Volunteer Plant Containment Pool Flow Analysis

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NRC Public Meeting

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ATTACHMENT 8

CFD Analysis of pool flows

- **Objective: Determine expected water velocities in containment pool for an anticipated break scenario, and determine debris transport probability.**

  Will the sump screens clog with debris?

  - 2 scenarios investigated, representing extremes (?)
    - Large loca break with sprays
      - Max. pool depth and flow rate
    - Small loca break, no sprays
      - Min. pool depth and flow rate
  - Performed a steady-state simulation and analysis of pool flow
  - Investigated the flow environment

  What is opportunity for debris to be transported?

Fluent Model Description

- **Commercial CFD Code**
- **1-, 2-, or 3-D, steady state or transient simulations**
- **Inviscid, laminar, or turbulent flow**
  - Wide variety of turbulence closures
    - Reynolds averaged equations (RANS) or large-eddy simulation (LES)
    - The κ–ε RNG closure includes turbulent effects of swirl, rapidly strained flows, high or low Reynolds number
- **Numerics**
  - 1st or 2nd order spatial differencing
  - 1st or 2nd order temporal integration
- **Meshing/Gridding**
  - Structured (hexahedral cells) or Unstructured (tetrahedral cells)
  - Wide variety of geometry import
    - ACAD, IDEAS, IGES, etc.

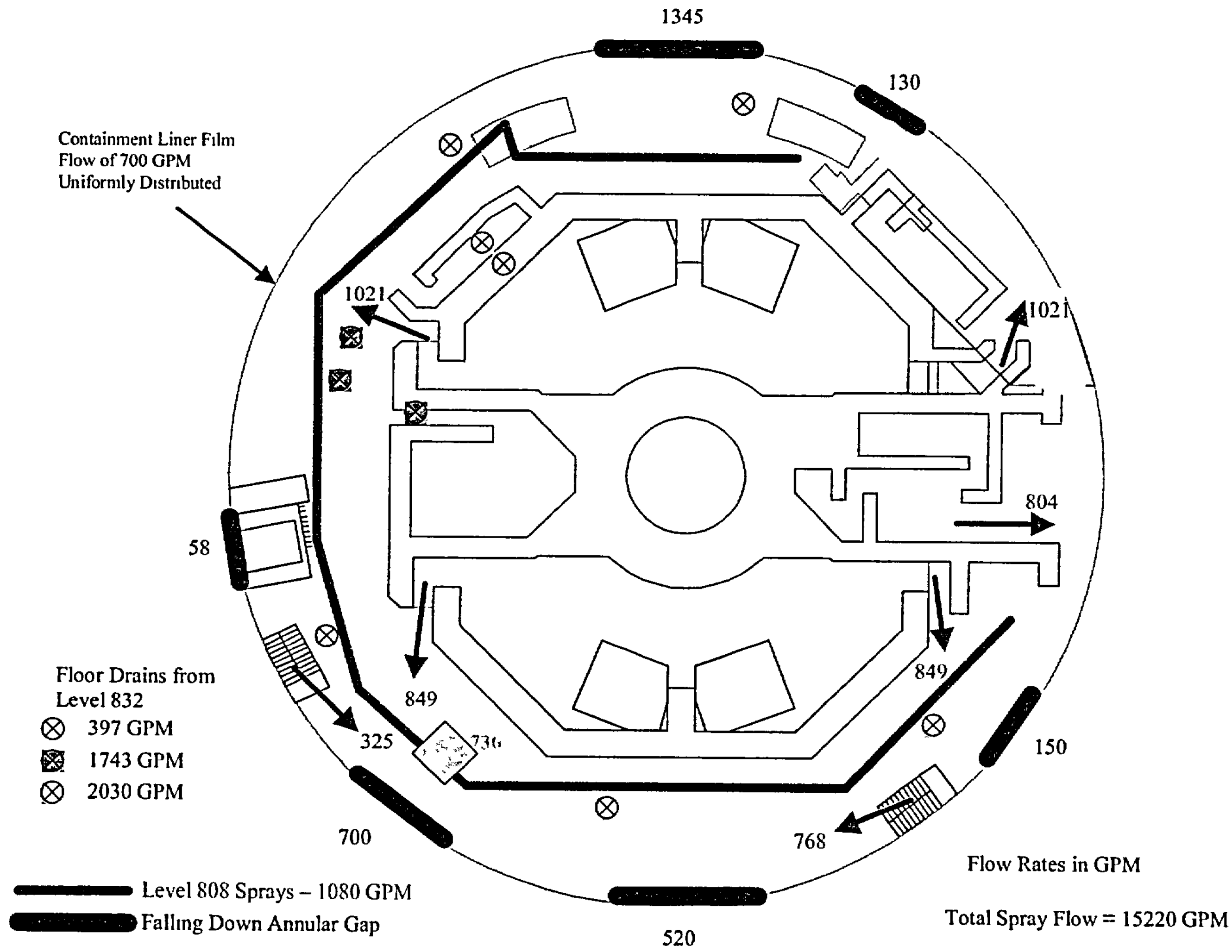
Model Parameters

- **Fluent Model Parameters**
  - 3D steady-state simulation (recirculation phase)
  - Unstructured mesh (tetrahedral cells)
    - ~463000 cells
    - ~12in Δx, Δy, ~1-4in Δz
  - Pressure outflow BC in sumps
  - Used the κ-ε RNG turbulence model
  - 2nd order numerics
- **Break and spray mass flows specified**
  - No free surface (air/water interface)
- **Initialized fluid to zero velocity**
- **Introduced mass flows and ran to steady-state**
  - Monitored sump mass outflow and 3-momentum equation residuals to determine "convergence"
  - Looked at flowfield "snapshots"

