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Aquaculture water body modeling (a few examples big and small)

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DHI Water and Environment

Talk Outline

- An introduction to modeling
- Types of models that I have used within ASEAN/NZ/AUS
- Examples of aquaculture projects with a focus on modeling
- Success
- Where I would like to see things going to in the future

What is modeling?

$$\eta = a\cos(kx - \omega t).$$

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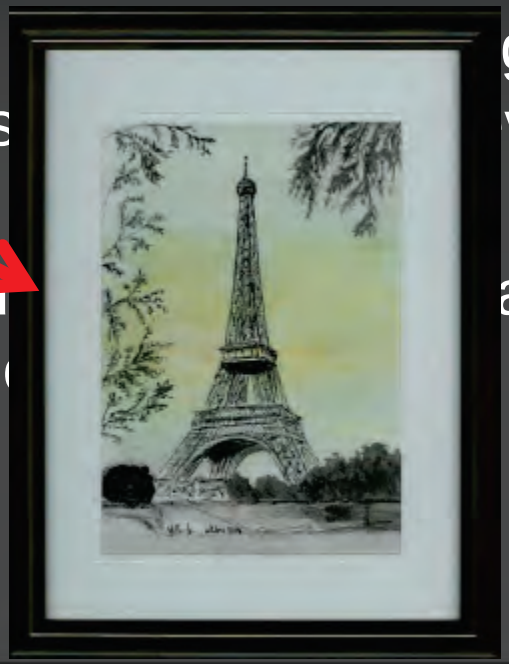
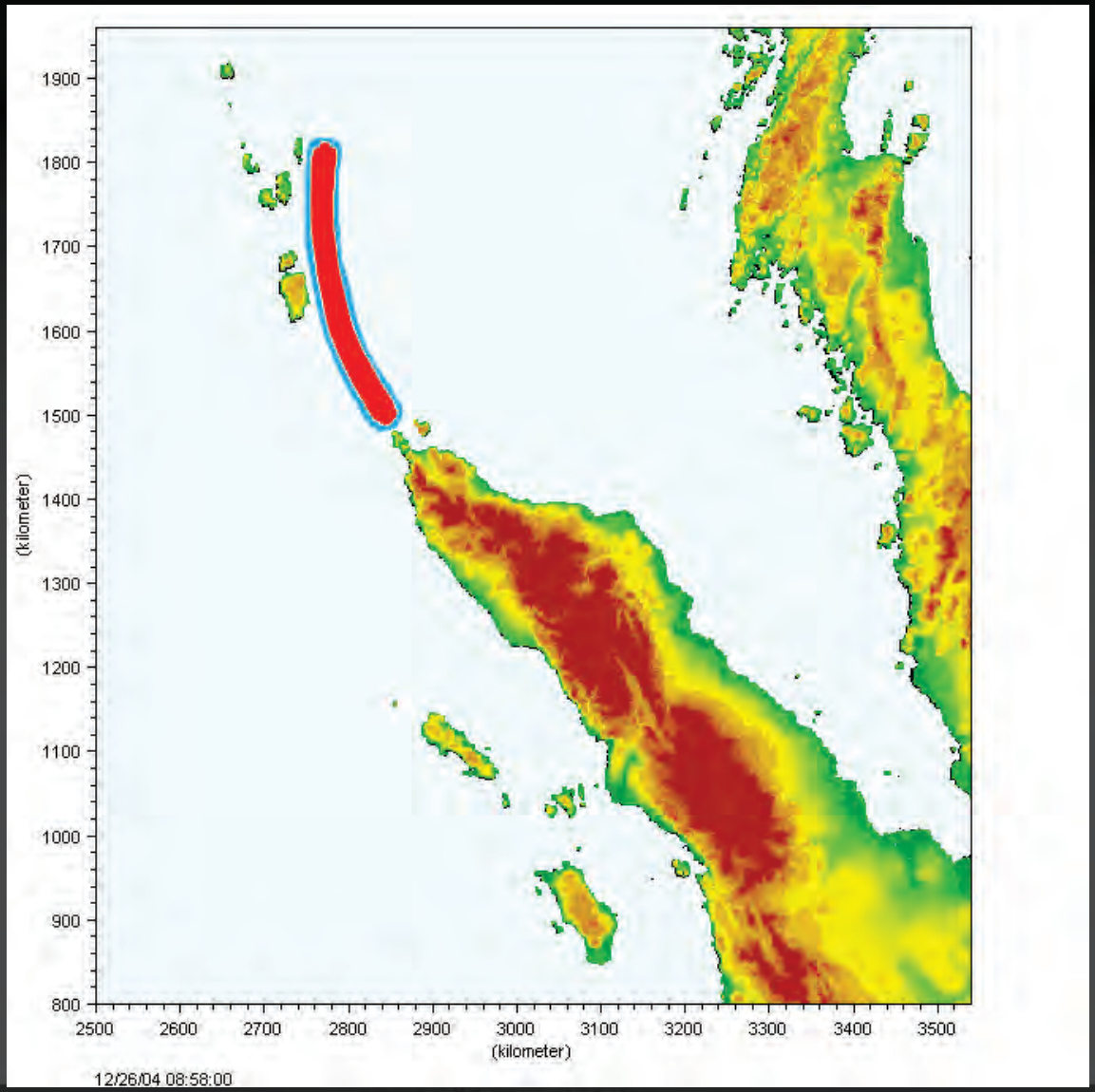
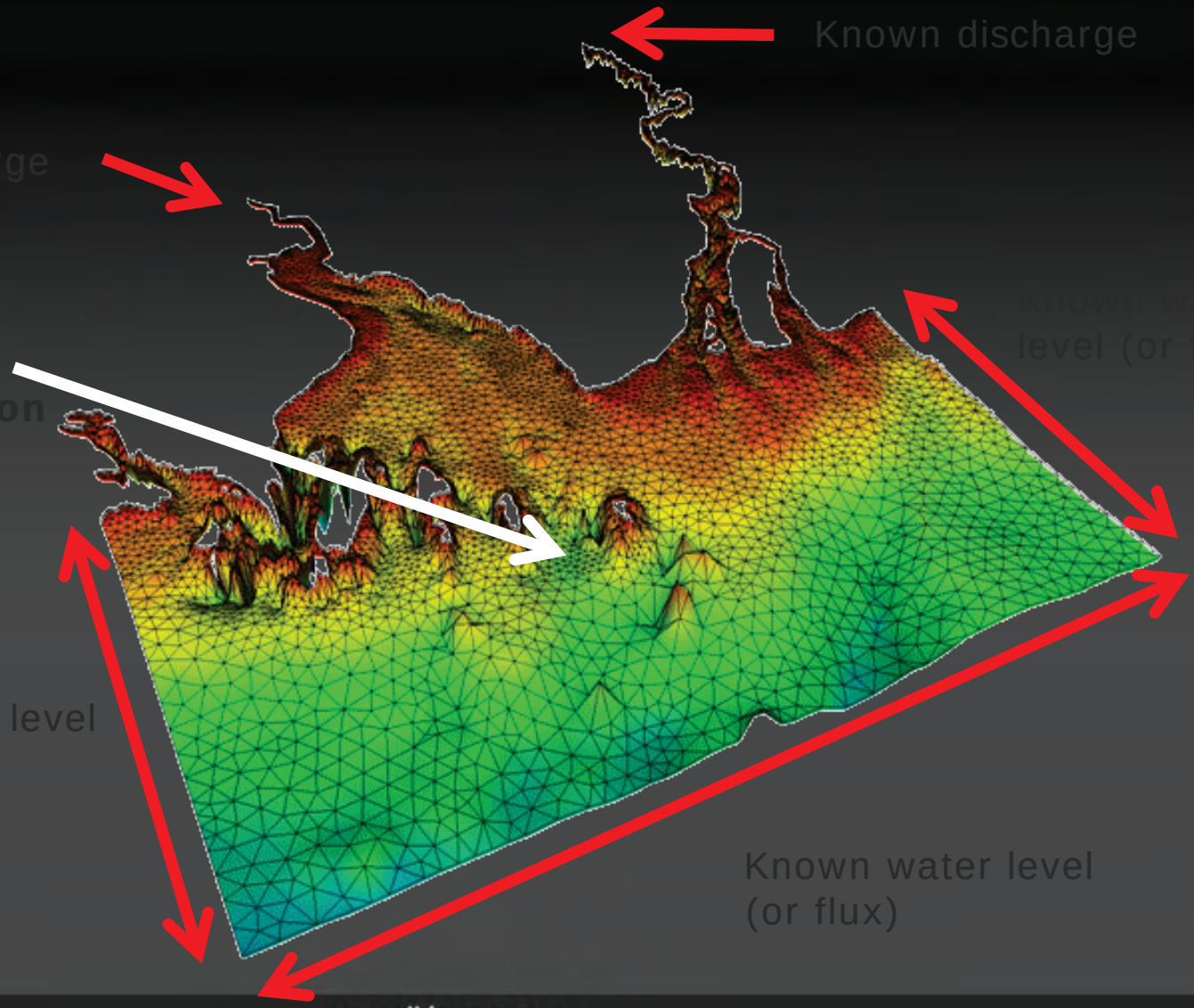


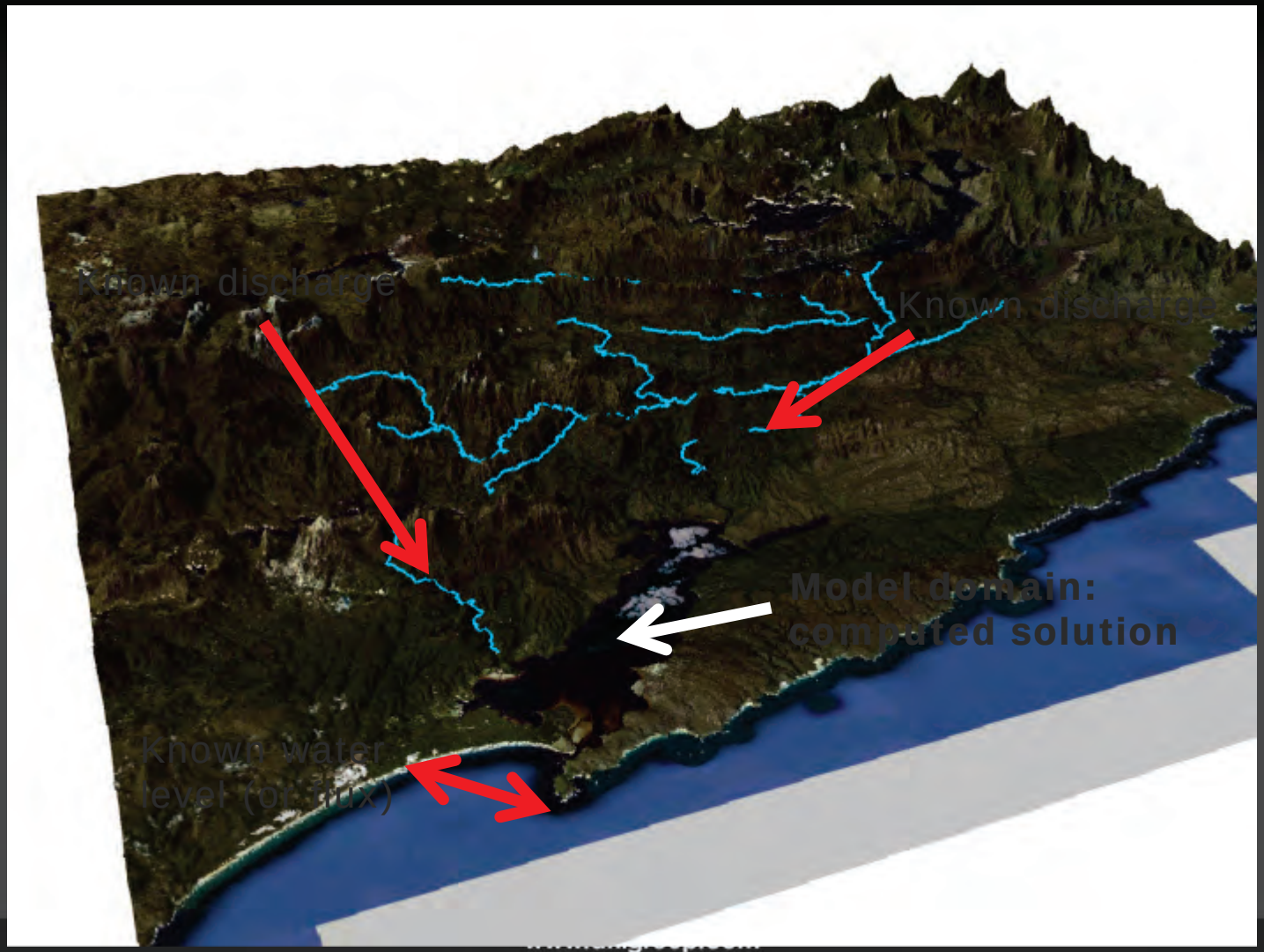
Many types....Tsunami



Example of a typical model (2D)



