SAND2011-4524C

SNL-EFDC: MHK Hydrodynamic Modeling and Optimization

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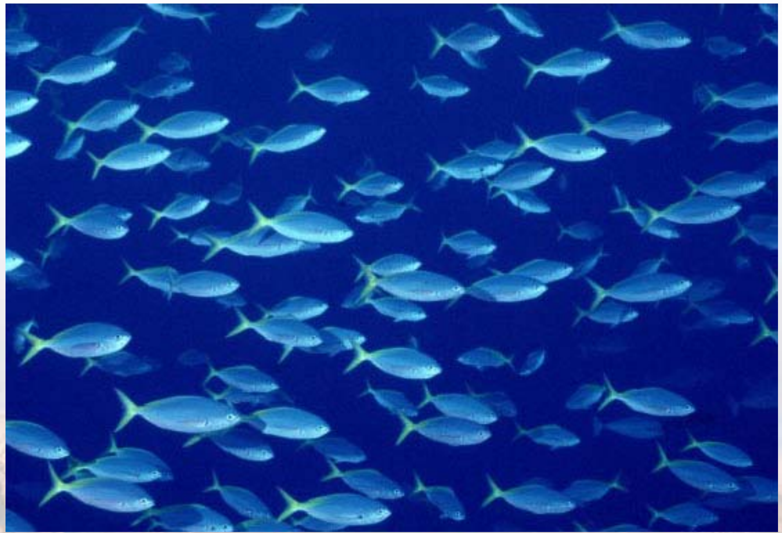
MHK Concerns



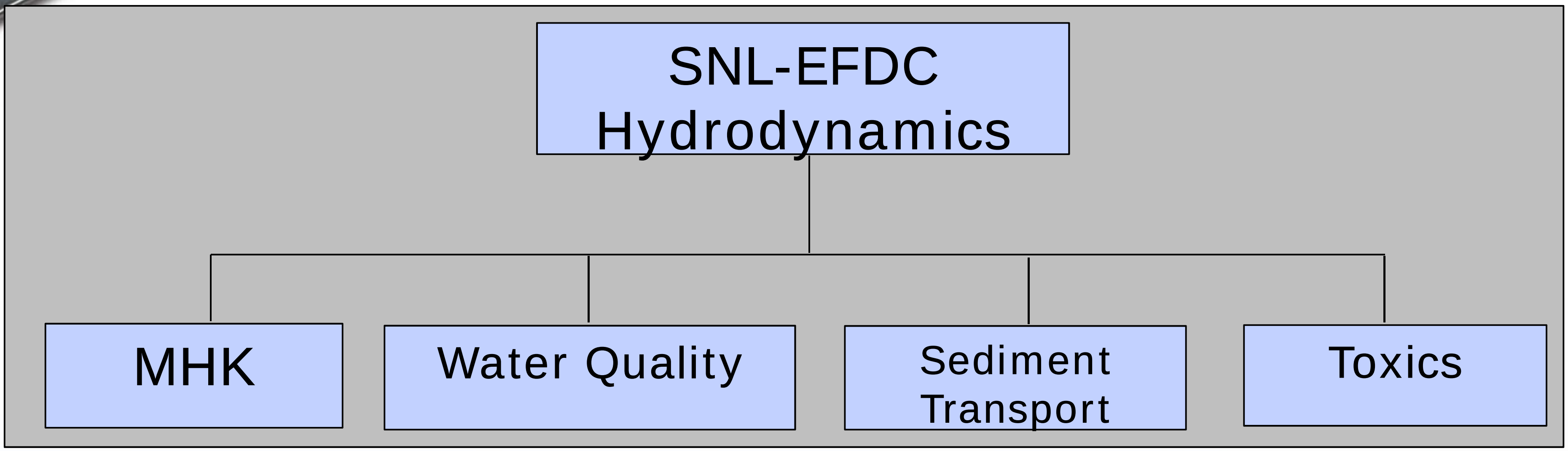
Economic

- Capital costs
- Operation and maintenance
- Environmental cost — ???
- Power-generation efficiency

Ecological

- Volumetric flow/tidal range
- Residence time (water age)
- Sediment dynamics
- Water quality
- Acoustics/EMF
- Migratory patterns