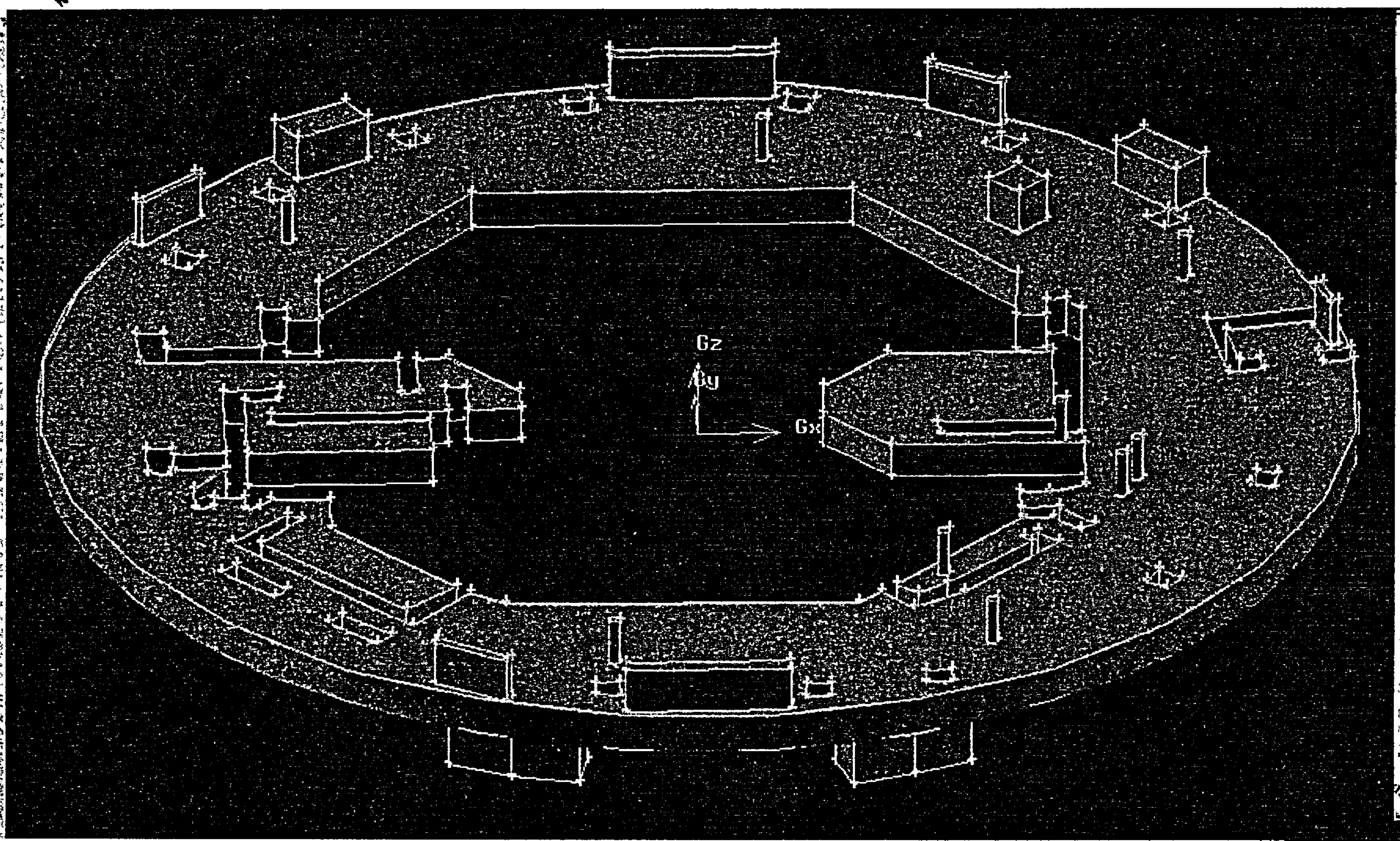
Break and Spray Flow Parameters

- **Large loca break**
  - 1.2m pool depth (4 ft.)
  - Break flow = 466 kg/s (7400 gpm)
  - Spray flows = 846 kg/s (13440 gpm)
    - Total = 1312 kg/s (20840 gpm)
  - Screen approach velocity = 0.0762 m/s (0.25 fps)
- **Small loca break**
  - 0.33m pool depth (1.3 ft.)
  - Break flow = 101.5 kg/s (1611 gpm)
  - No sprays
  - Screen approach velocity = 0.0213 m/s (0.07 fps)
- **Breaks**
  - Break modeled in 4 quadrants; 75%/25% split assumed
    - i.e.) Upper left = 75% flow in UL, 25% in UR, 0% in lower
  - 8 cases simulated (4 quadrants for each break size)