Same example applied to a real site



Flow Equations - Navier-Stokes:

x- direction

$$\frac{\partial u}{\partial t}+\frac{\partial u^2}{\partial x}+\frac{\partial vu}{\partial y}+\frac{\partial wu}{\partial z}=fv-g\frac{\partial \zeta}{\partial x}-\frac{1}{\rho_0}\frac{\partial p_a}{\partial x}-\frac{g}{\rho_0}\int_z^{\zeta}\frac{\partial \rho}{\partial x}dz+F_u+\frac{\partial}{\partial z}\left(\upsilon_t\frac{\partial u}{\partial z}\right)+u_sS_c$$

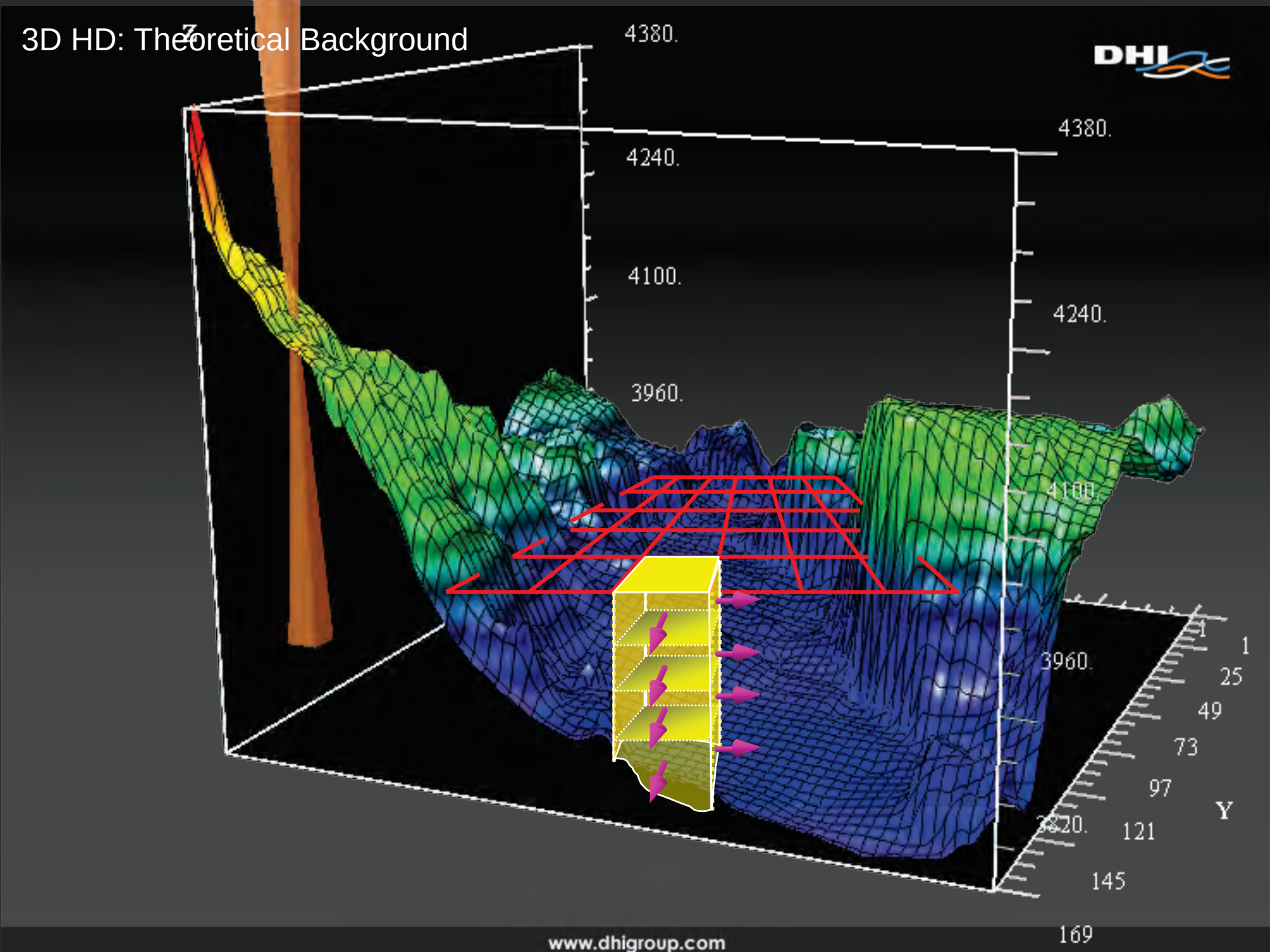
y- direction

$$\frac{\partial v}{\partial t}+\frac{\partial v^2}{\partial y}+\frac{\partial uv}{\partial x}+\frac{\partial wv}{\partial z}=fu-g\frac{\partial \zeta}{\partial y}-\frac{1}{\rho_0}\frac{\partial p_a}{\partial y}-\frac{g}{\rho_0}\int_z^{\zeta}\frac{\partial \rho}{\partial y}dz+F_v+\frac{\partial}{\partial z}\left(\upsilon_t\frac{\partial v}{\partial z}\right)+v_sS_c$$

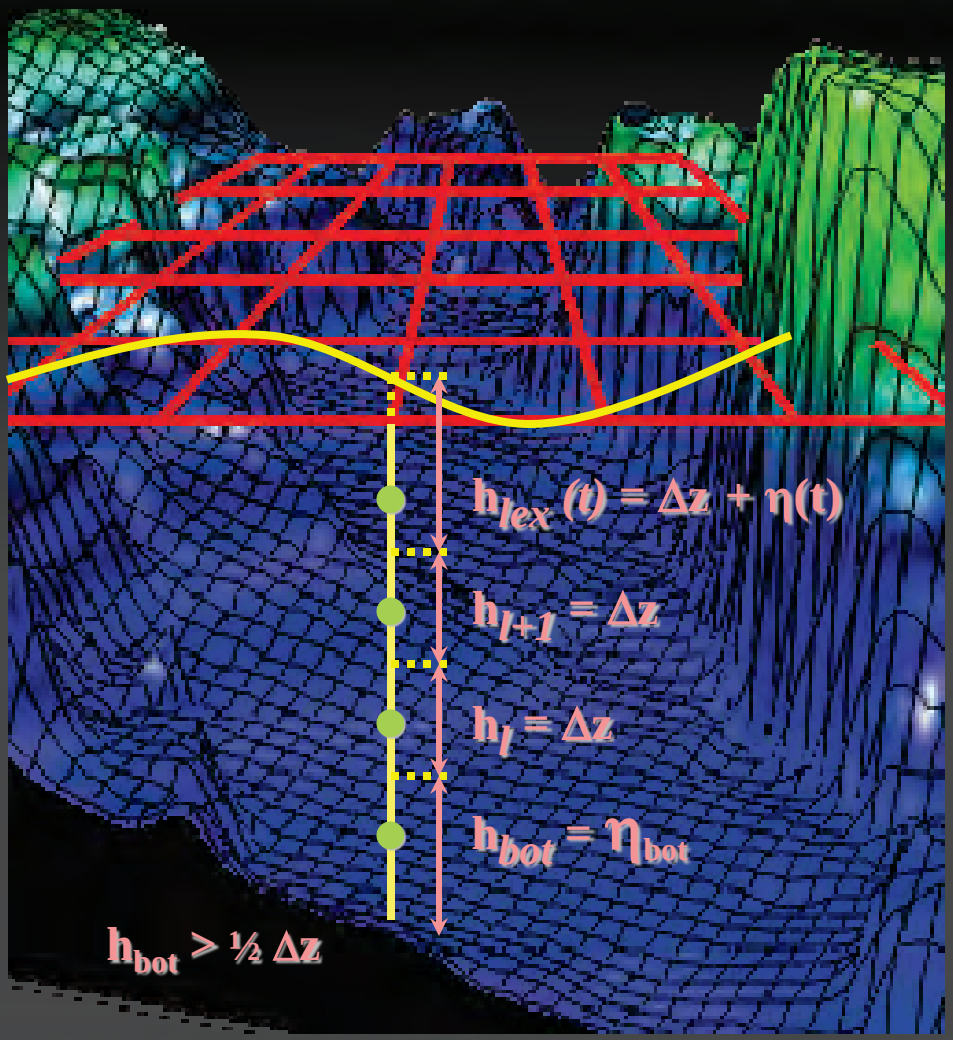
1 2 3 4 5 6 7 8 9

- 1. Fluid acceleration
- 2. Horizontal gradients in the velocity
- 3. Coriolis acceleration
- 4. Acceleration from sea-surface elevation
- 5. Pressure gradient term
- 6. Acceleration from buoyancy effects
- 7. Imbalance of horizontal Reynolds stresses
- 8. Vertical stresses from the Bousinesq approximation
- 9. Acceleration from discharges