Sandia MHK Modeling Capabilities



- EPA open-source 3D code
- Curvilinear-orthogonal grid and sigma (stretched) vertical grid
- Conservative, 2nd-order-accurate finite difference/finite volume numerics
- Coupled-equation solutions to:
  - Mass, momentum, and K-ε conservation
  - Temperature transport
  - Salinity transport
  - Dye transport

Momentum Sink

$$P_{\mathrm{MHK}} = \frac{1}{2} C_{\mathrm{T}} A_{\mathrm{MHK}} \rho U^{3}$$

$$S_{Q} = -\frac{1}{2} C_{\mathrm{T}} A_{\mathrm{MHK}} U^{2}$$

K—ε Modifications

Empirical constants

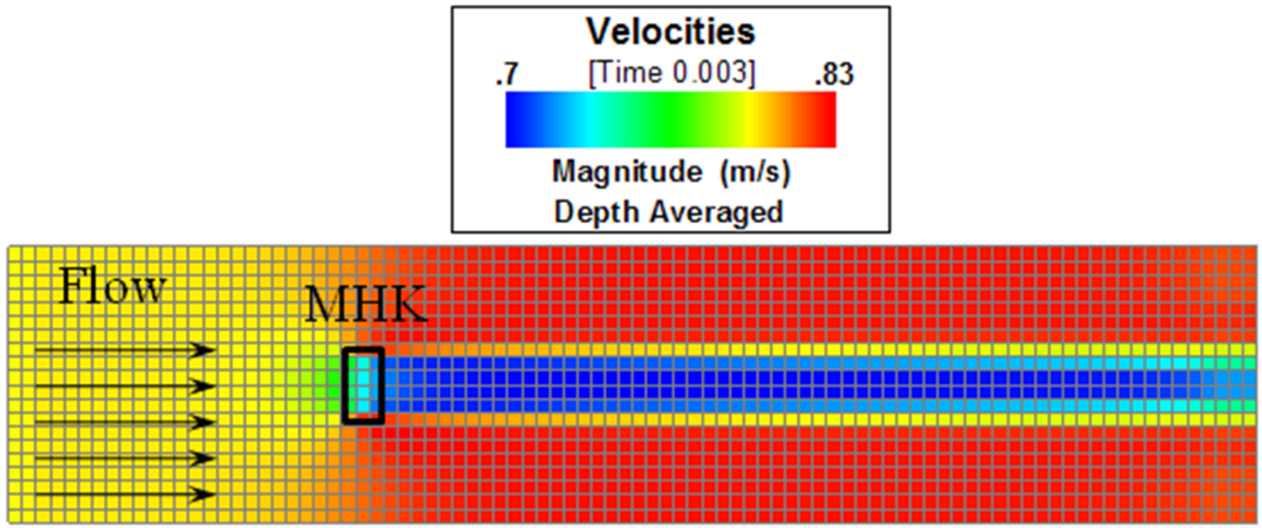
$$S_K = \frac{1}{2} C_T A_{MHK} \left(\beta_p U^3 - \beta_d U K \right)$$

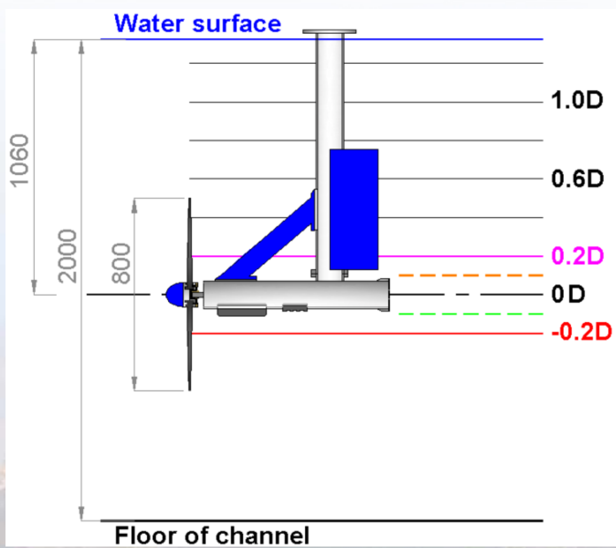
$$S_\varepsilon = C_{\varepsilon 4} \frac{\varepsilon}{K} S_K$$

Katul, G. G., L. Mahrt, D. Poggi, and C. Sanz (2004), One- and two-equation models for canopy turbulence, *Boundary-Layer Meteorology, 113, 81-109*.