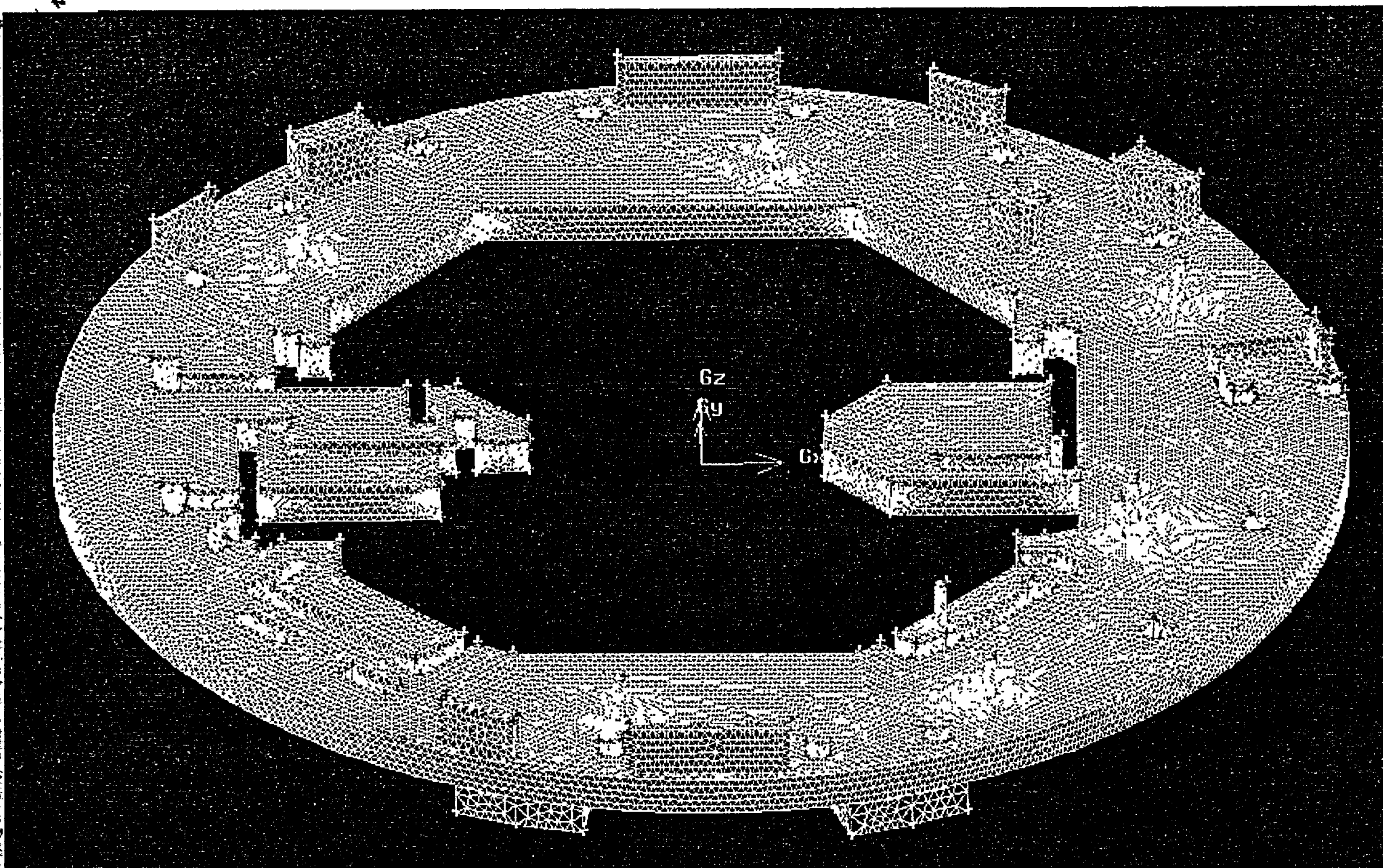
Spray Mass Flows



Volunteer Plant Modeled Geometry



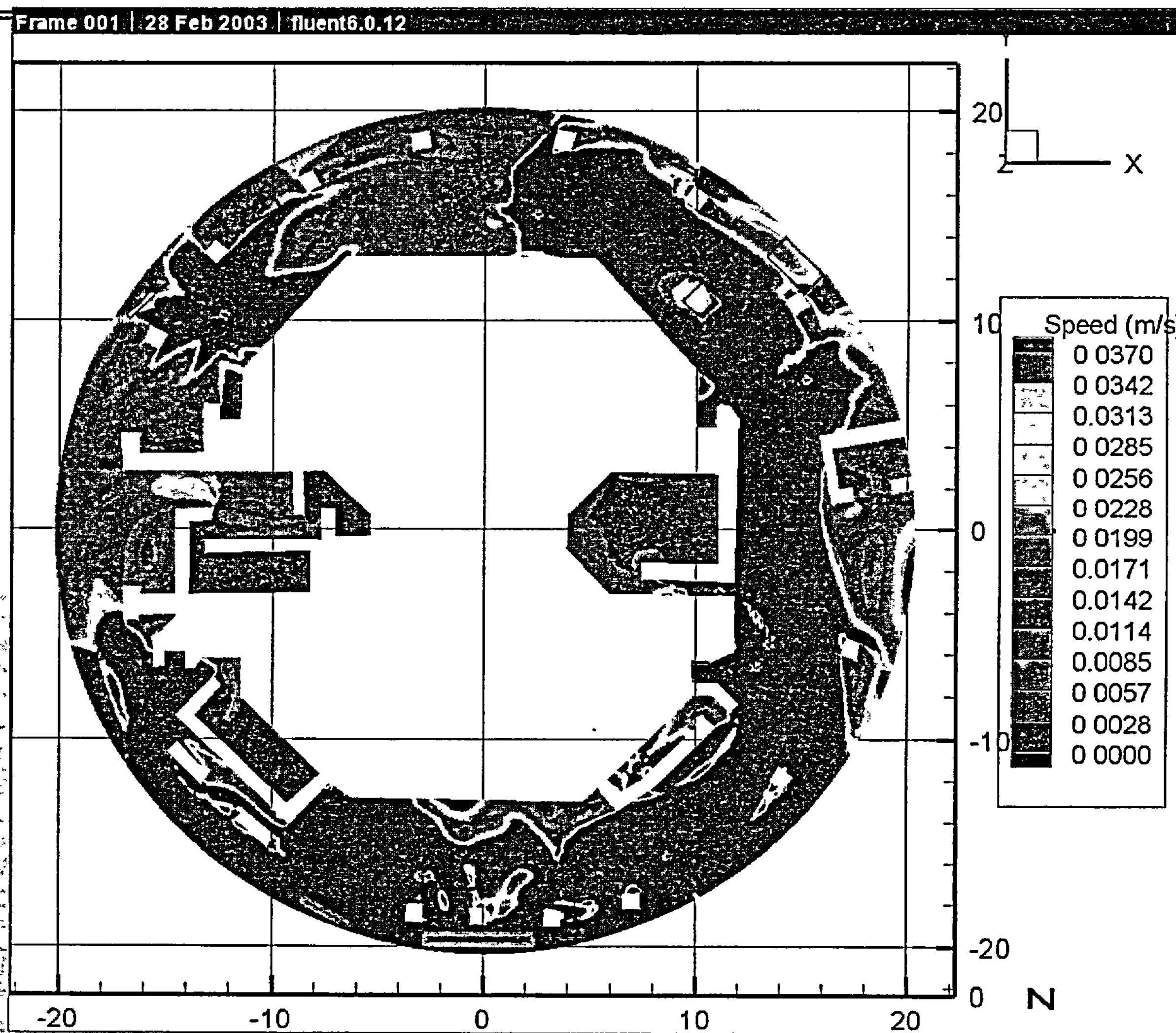
Tetrahedral Mesh



Two Threshold Transport Velocities

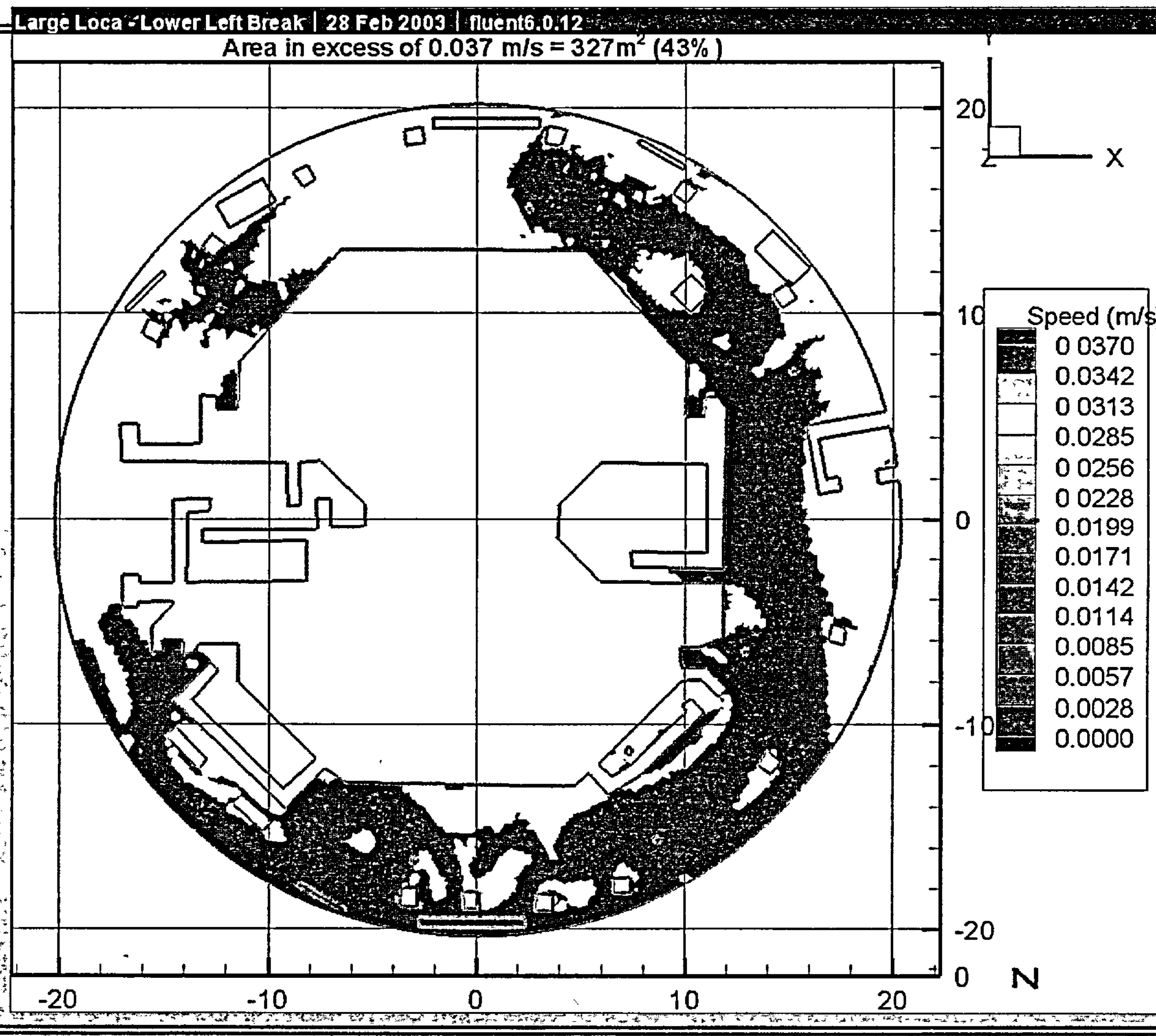
- **From the UNM separate effects tests:**
  - Fiber flocks transport threshold
    - 0.037 m/s (0.12 fps)
  - RMI foil transport threshold
    - 0.085 m/s (0.28 fps)
- **From CFD simulations:**
  - For each case, what fraction of the surface area is in excess of these velocities?
    - Extracted "slice" from simulation at 0.15m (6in) from lower surface
    - Computed area fractions above threshold velocity
      - Total pool transport area = 767.7 m^2 (8263.5 ft^2)