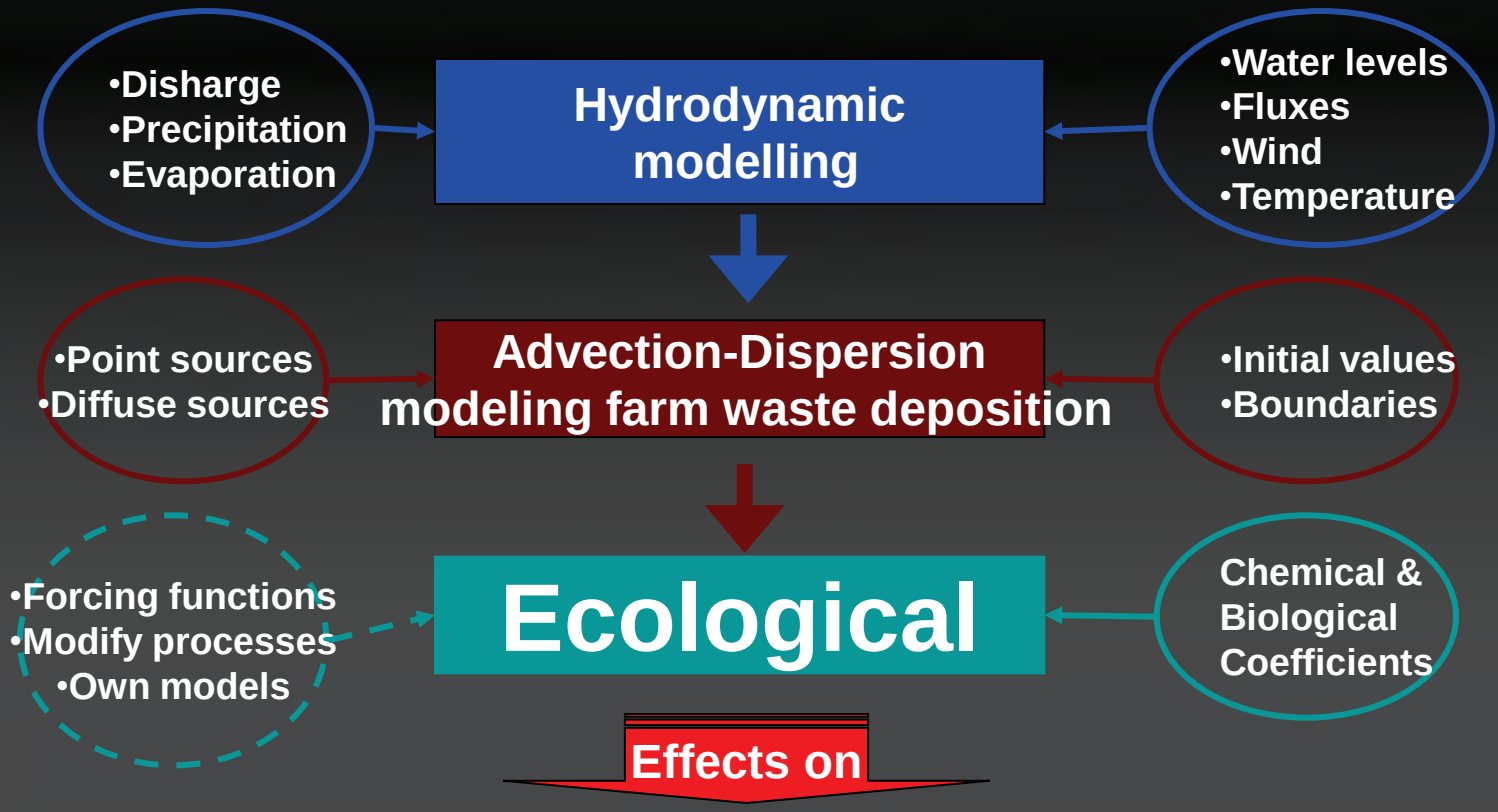
3D HD: Theoretical Background



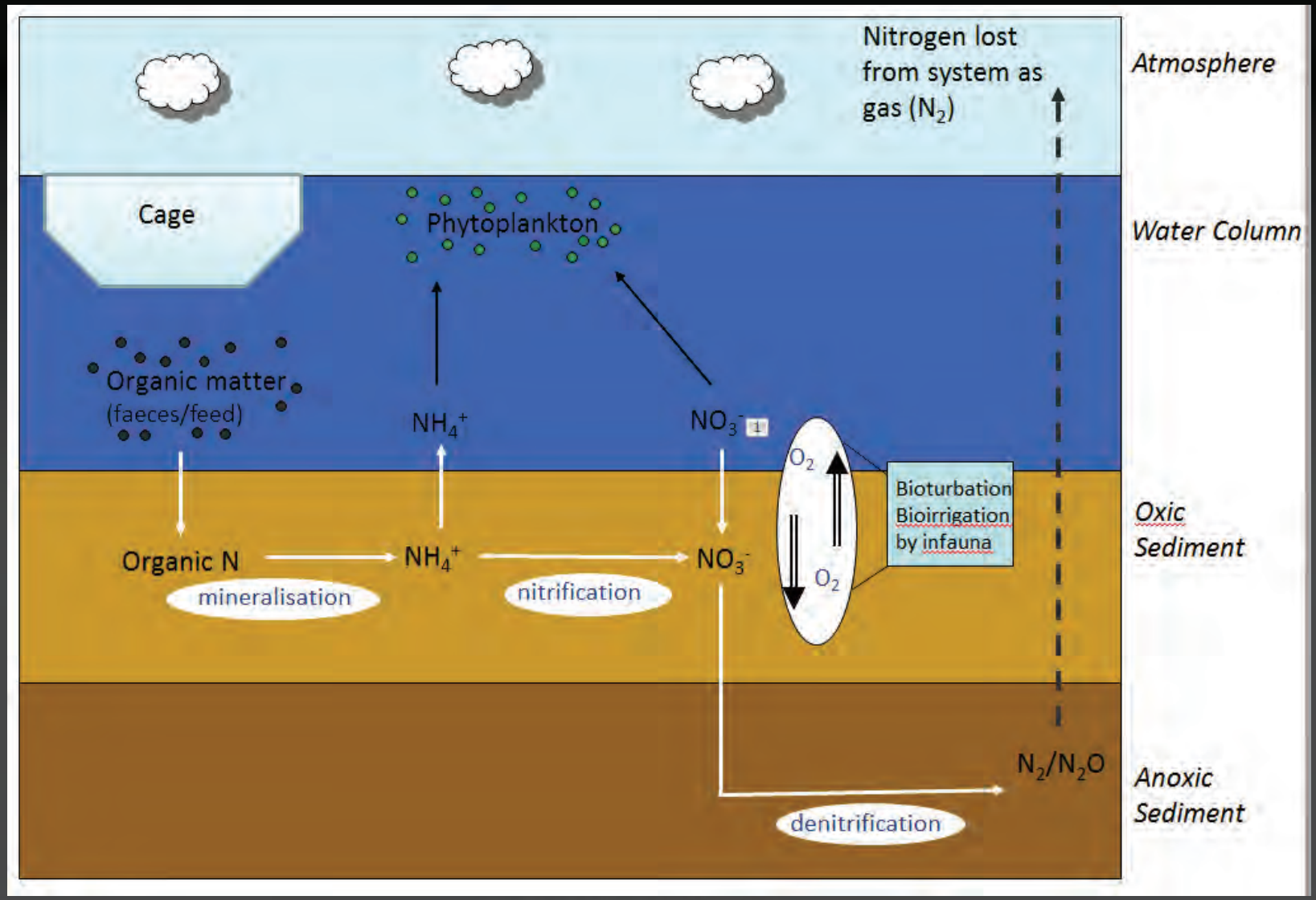
3D HD: Theoretical Background



Adding modeling tools together



A simple ecological model example I use regularly (key processes)



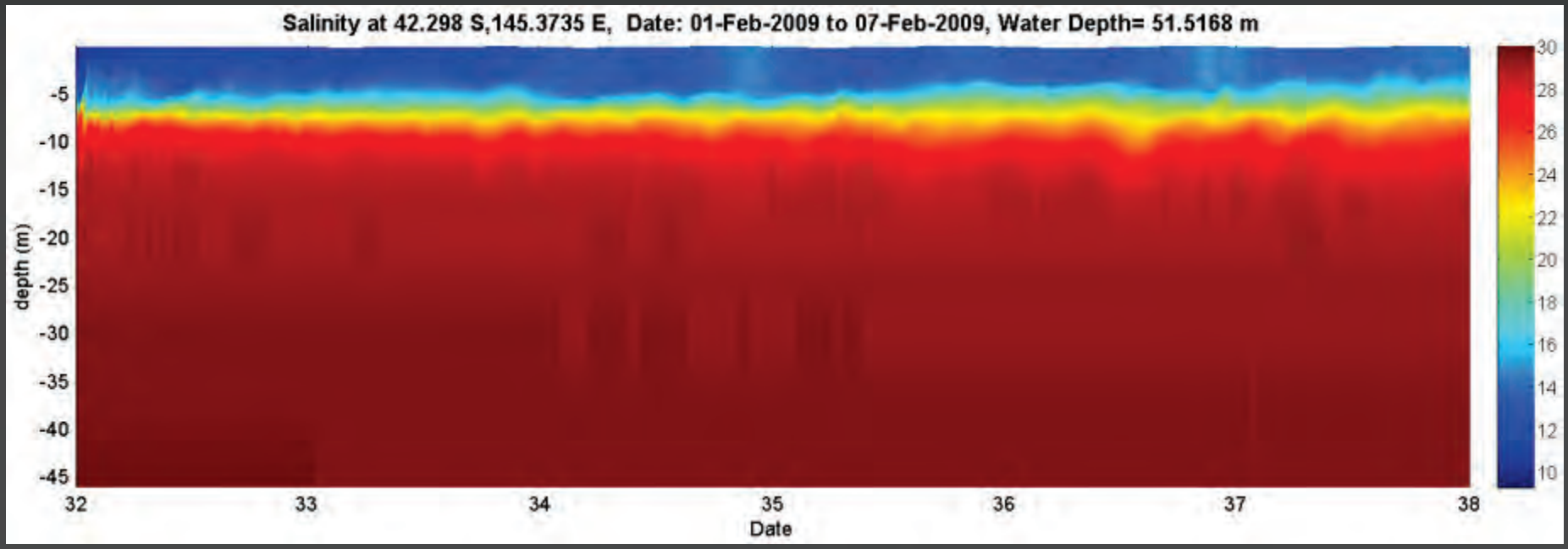
MODELS NEED TO BE CALIBRATED WITH REAL DATA

Types of models I have used

- ROMS (HD only)
- DHI Software
- DEPOMOD
- Programing/equation solver types coupled to other hydrodynamic packages

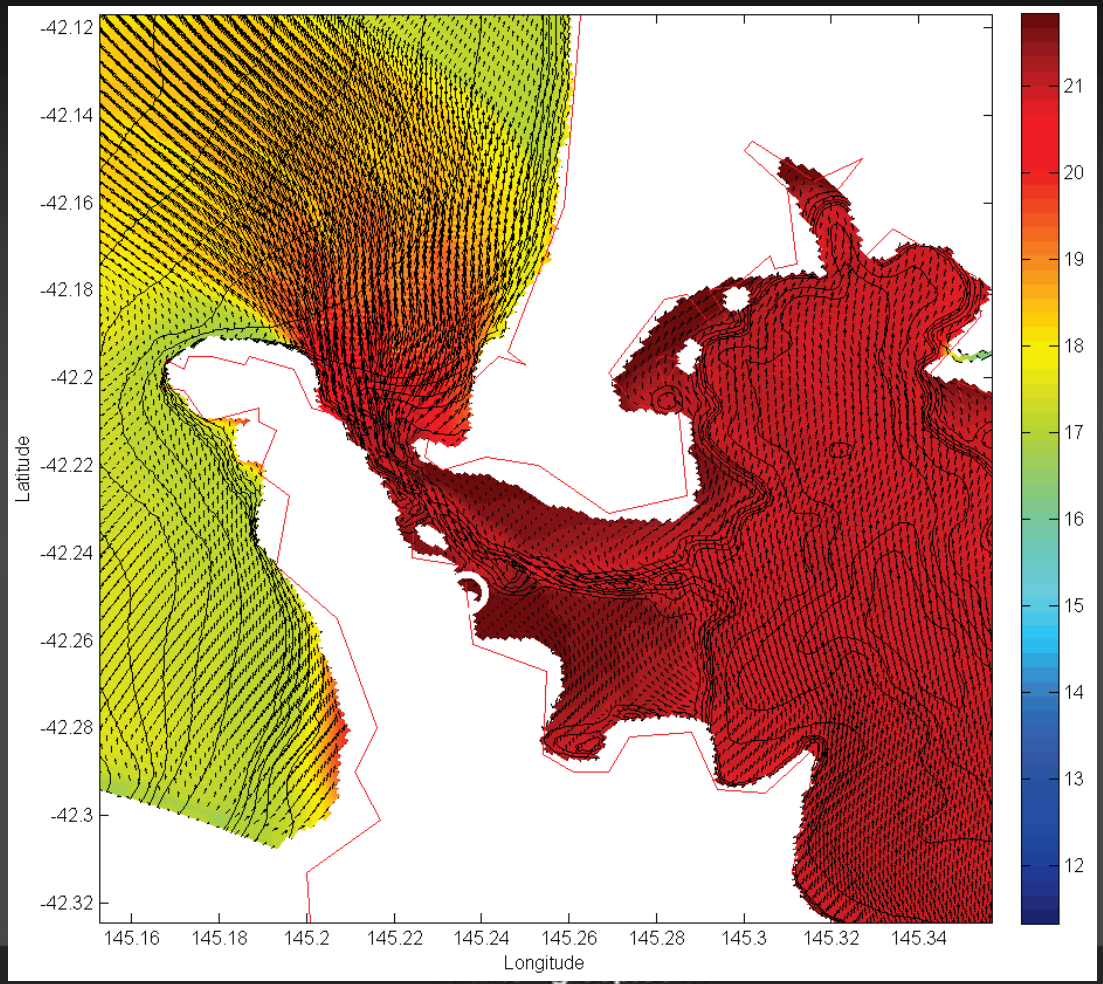
ROMS

- Excellent open ocean open source software
- Difficult to use and needs very good programming skills.
- Very good in stratified environments
- Not easily coupled with ecological models



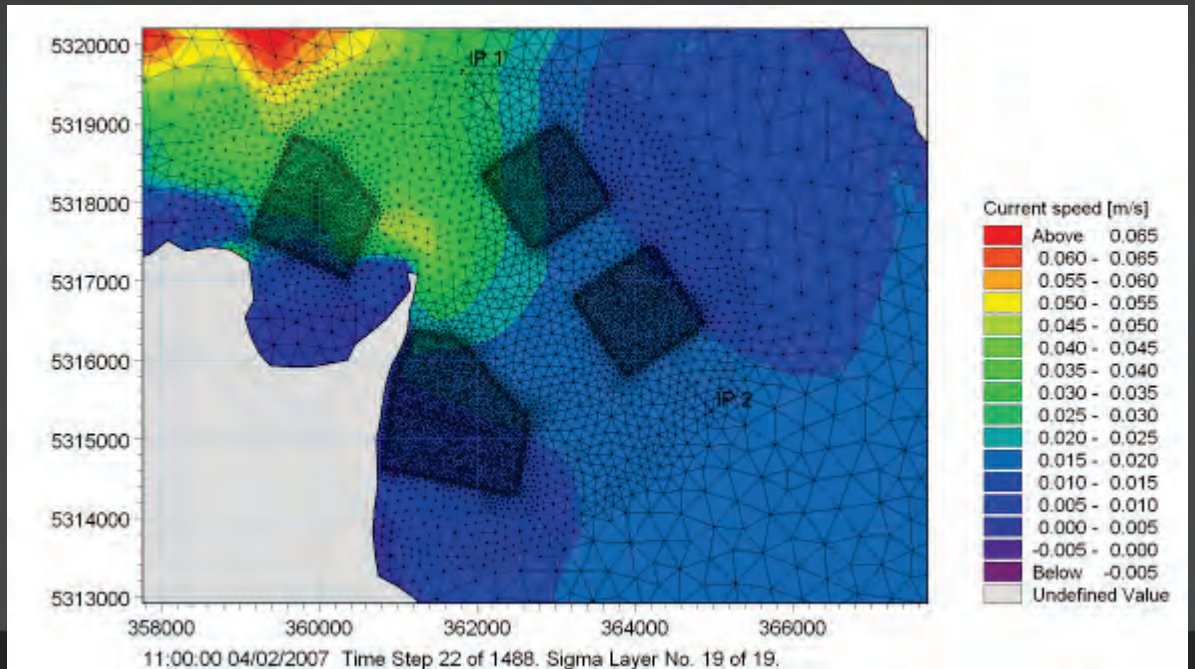
ROMS

- High resolution 3D FM or classic grid ☺
- However would likely be my choice if I had the time and money (which so far doesn't happen unless it's a research project