Model Calibration/Verification

Viewed from above



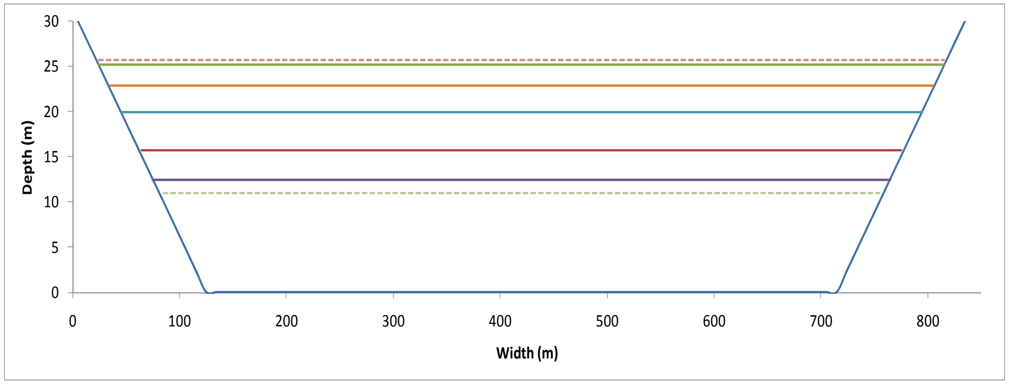


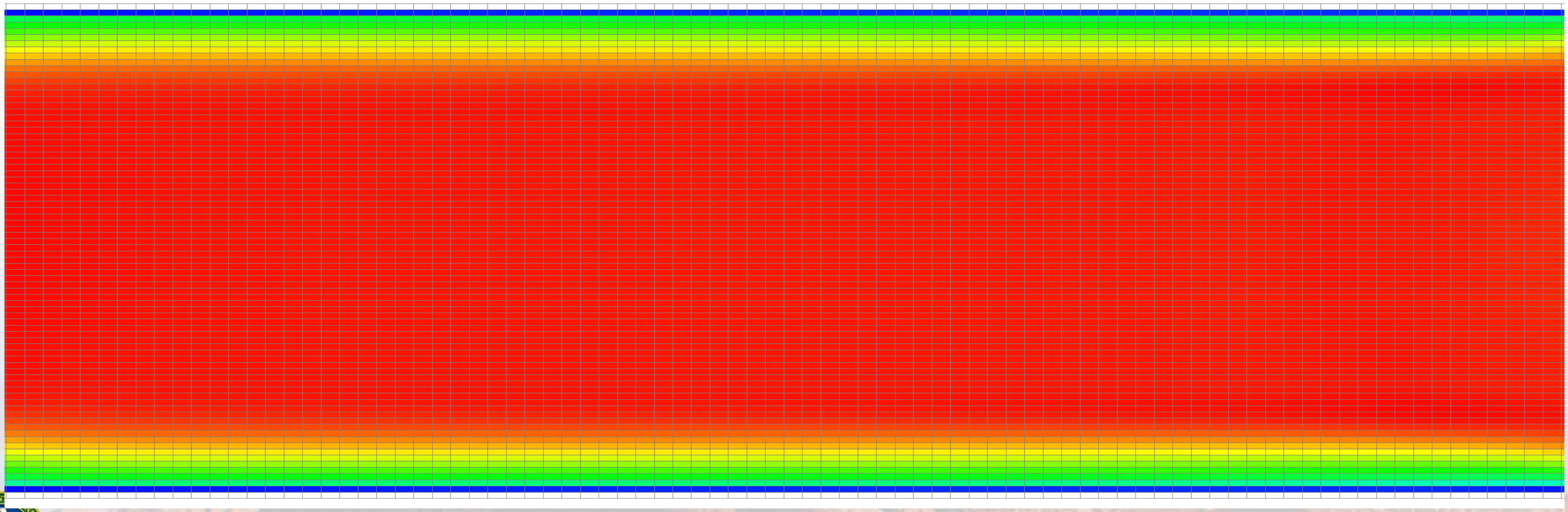
Parameter	Value
β_p	1.21
β_d	3.80
$C_{\varepsilon 4}$	1.82
ahd	0.10