Large Loca – Lower Left Break

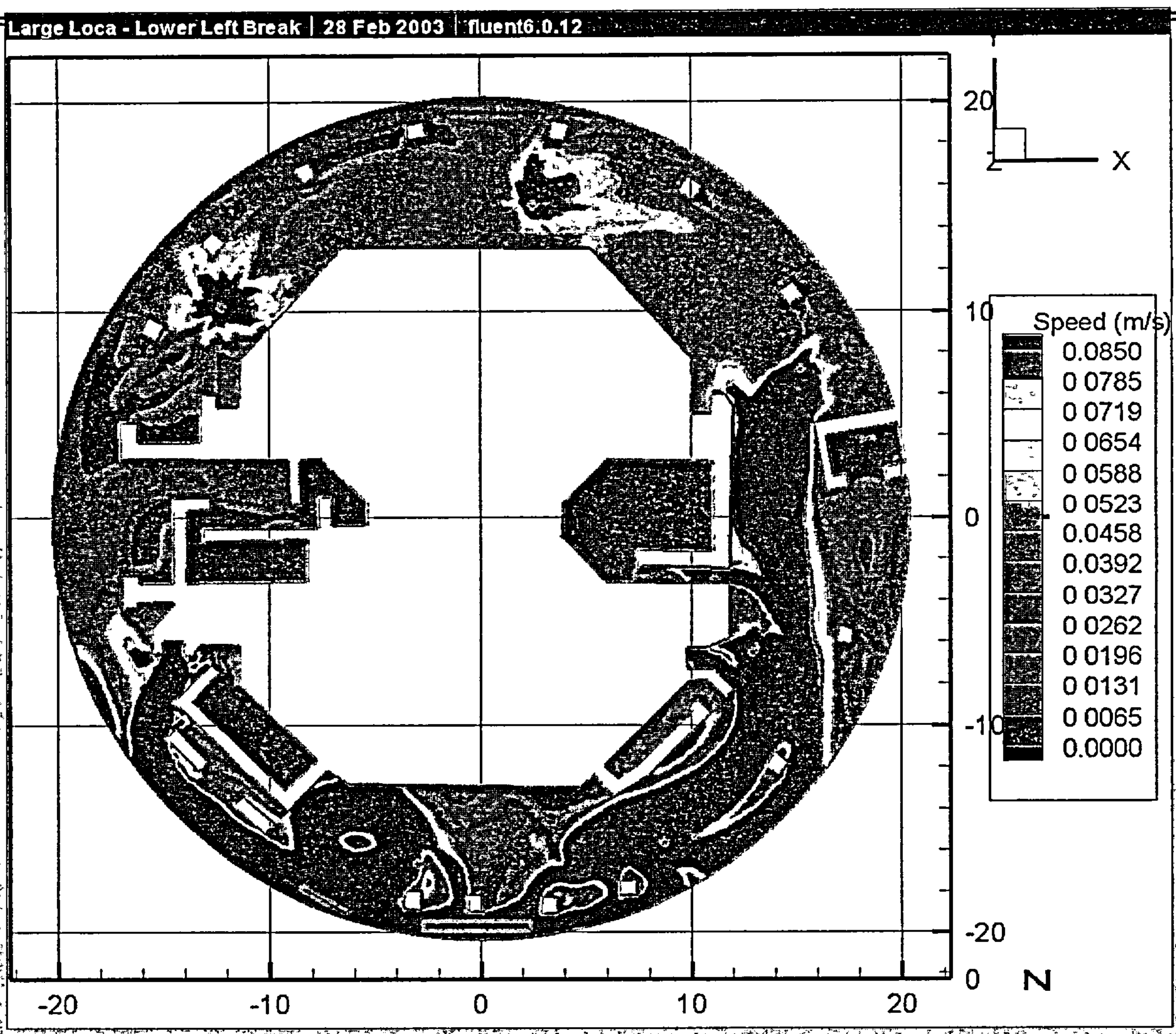


0.037 m/s
cutoff

Large Loca – Lower Left Break

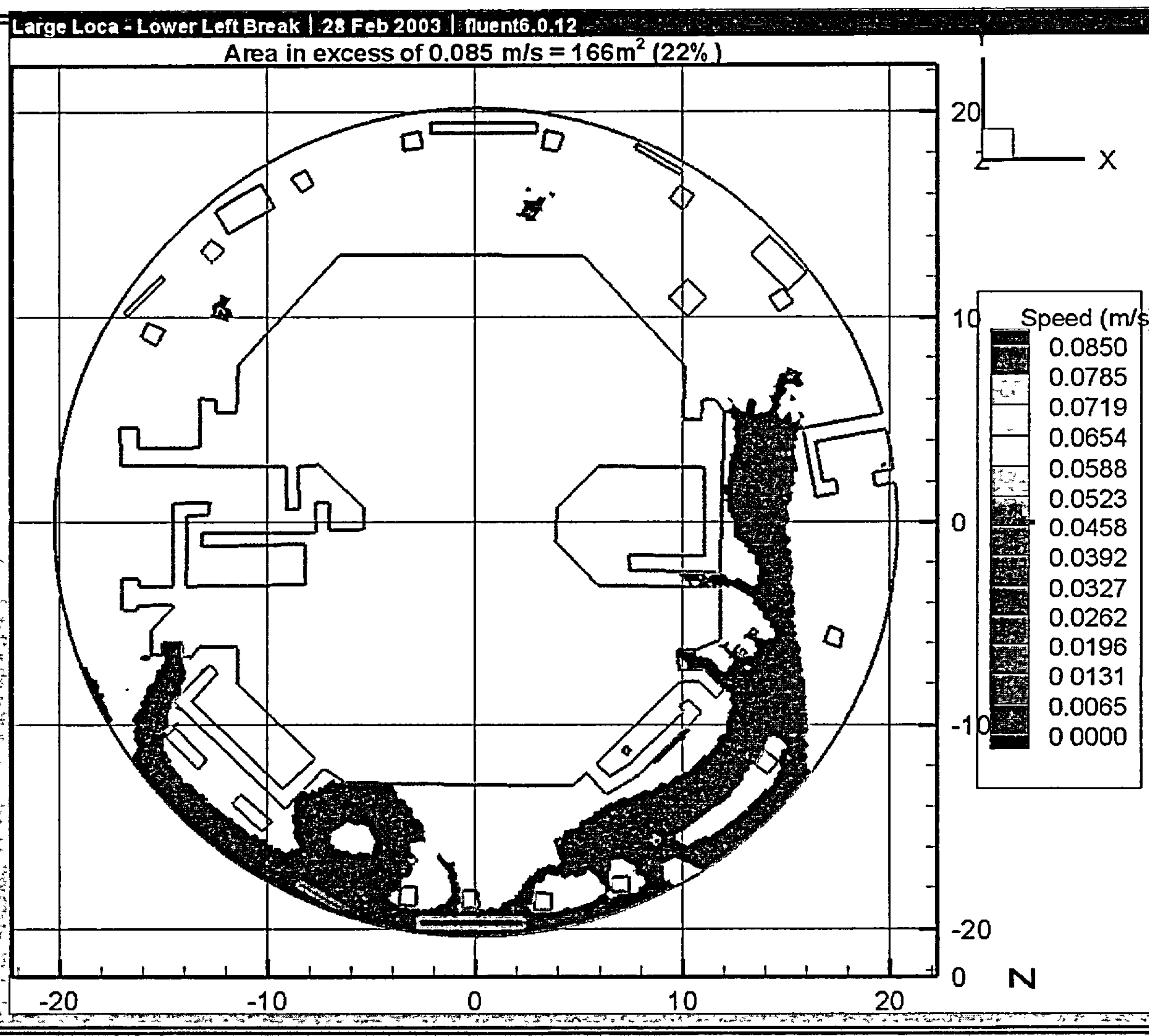


Large Loca – Lower Left Break



0.085 m/s cutoff

Large Loca – Lower Left Break



Large Loca Break, Fiber Flock Threshold

Break Location	Area in excess of 0.037 m/s (m^2)	Percentage (%)
Upper Left	411	54
Lower Left	327	43
Upper Right	457	60
Lower Right	311	41