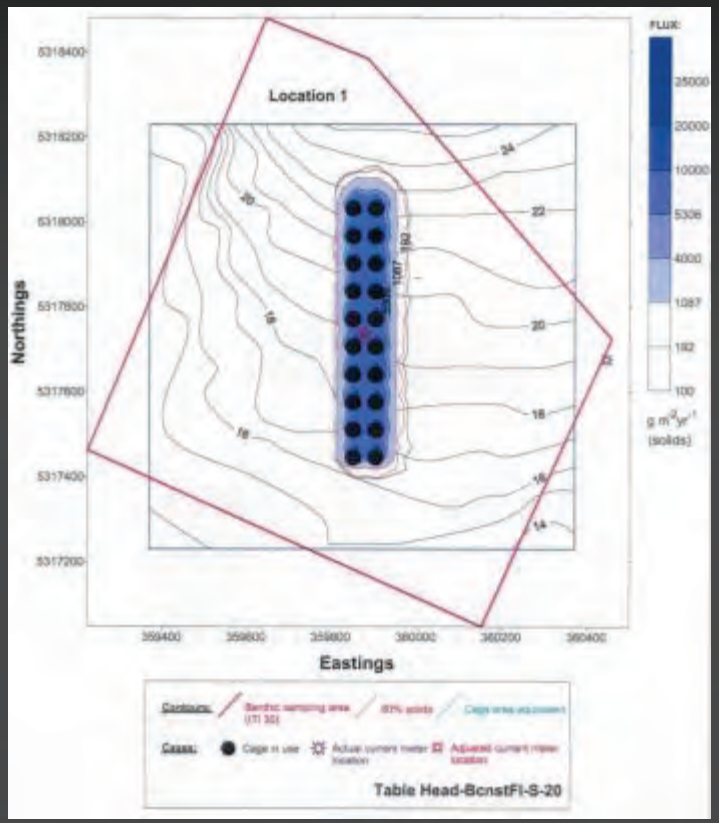
MIKE

- Easier to use than ROMS
- Well known with 24/7 support (expensive)
- Very high resolution 3D FM
- Has HD, depostional, ecological models that are easy to couple togeather
- Limited (HD 3D FM ONLY) with numerical issues in 3D stratified envionments



DEPOMOD

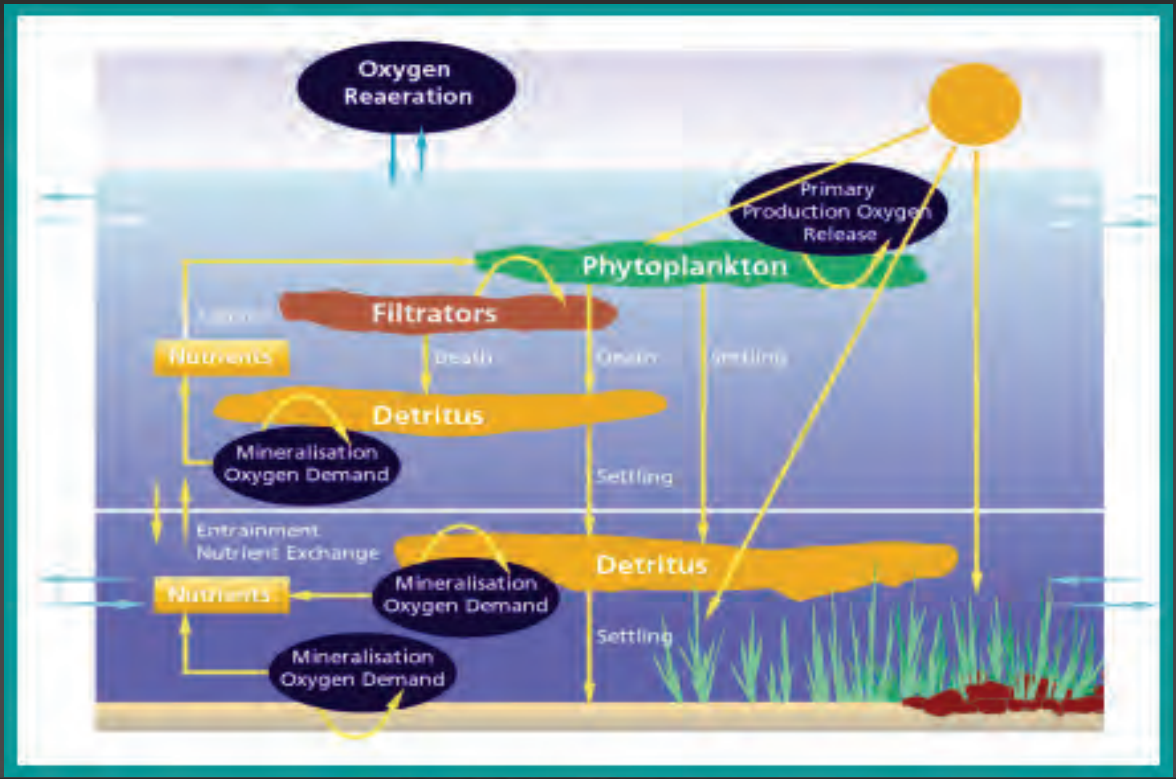
- Well known and easy to use
- Very cheap
- However limited.. And simplified..for my liking….



Equation Solvers a few examples

these are coupled to other HD models i.e. ROMS or MIKE, and others… ROMS has one or two specific templates.. Mike has many.. Others have some like DELTARES…SELFE.

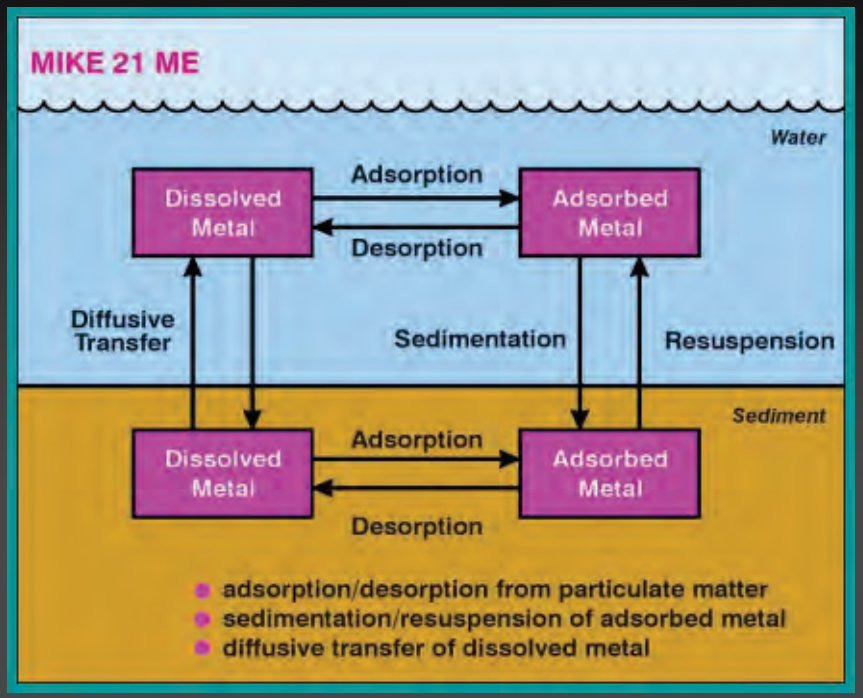
The EU below Template describes nutrient cycling, phytoplankton and zooplankton growth, growth and distribution of rooted vegetation and macro algae in addition to simulating oxygen conditions



Ecolab: Heavy Metals template

The ME Template describes the adsorption/desorption of metals to suspended matter, the sedimentation of sorbed metals to the seabed as well as re-suspension of settled metals

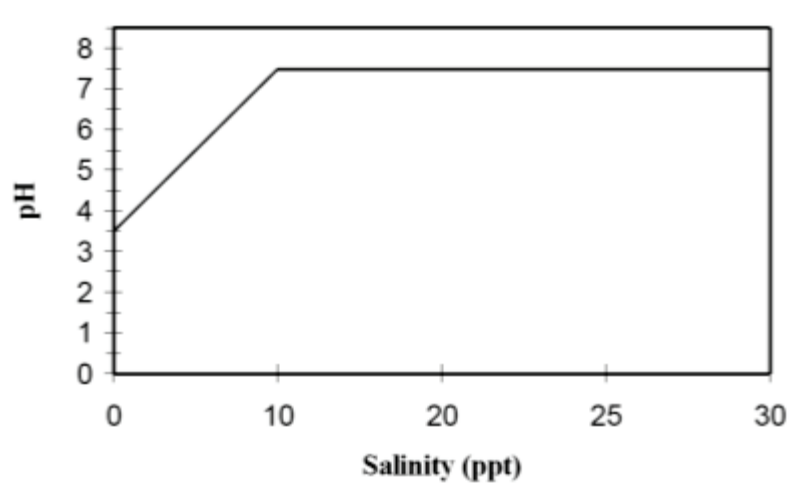
It also includes the exchange of metal between the particulates of the seabed sediment and interstitial waters of the bed

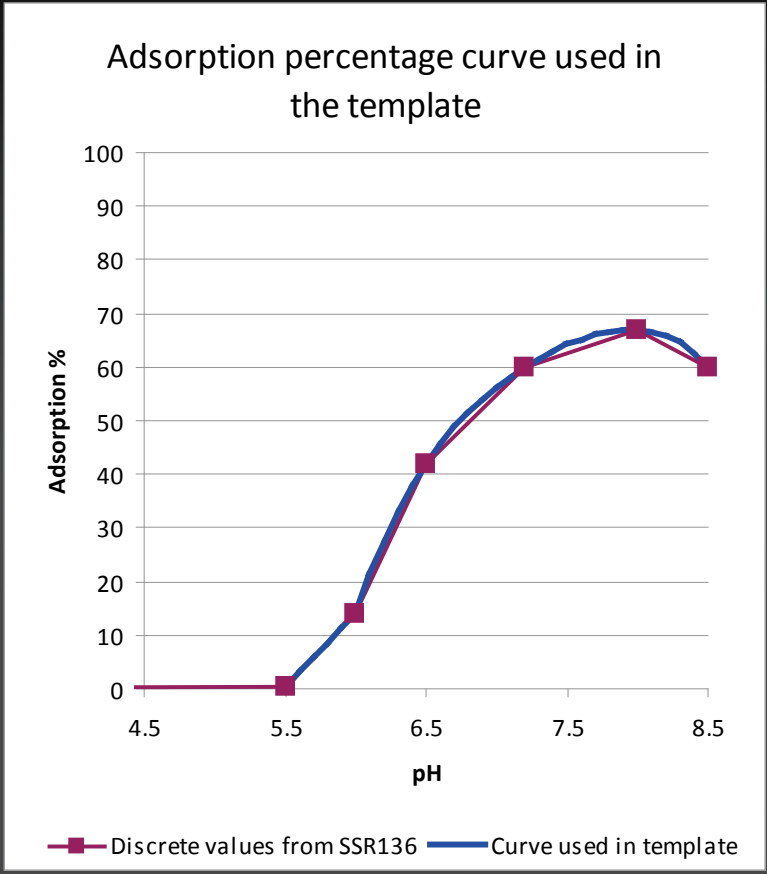


A specific example

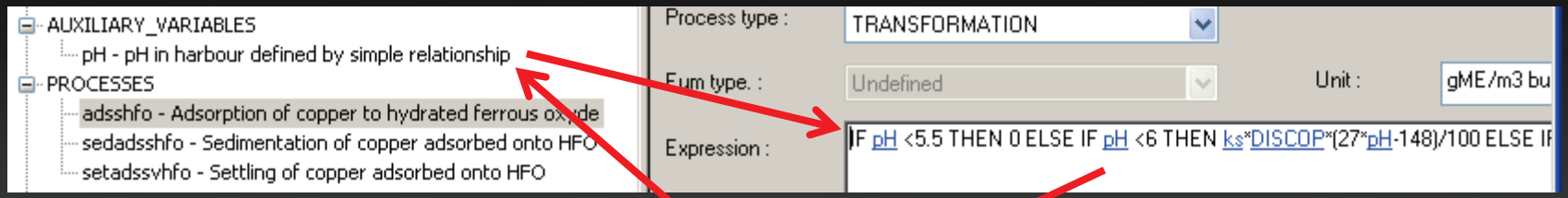
Ecolab: Heavy Metals template variables

- Adsorbed Metal
- Dissolved Metal
- pH = f(salinity)
- ***Modified equations for Macquarie Harbour***

