows for the wave kinematics and hydrodynamic loads to be computed at all nodes within the fluid domain up to the instantaneous free surface (above SWL in a wave crest and below SWL in a wave trough), unlike models without wave stretching, which compute wave kinematics and loads at nodes between the seabed and SWL regardless of the instantaneous free surface. This plan includes details for adding *vertical stretching* and *extrapolation stretching*; *Wheeler stretching* is intentionally left for future work (not FY16), as the numerical implementation is very different, likely requiring a grid of wave kinematics that can be interpolated into. The extrapolation stretching approach is most consistent with the second-order theory currently implemented within HydroDyn.

Wave stretching applies to the velocity, acceleration and dynamic pressure terms of the wave kinematics; the current velocity; and the hydrodynamic added-mass, fluid-inertia, buoyancy, and viscous-drag terms of the loads (both distributed and lumped). Wave stretching does not affect the marine growth or flooded/filled buoyancy terms of the loads. When wave stretching is disabled, the solution is the same as prior versions of HydroDyn.

The first phase (documented here) will be to compute wave kinematics and loads only at existing hydrodynamic analysis nodes. No attempt will be made to place additional nodes at the instantaneous free surface to “correct” the solution for high accuracy. This will be added in a second phase (not yet documented). Until then, a fine discretization of nodes at the free surface will be required to obtain a “numerically smooth” solution.

**Input File Changes**

Other than comments, the input file is left unchanged. WaveSTMod = 0 (no wave stretching) is kept as an option and WaveSTMod = 1 and 2 will be enabled. WaveSTMod = 1 is for vertical stretching. WaveSTMod = 2 is for extrapolation stretching. WaveSTMod = 3 (Wheeler stretching) will not yet be supported. WaveSTMod is unused with WaveMod = 0 or 6 or potential-flow-only solutions (NJoints = NMembers = 0)

**Theory Background**

In the following equations,  is defined such that it is zero at SWL and positive upwards; the water depth is . (Note: this is different than the HydroDyn input file, whereby  is defined relative to MSL, not SWL).

Before applying stretching, the wave and current kinematics (only valid for ) in HydroDyn are computed as follows:









where the first-order wave terms are[[1]](#footnote-1)[[2]](#footnote-2)[[3]](#footnote-3):









with:









**Wave Stretching Theory**

To calculate stretching, new points where wave kinematics calculations take place must be added to HydroDyn, but no loads are calculated at these points. That is, for each strip-theory node  above SWL , a point is added at .

***Vertical stretching (WaveSTMod = 1):***

Vertical stretching means that wave kinematics in a wave crest (above SWL to the instantaneous free surface) are computed using values at SWL; wave kinematics in a wave trough (below SWL to the instantaneous free surface) are truncated. The updated wave and current kinematics are as follows[[4]](#footnote-4):



***Extrapolation Stretching (WaveSTMod = 2):***

Extrapolation stretching means that wave kinematics in a wave crest (above SWL to the instantaneous free surface) are computed using values at SWL plus a linear extrapolation based on the slope of the first-order wave kinematics at SWL; wave kinematics in a wave trough (below SWL to the instantaneous free surface) are truncated. It is noted that the slope of the second-order wave kinematics is not included in the linear extrapolation, which is consistent with second order theory; effectively, the second-order terms are vertically extrapolated. Likewise, the slope of the current profile is not included in the linear extrapolation because such extrapolation is known to over-predict the current speed in wave crests; effectively, the current terms are vertically extrapolated. The updated wave and current kinematics are as follows:



where the partial derivatives of the first-order terms are:







with:





**Domain for Hydrodynamic Load Calculations:**

Section 6.3 from the draft HydroDyn User’s Guide and Theory Manual is replaced as follows:

When WaveSTMod = 0, part of the automated geometry refinement mentioned in the above section deals with splitting of input members into sub-elements such that both of the resulting nodes at the element ends lie within the discrete domains described in the following sections. When WaveSTMod > 0, elements at the instantaneous free surface may be partially submerged.

***Distributed Loads***

*Inertia, Added Mass, Buoyancy*

When WaveSTMod = 0 and PropPot = FALSE, these loads are generated at a node as long as the Z-coordinate is in the range [–WtrDpth,MSL2SWL], and the element the node is connected to is in the water. When WaveSTMod > 0 and PropPot = FALSE, these loads are generated at a node as long as the Z-coordinate is in the range [–WtrDpth,MSL2SWL+], and the element the node is connected to is in the water. When WaveMod = 6, the domain is determined by the use of numeric values and nonnumeric strings in the wave data input files.

*Viscous Drag*

When WaveSTMod = 0, these loads are generated at a node as long as the Z-coordinate is in the range [–WtrDpth,MSL2SWL] and the element the node is connected to is in the water. When WaveSTMod > 0, these loads are generated at a node as long as the Z-coordinate is in the range [–WtrDpth,MSL2SWL+] and the element the node is connected to is in the water. When WaveMod = 6, the domain is determined by the use of numeric values and nonnumeric strings in the wave data input files.

*Filled Buoyancy, Filled Mass Inertia*

These loads are generated at a node as long as the Z-coordinate is in the range [–WtrDpth, FillFSLoc] and the element the node is connected to is in the filled fluid.

*Marine-Growth Weight, Marine-Growth Mass Inertia*

These loads are generated at a node as long as PropPot = FALSE, the Z-coordinate is in the range [MIN(MGDpth),MAX(MGDpth)], and the element the node is connected to is in the marine growth zone.

***Lumped Loads***

Lumped loads at member ends (axial effects) are only calculated at user-specified joints, and not at joints HydroDyn may automatically create as part its solution process (see Section 7.5.2 for differences between the input-file discretization and the simulation discretization). For example, if you want axial effects at a marine-growth boundary, you must explicitly set a joint at that location.

*Inertia, Added Mass, Buoyancy*

When WaveSTMod = 0 and PropPot = FALSE, these loads are generated at a node as long the Z-coordinate is in the range [–WtrDpth,MSL2SWL]. When WaveSTMod > 0 and PropPot = FALSE, these loads are generated at a node as long the Z-coordinate is in the range [–WtrDpth,MSL2SWL+]. When WaveMod = 6, the domain is determined by the use of numeric values and nonnumeric strings in the wave data input files.

*Axial Drag*

When WaveSTMod = 0, these loads are generated at a node as long as the Z-coordinate is in the range [–WtrDpth,MSL2SWL]. When WaveSTMod > 0, these loads are generated at a node as long as the Z-coordinate is in the range [–WtrDpth,MSL2SWL+]. When WaveMod = 6, the domain is determined by the use of numeric values and nonnumeric strings in the wave data input files.

*Filled Buoyancy*

These loads are generated at a node as long as the Z-coordinate is in the range [–WtrDpth,FillFSLoc]

**Outputs:**

There are no new outputs associated stretching, but nodes/joints may now move in and out of the water; when they are out of the water, the wave kinematic and load outputs should be zeroed.

1. The definition of the Inverse Discrete Fourier Transform (IDFT) is , with . [↑](#footnote-ref-1)
2.  is the Discrete Fourier Transform (DFT) of , and includes the amplitudes and phases of each first-order wave component, but need not be defined further in this document. [↑](#footnote-ref-2)
3. The second-order wave terms and current need not be defined further in this document. [↑](#footnote-ref-3)
4. The wave and current kinematics are undefined outside of the fluid domain. For output purposes, undefined values will be reported as zero. Likewise, hydrodynamic loads are not computed outside of the fluid domain, but will be reported as zero for output purposes. [↑](#footnote-ref-4)