Large Loca Break, RMI Threshold

Break Location	Area in excess of 0.085 m/s (m^2)	Percentage (%)
Upper Left	227	30
Lower Left	166	22
Upper Right	267	35
Lower Right	168	22

Small Loca Break, Fiber Flock Threshold

Break Location	Area in excess of 0.037 m/s (m^2)	Percentage (%)
Upper Left	189	25
Lower Left	109	14
Upper Right	238	31
Lower Right	148	19

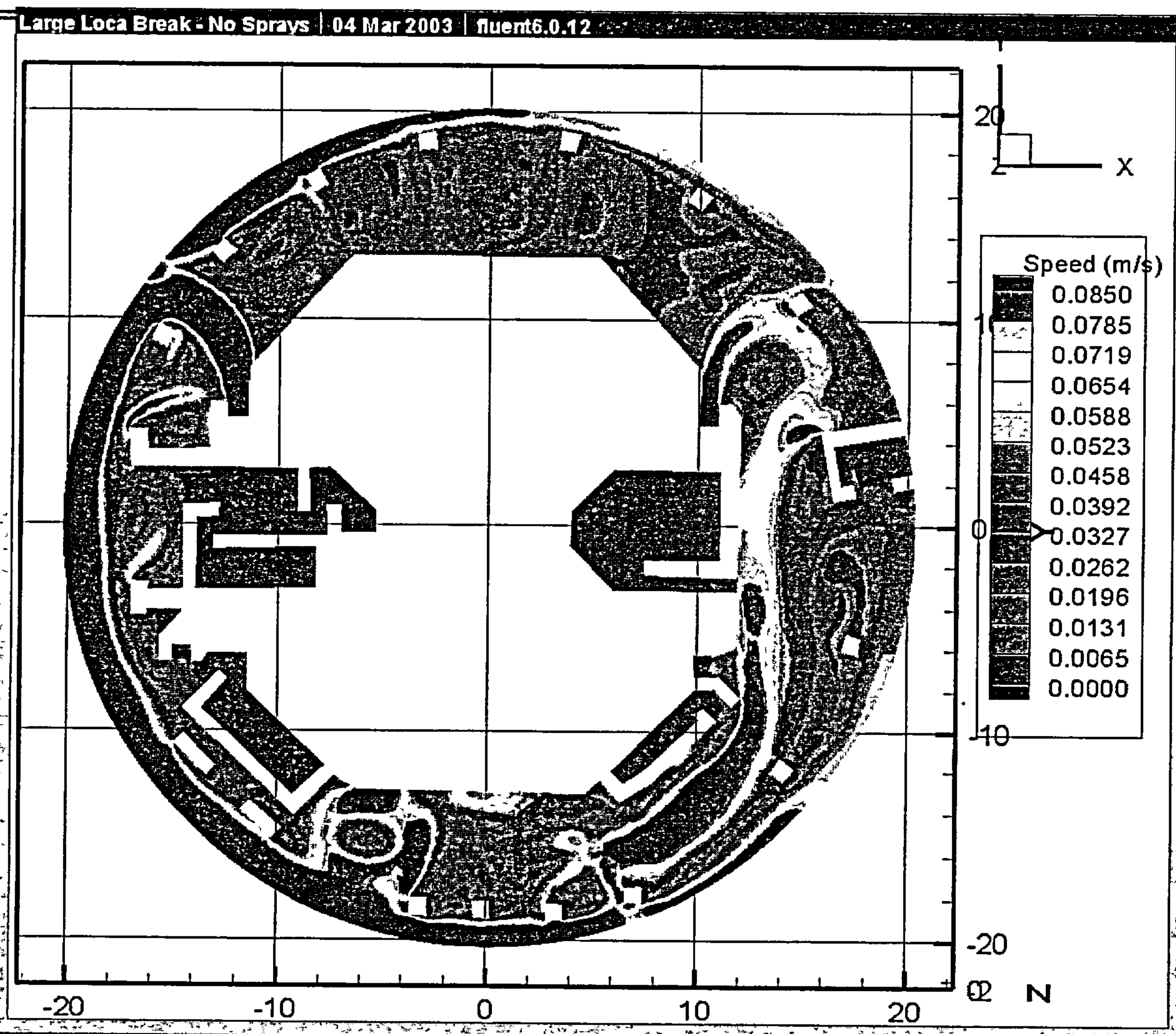
Small Loca Break, RMI Threshold

Break Location	Area in excess of 0.085 m/s (m^2)	Percentage (%)
Upper Left	16	2
Lower Left	35	5
Upper Right	38	5
Lower Right	40	5