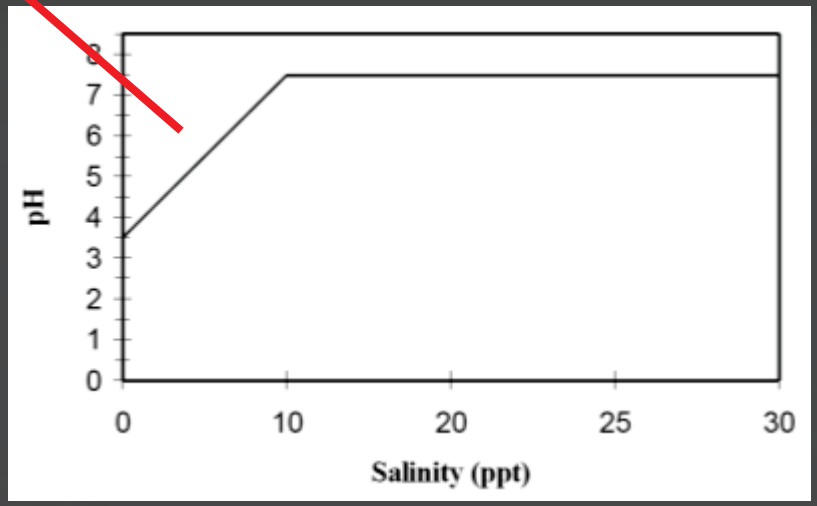




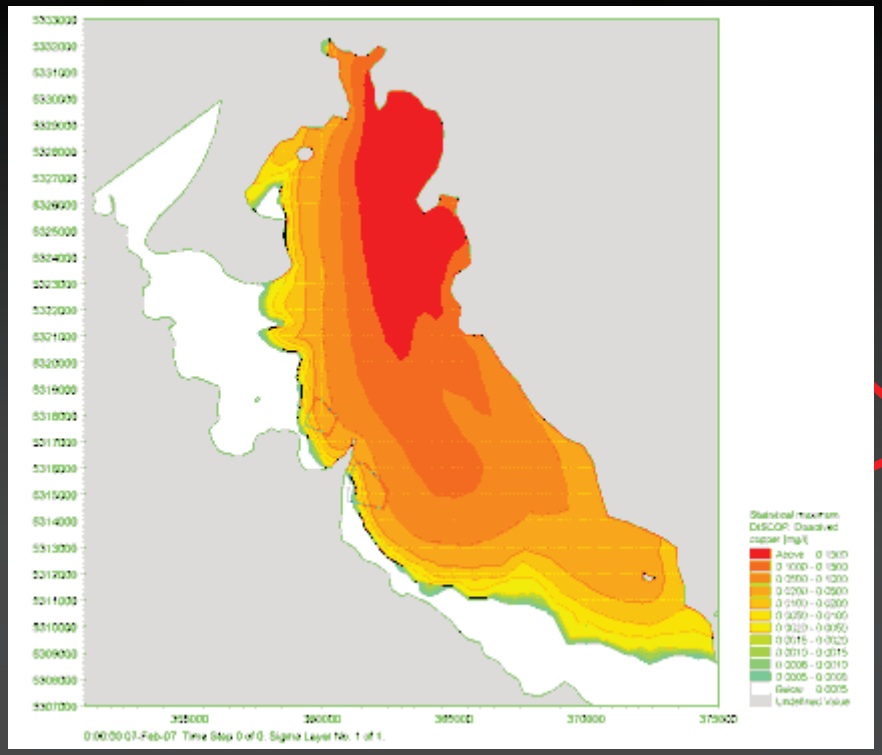
Copper Template

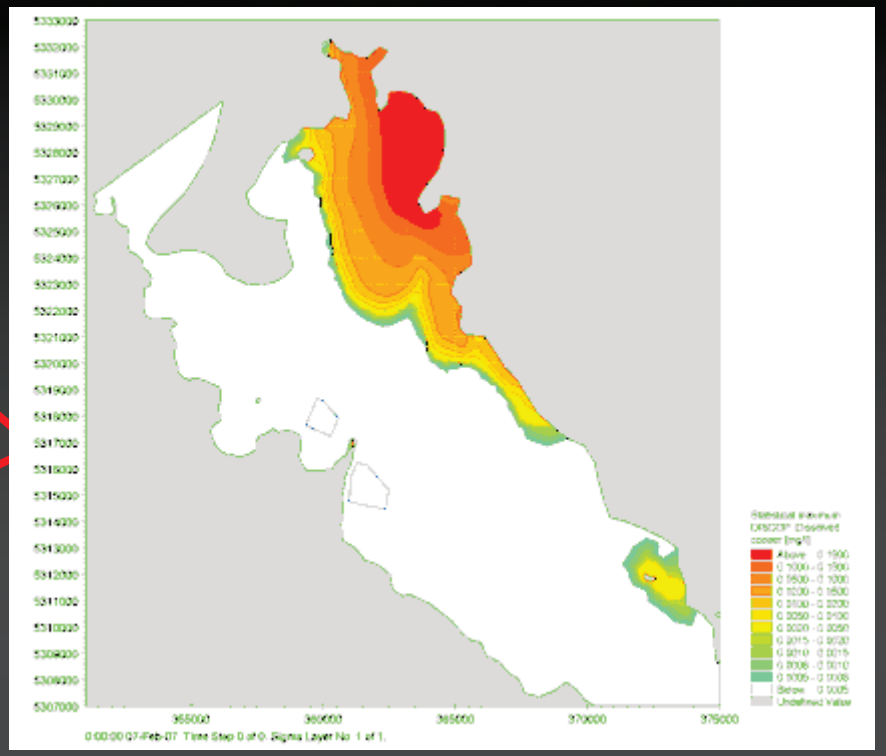


Adsorption rate = f(Salinity)



Copper Template





EXAMPLES OF AQUACULTURE PROJECTS USING MODELING (A means to an end)

Using a few methods:

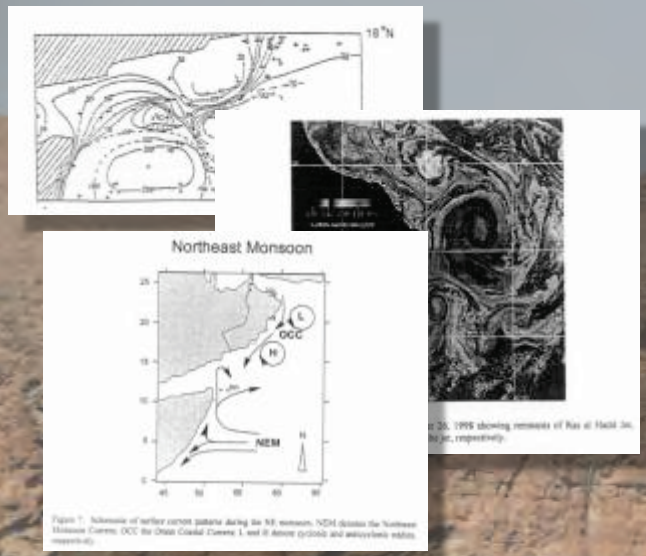
- Literature reviews (processes, local issues)
- In-situ sampling:
  - physical properties (currents, seabed, temperature, salinity, etc.)
  - water quality (NH4, NO3, P, etc.)
- Geographic Information Systems (GIS)
- Modelling:
  - Hydrodynamics
  - Water Quality / Ecology
  - Deposition

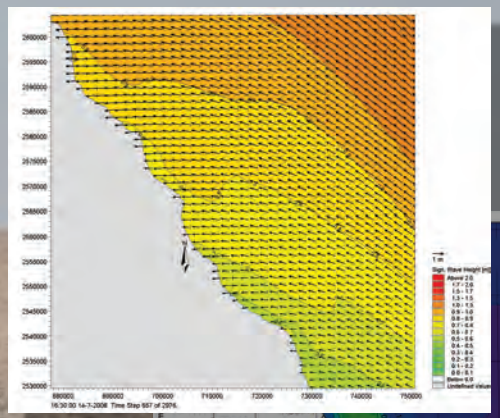
Site selection / feasibility studies

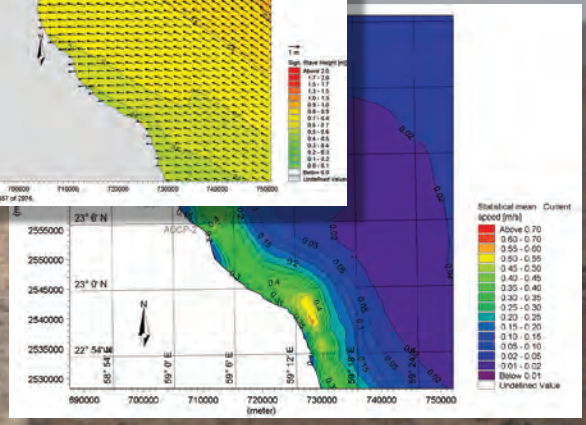
Oman

Site selection / feasibility studies

Oman







1.Literature review

2.In-situu sampling

3.Modelling

Site selection / feasibility studies

Site selection / feasibility studies

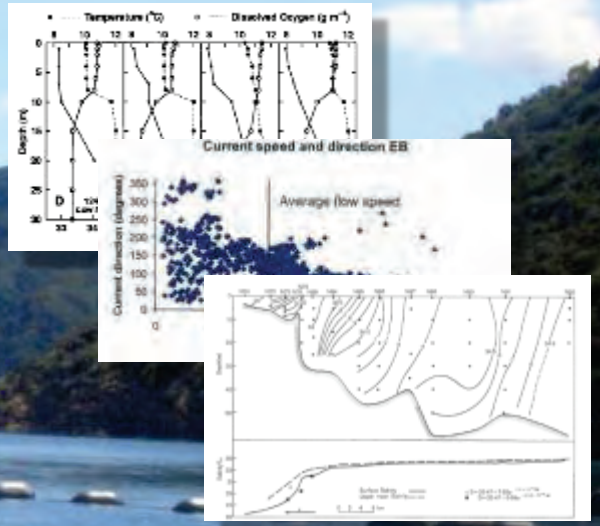
Marlborough Sounds, NZ

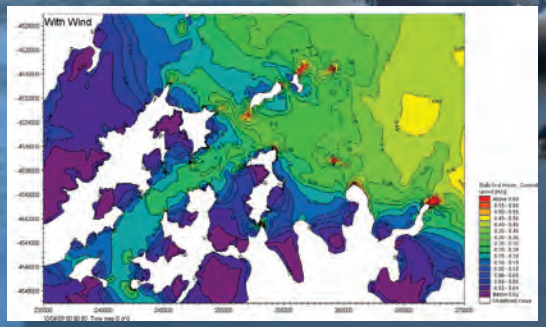
Key project details:

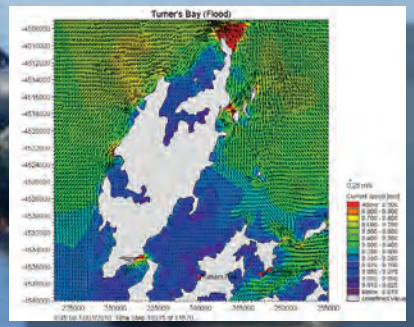
- Find locations within the sounds region suitable for fin-fish farming

Key solutions:

- Use of historical literature datasets
- Collection of ADCP data
- Calibrated hydrodynamic modelling defining areas with suitable flows



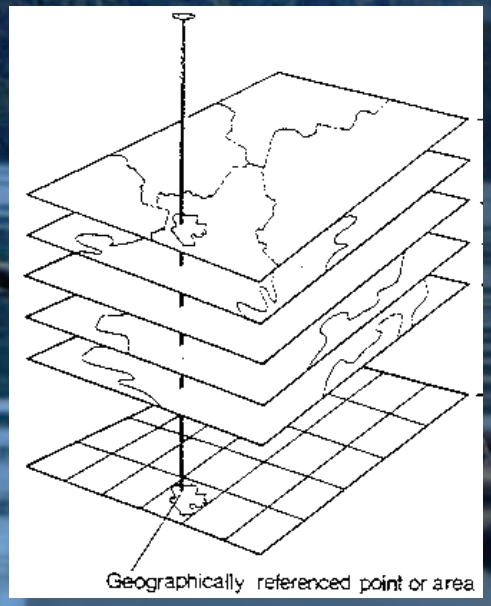




Site selection / feasibility studies

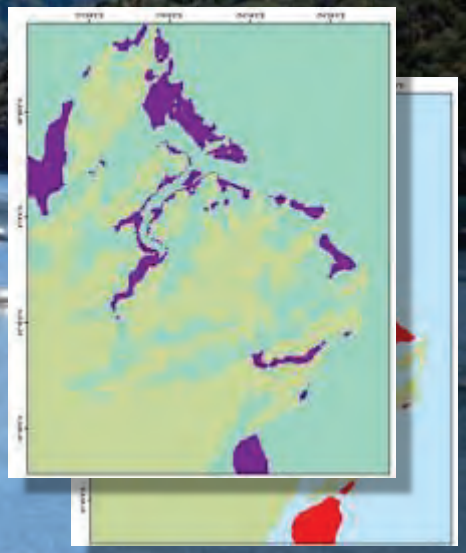
Marlborough Sounds, NZ

Layers for analysis



Weighted analysis

Maps of suitable areas

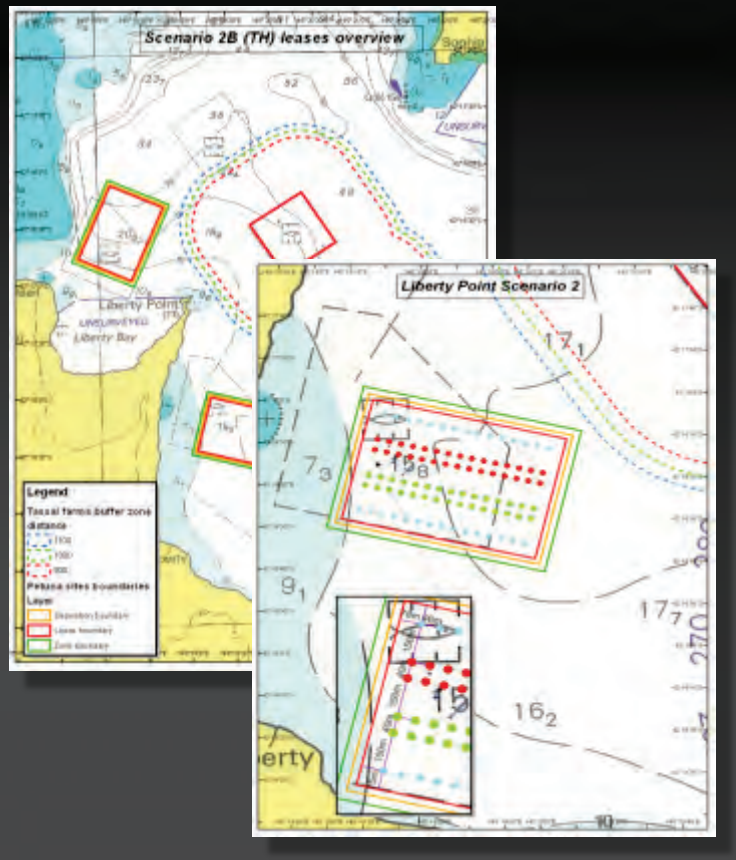


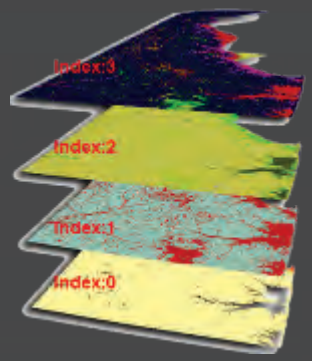
Site optimization studies

Western Tasmania

Making use of various sources of information:

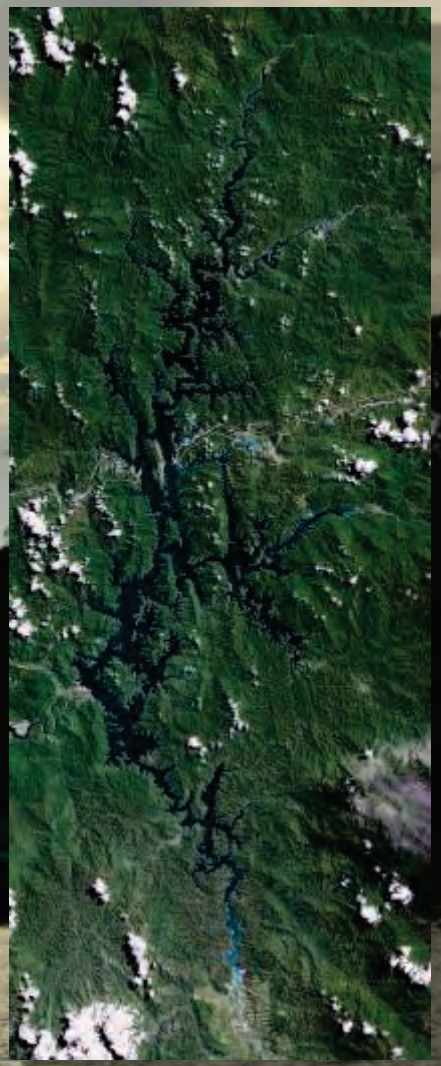
- Knowledge of the farming operation characteristics (stocking densities, schedules, etc.)
- In-situ sampling datasets:
- Modelling:
- Some common sense!





Carrying capacity assessments

Perak, Malaysia
Lake Temenggor



Carrying capacity assessments

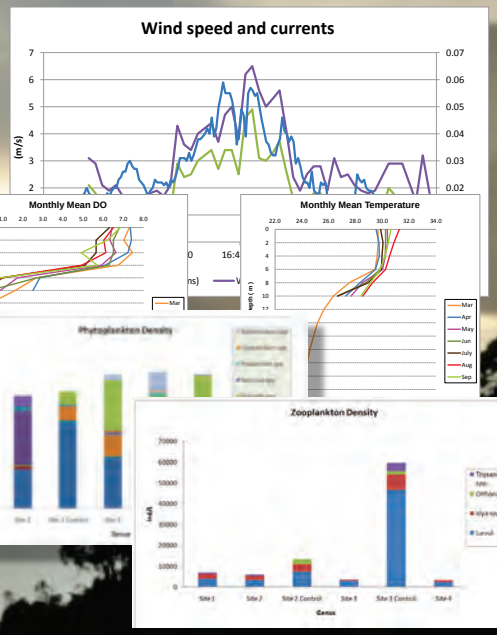
Perak, Malaysia

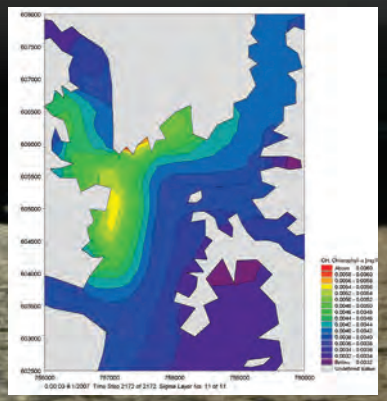
Key project details:

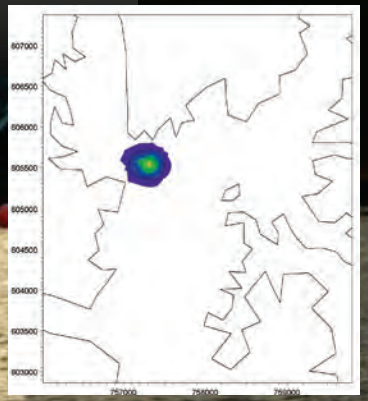
- Preliminary assessment of the carrying capacity of the mesotrophic lake for a production of traceable Tilapia

Key solutions:

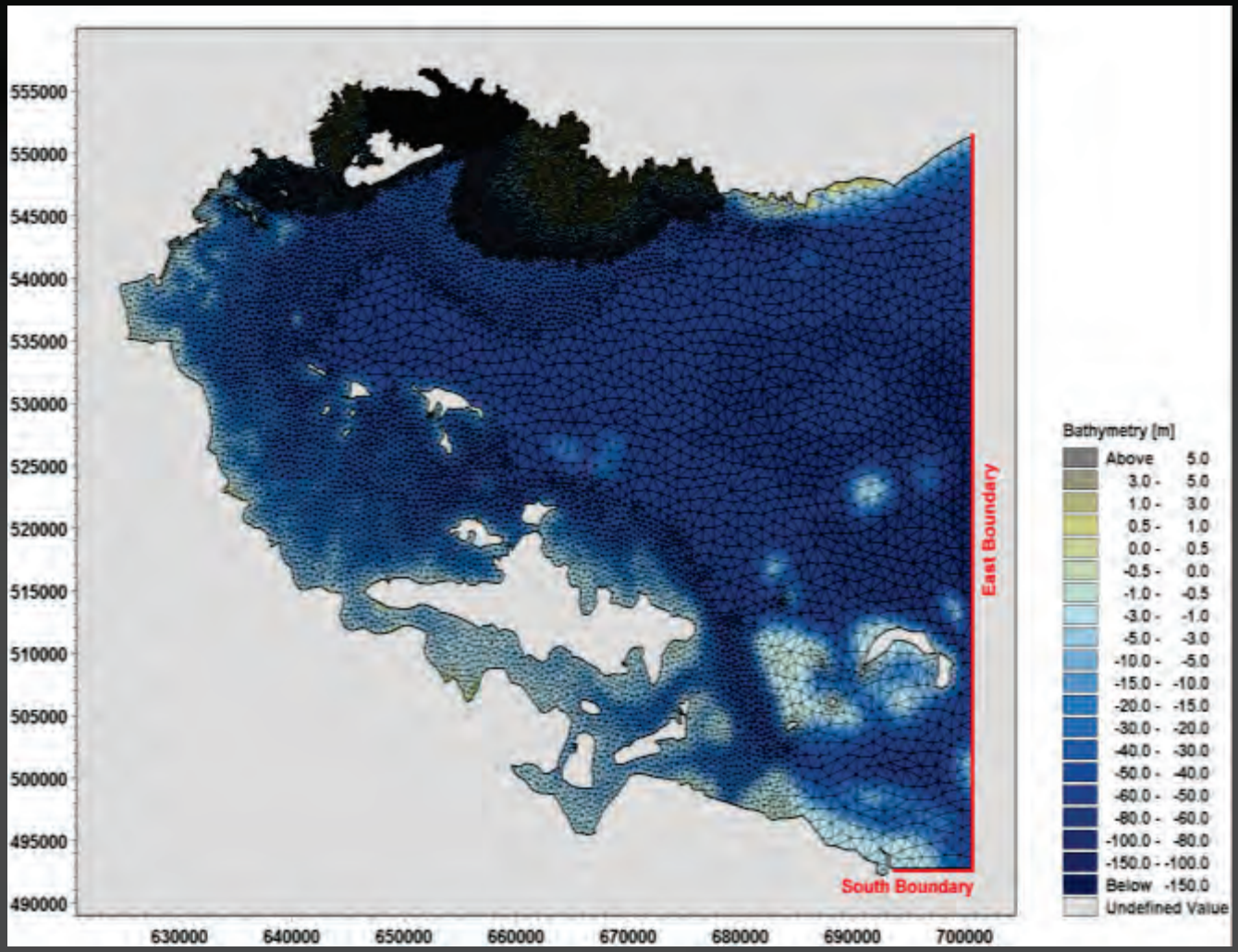
- Monitoring and in-situ sampling
- Coupled hydrodynamic, deposition and ecological modelling defining impacts of proposed production