Sandia National Laboratories

Straight Channel: EFDC Model Domain

- Grid is 840 × 4,200 m^2
- Cells are 10 × 30 m^2
- 10 vertical layers
- Top width is 840 m
- Bottom width is 600 m
- Depth is 30 m

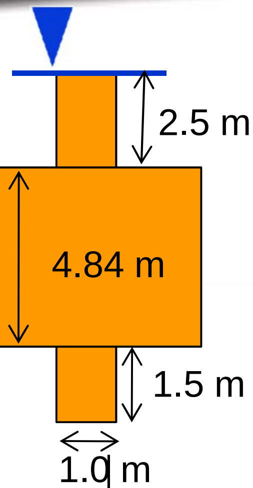




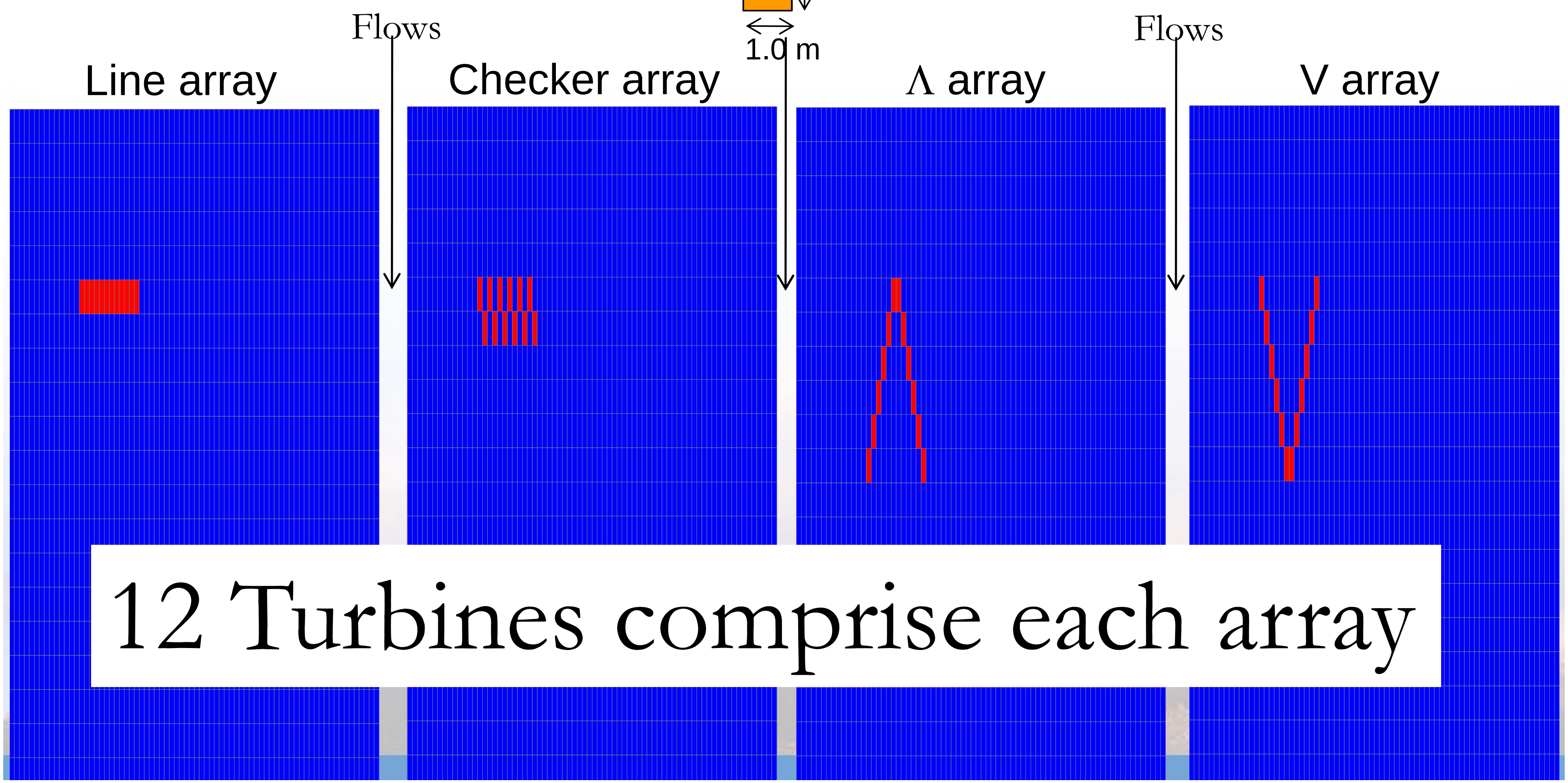
Array Scenarios

{$Q = 20{,}000\ m^3/s$}

■ = 1 – 6.45 m diameter VAWT “floating” from water surface centered at 15.08 m



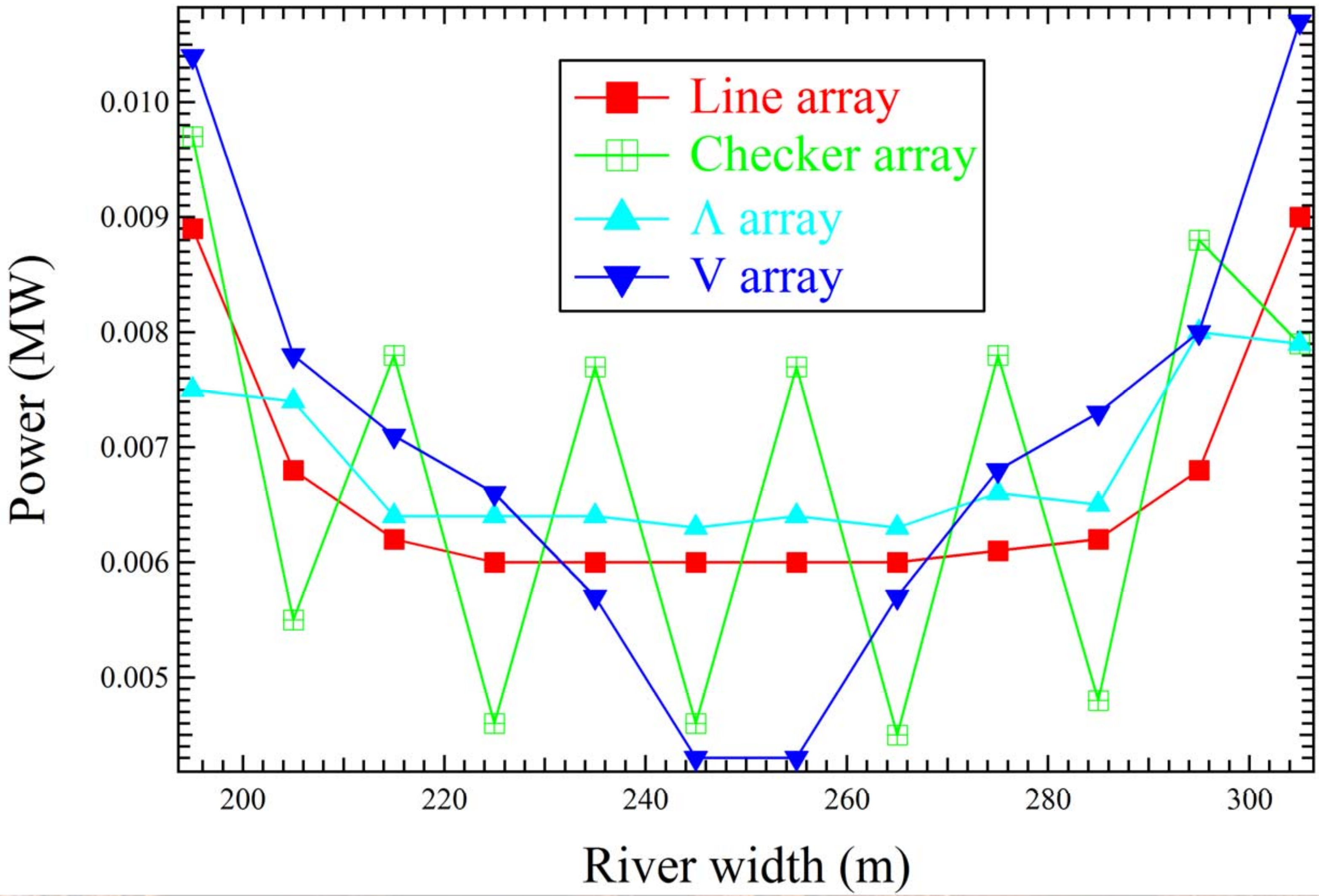
Line array | Checker array | Λ array | V array