Observations

- **Flow patterns are very complex**
  - Extensive regions of strong velocity shear
    - Will this "tear apart" fiber flocks and lead to a mat on the screens?
  - Also extensive regions of low/stagnant velocities
- **Often there is a high velocity zone at outer annulus**
  - Preferential flow induced by sump pumps
  - Directed flow out doorways from breaks
- **Sensitive to break location and composition**
  - 75/25% split
- **Small loca break in lower half impacts smallest area**
- **Large loca break in upper half impacts largest area**
- **Spray flows dominate turbidity in pool**

Large Loca – Upper Left Break, No Sprays



$104 m^2$
14%

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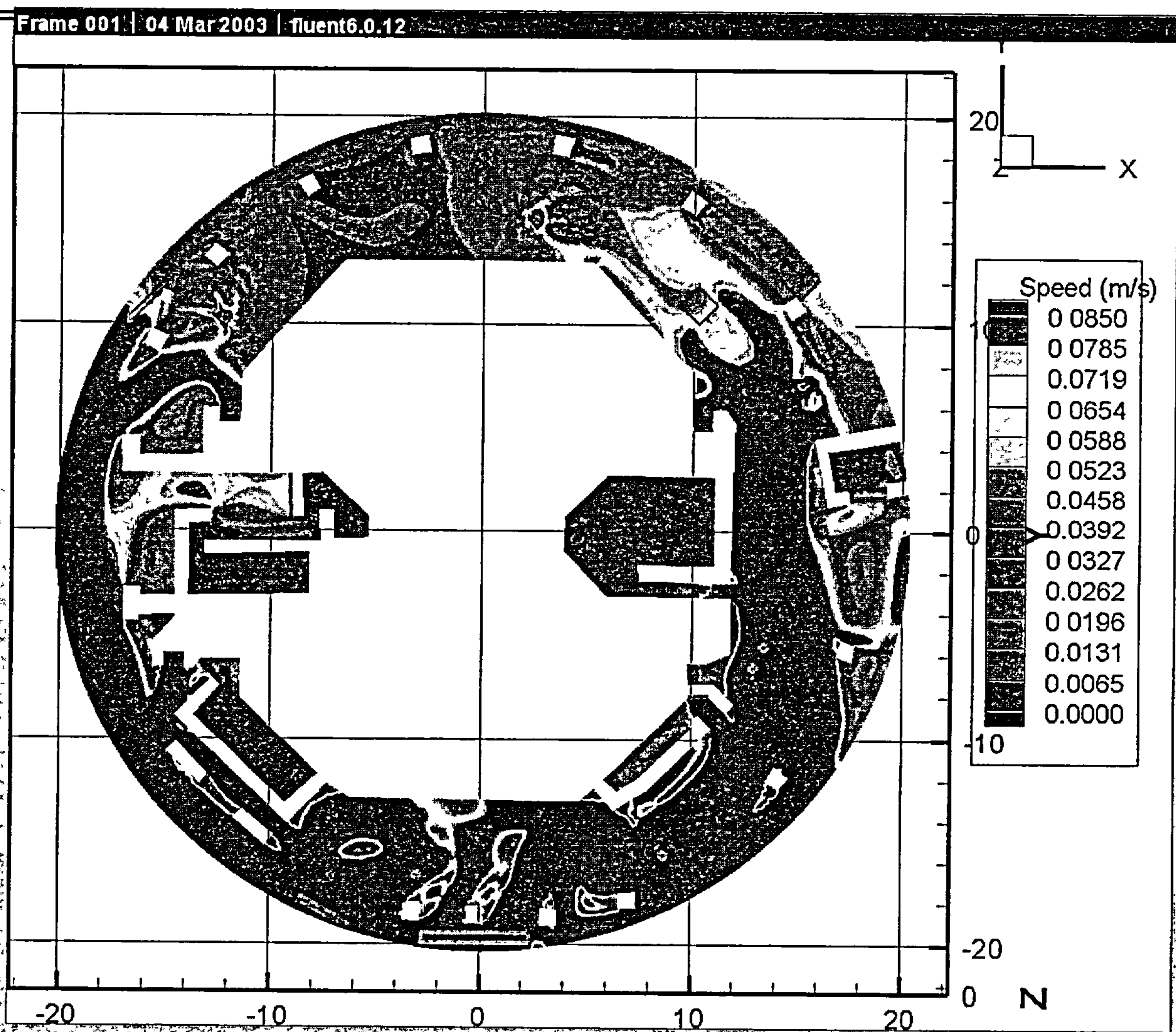
Small Loca – Lower Left Break, With Sprays



295m^2

39%

Concluding Comments

- **Performed an initial steady-state simulation of pool flow**
- **Need to compare to plant engineer calcs of water velocities**
- **Water flows can accelerate due to obstacles (pilings, walls, etc.)**
  - Plant specific analyses?
- **Transient (fill-up) analysis is being scoped**
  - When the pool is filling…
    - What are the water velocities?
    - What is the debris dispersal and when will it (will it?) transport to the screens?
  - Computationally intensive
    - May need to investigate "separate effects" rather than an integrated pool simulation
- **Clearly a complex flow phenomena, and needs more study**