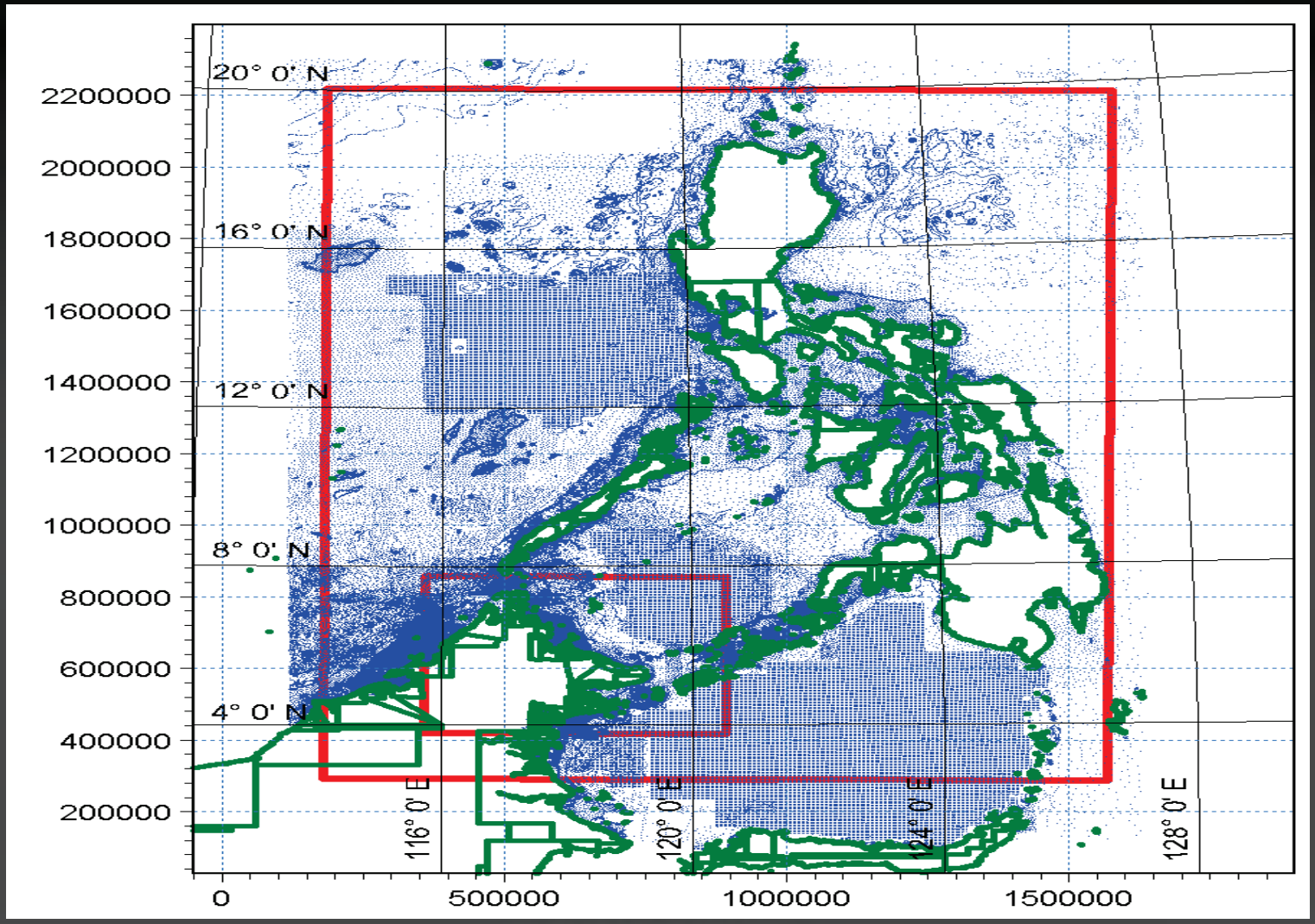




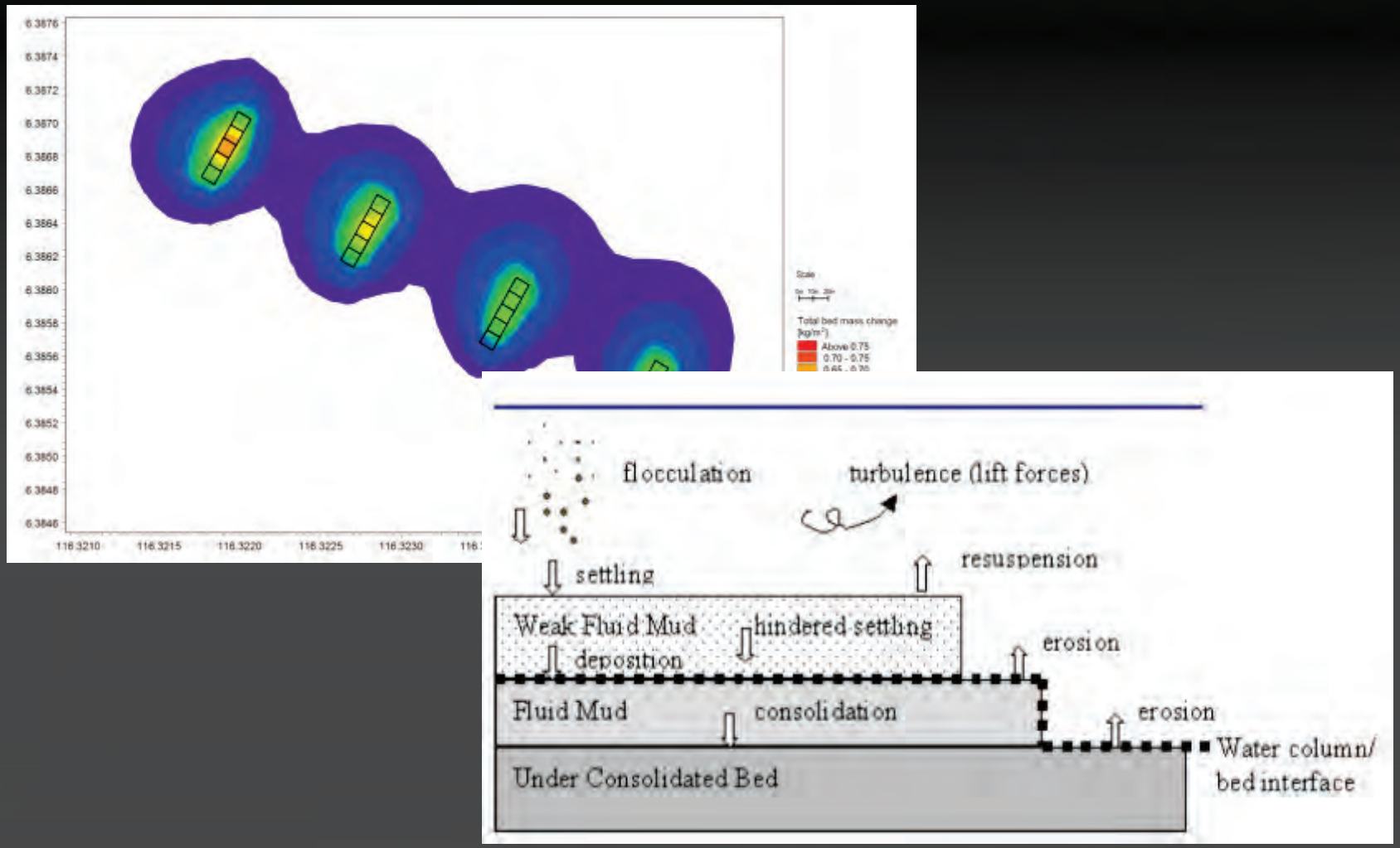
Carrying capacity assessments (Lobster farming in Borneo)



Carrying capacity assessments
Regional Carrying capacity modeling potential (10+ studies)

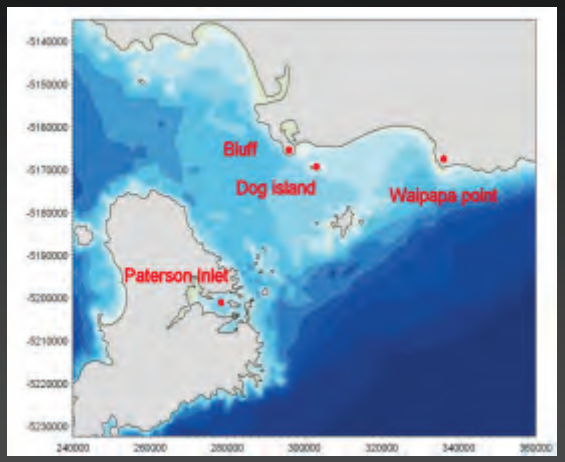


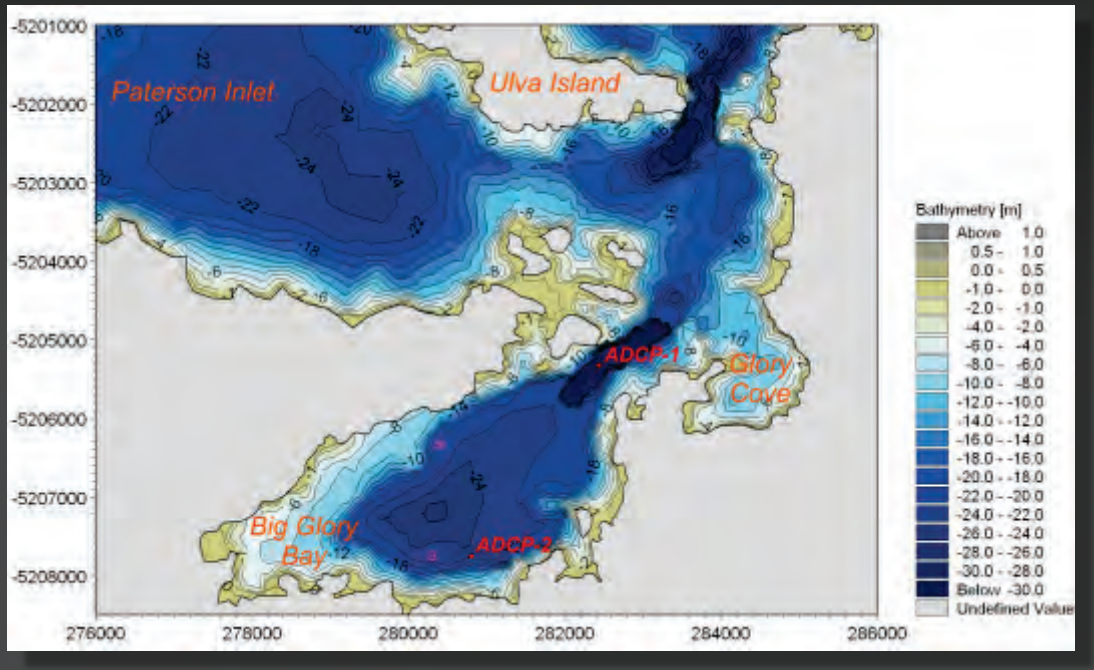
Carrying capacity assessments SEA Depositional footprints from small scale farms)



Carrying capacity assessments

Big Glory Bay, NZ





Carrying capacity assessments

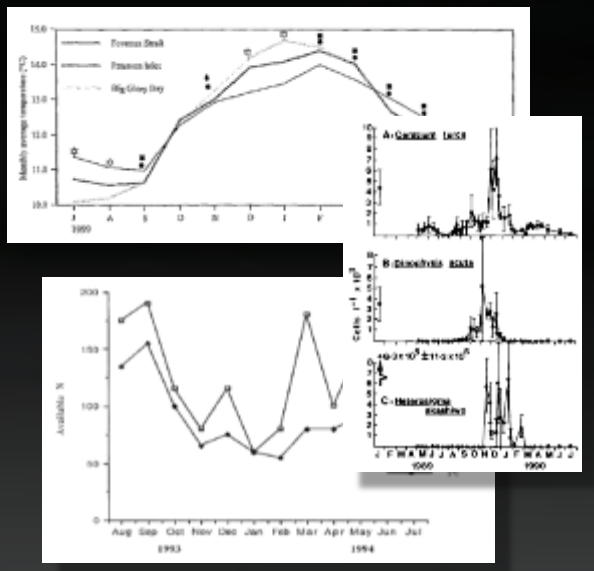
Big Glory Bay, NZ

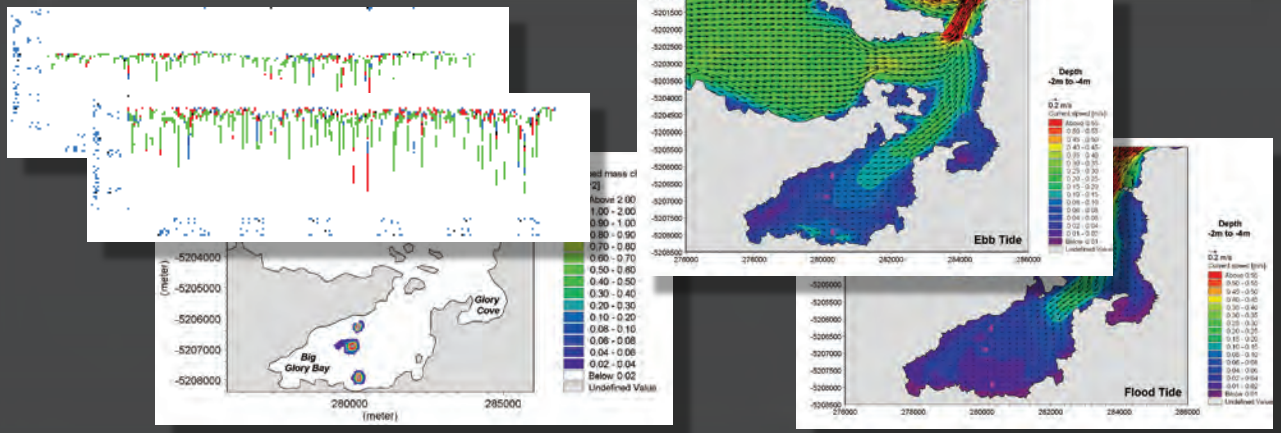
Key project details:

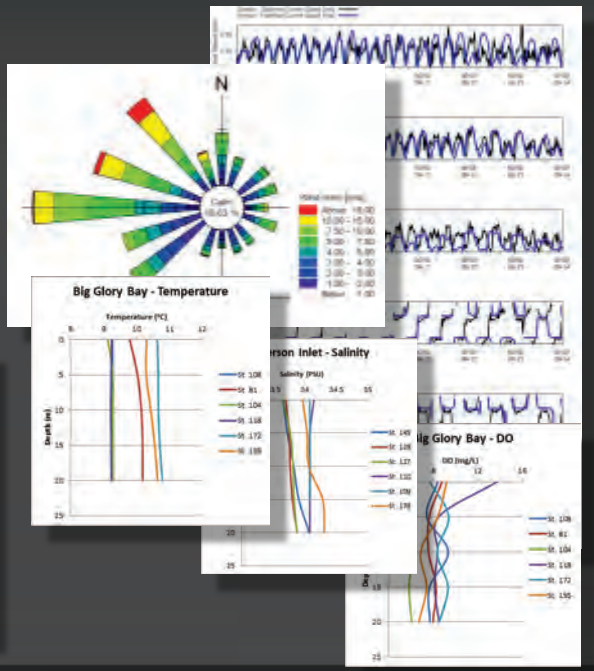
- Refined assessment of the carrying capacity for salmon farming

Key solutions:

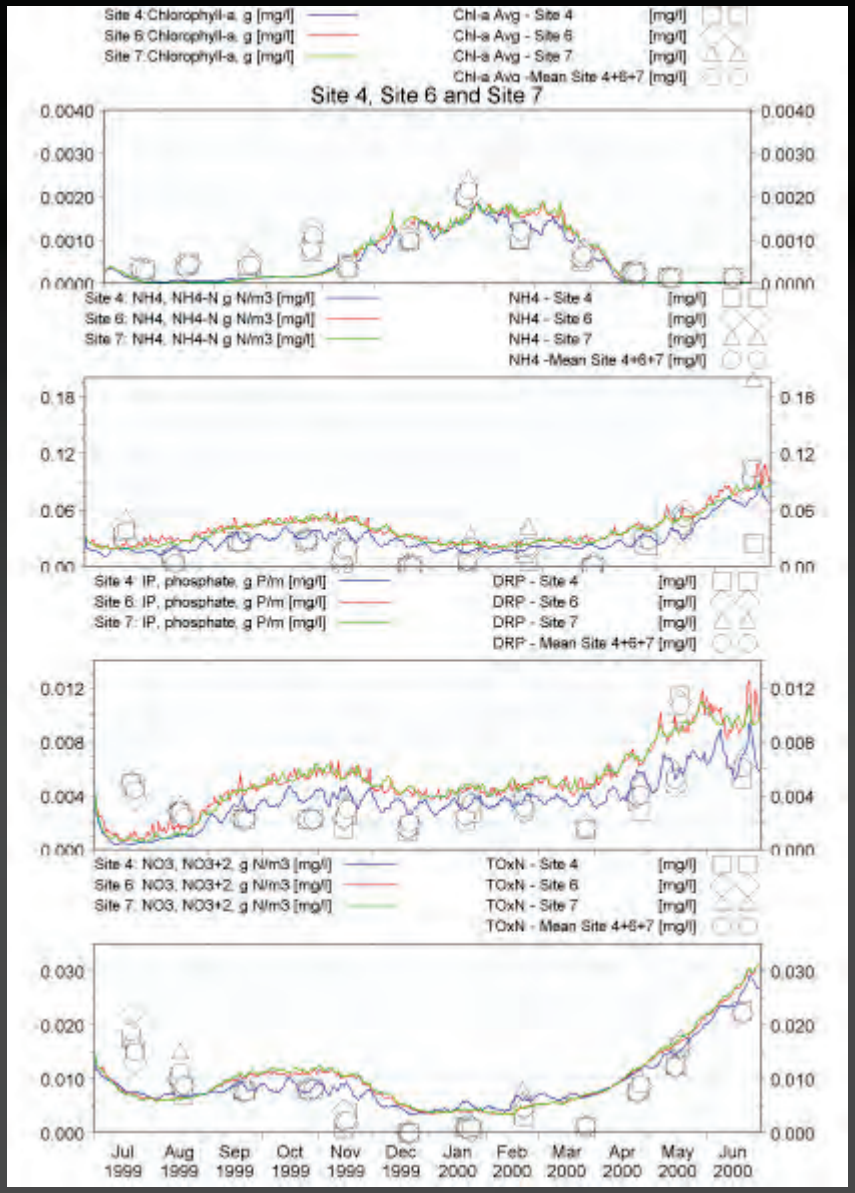
- Historical datasets
- Confirmation by in-situ sampling
- Advanced coupled hydrodynamic, deposition and ecological modelling defining impacts of proposed production