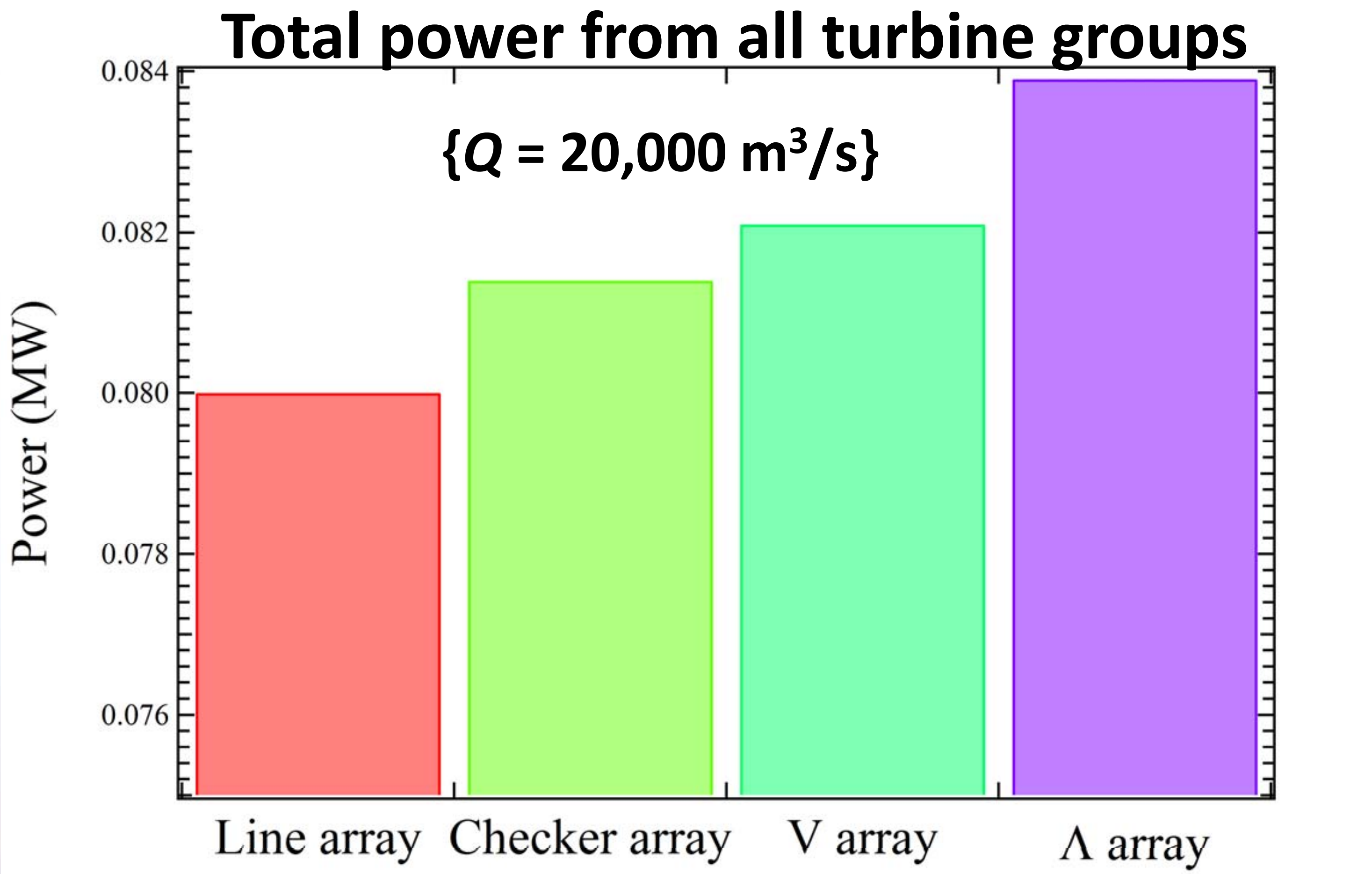
12 Turbines comprise each array

Array Performances

{Q = 20,000 m^3/s}

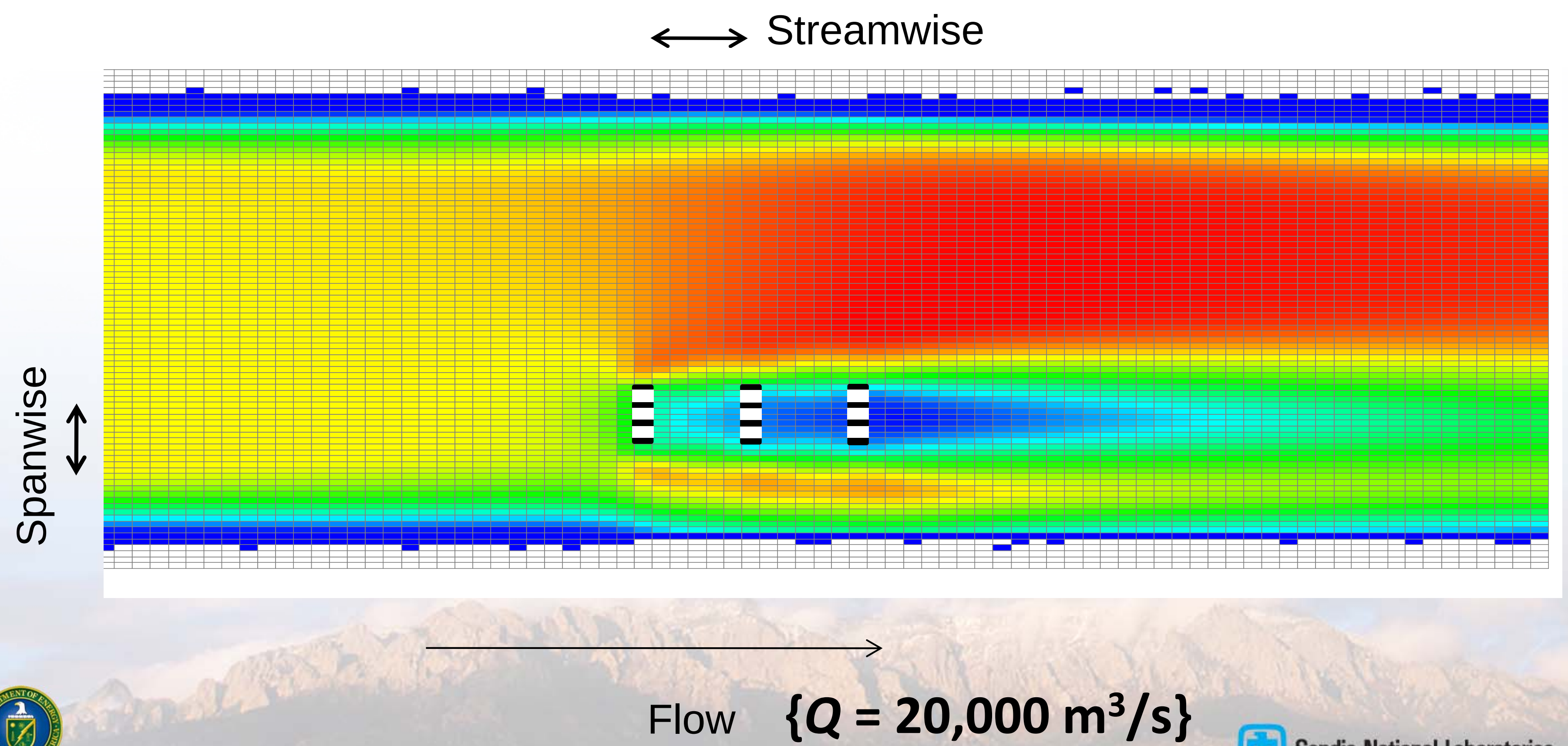


Array Performance



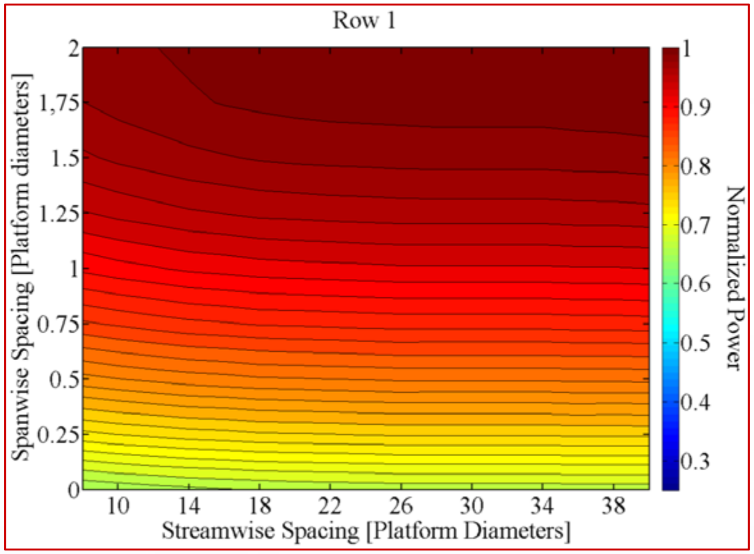
Effects of Spanwise and Streamwise MHK Spacings

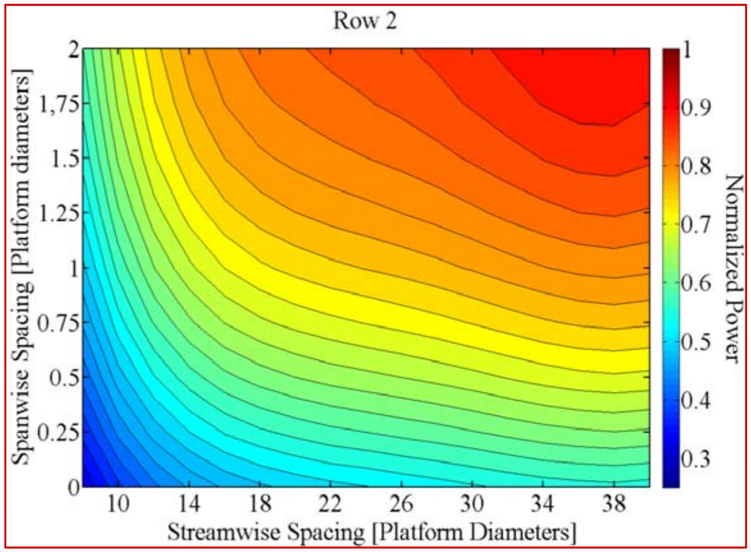
- Array width (spanwise) is preserved to maintain the development footprint
- Spanwise spacing is increased from 0 to 2 platform spacings by removing turbines
- Streamwise spacing is increased from 8 to 40 platform spacings by increasing distance

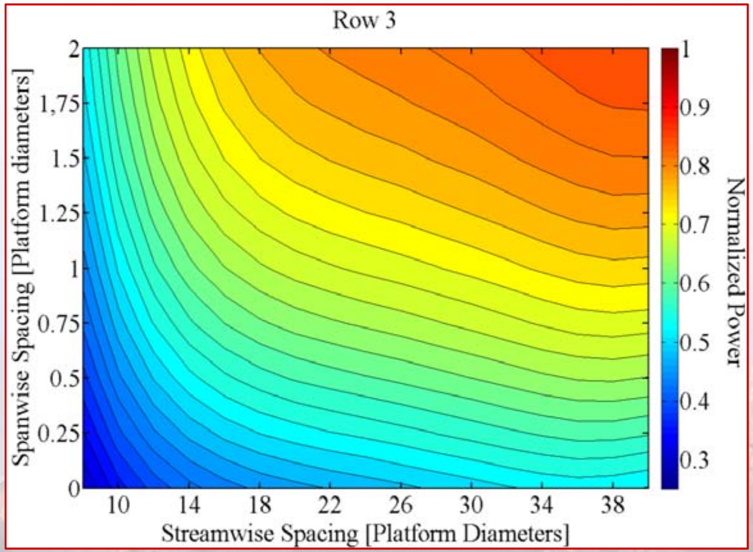


{Q = 20,000 m^3/s}

Effects of Spanwise and Streamwise Spacing







- Spanwise array spacing dominates the power output in Row 1.
- Significant power reduction in Rows 2 and 3 that diminishes with increased streamwise spacing (compared to Row 1).
- Improved (per platform) efficiency is observed as spanwise and streamwise spacing is increased.

Conclusions, Implications, and Future Work

- This work demonstrates a newly developed modeling tool for optimizing array layouts to maximize energy capture while minimizing environmental effects.
- SNL-EFDC's "MHK friendly" tool is and will remain open source so that regulators, industry developers, and all others will have free access to the tool for independent studies and to facilitate easy and common communication of study results.