Big Glory Bay Calibration (WQ/Eco)



SUCCESS

Western Tasmania: Macquarie Harbour

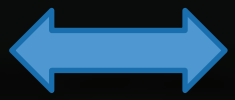
Western Tasmania: Macquarie Harbour

- Project details:
  - 3 growers operating
  - Increase of farming area by 66%
  - Creation of new zones
  - Increase by 20k

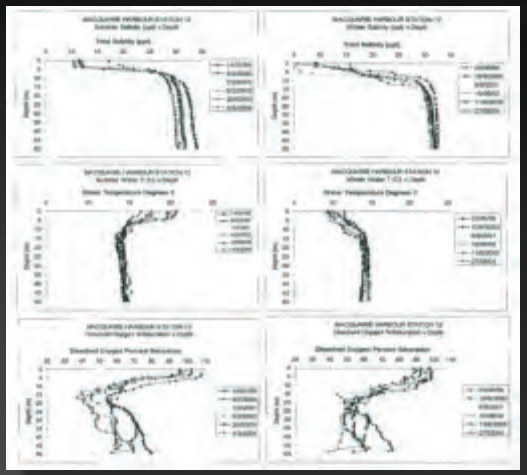
Macquarie Harbour modelling

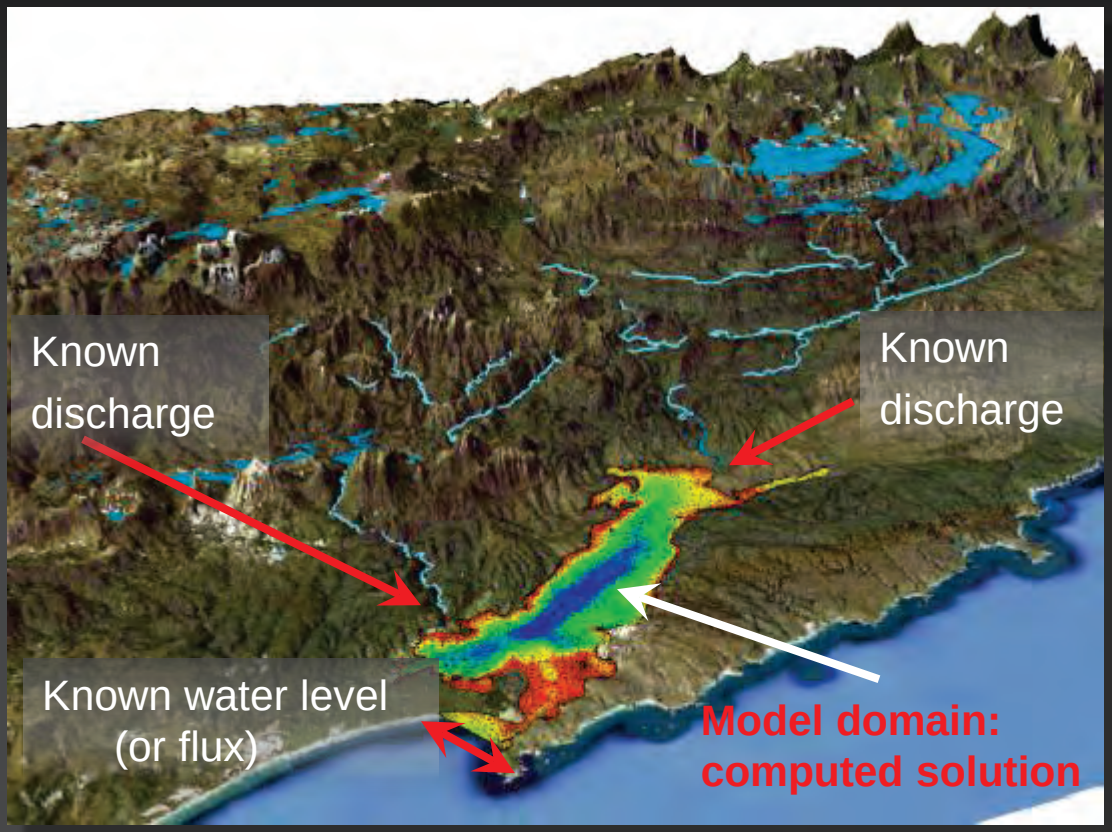
Hydrodynamic modelling: which type of model?

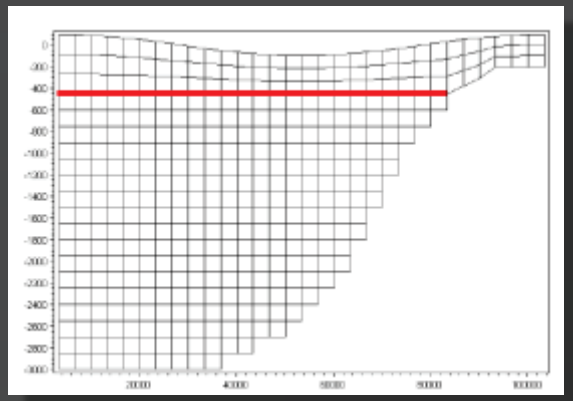
- The stratified parameters
- Floating cages (10-15m deep)



3D MODEL



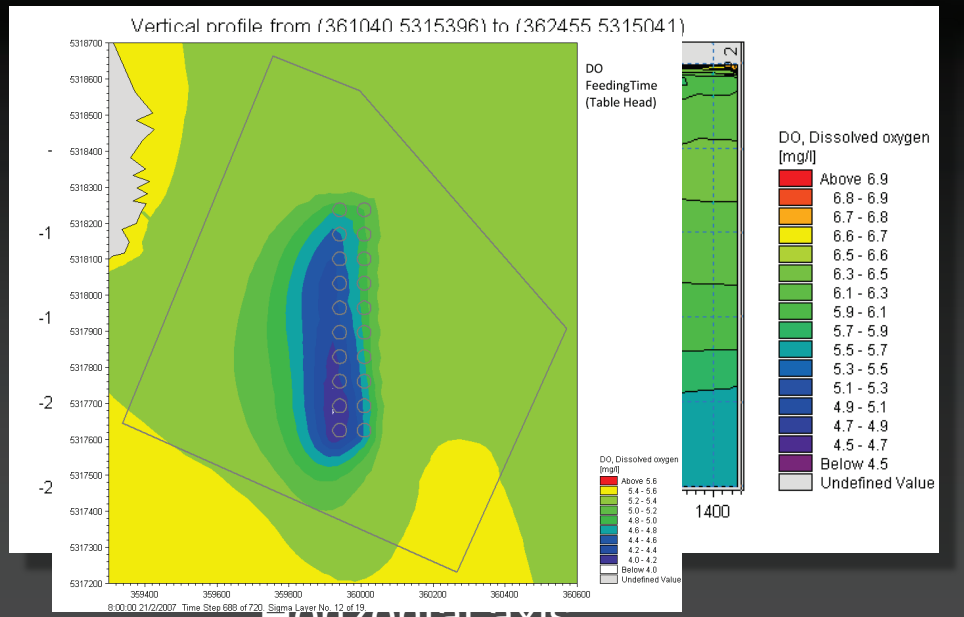


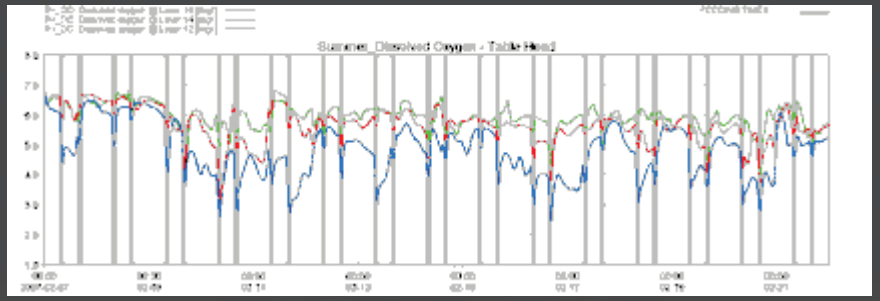


Macquarie Harbour modelling

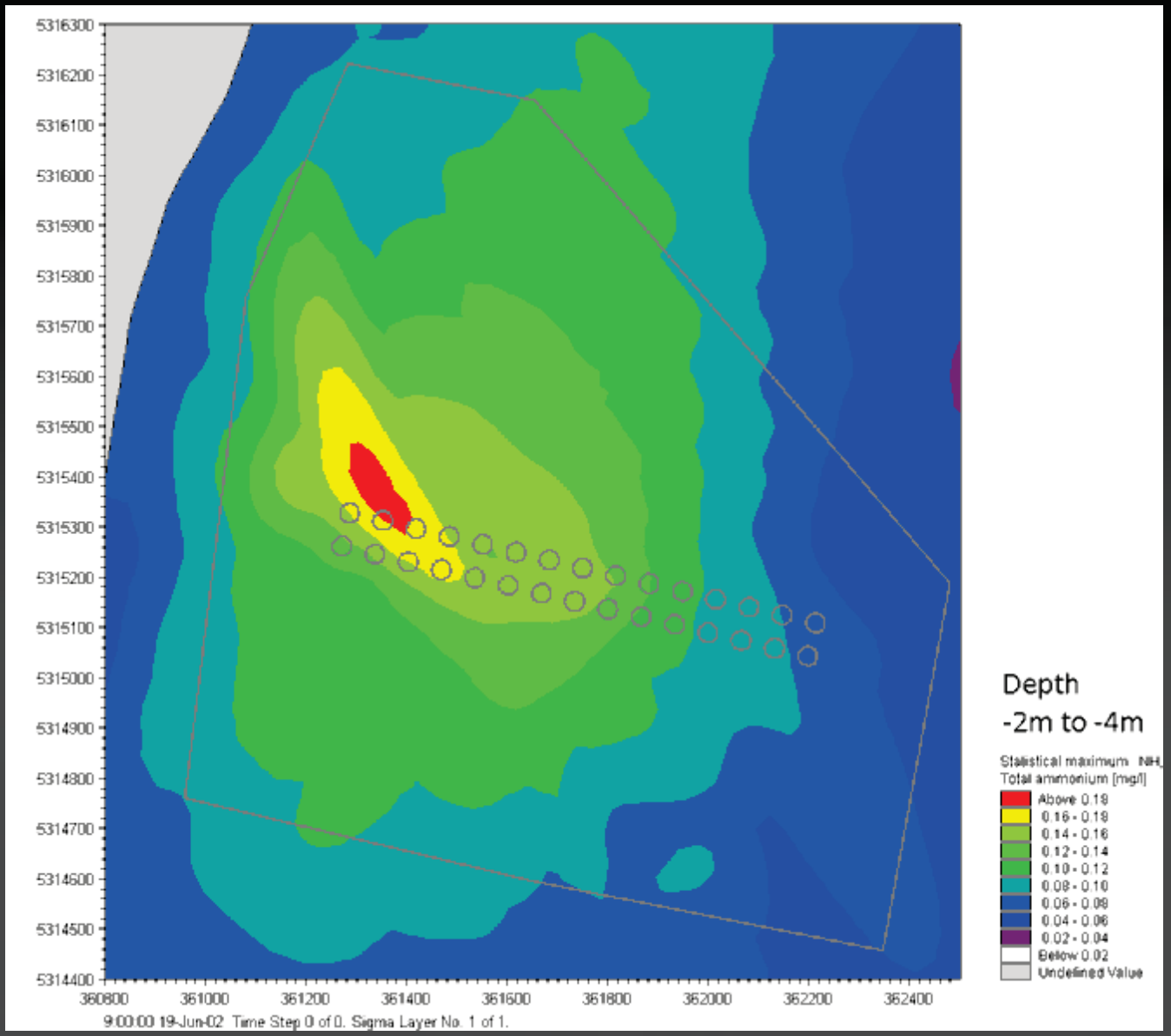
Ecological modelling: processes and parameters

- Dissolved oxygen depletion from fish respiration (maximum respiration at feeding)

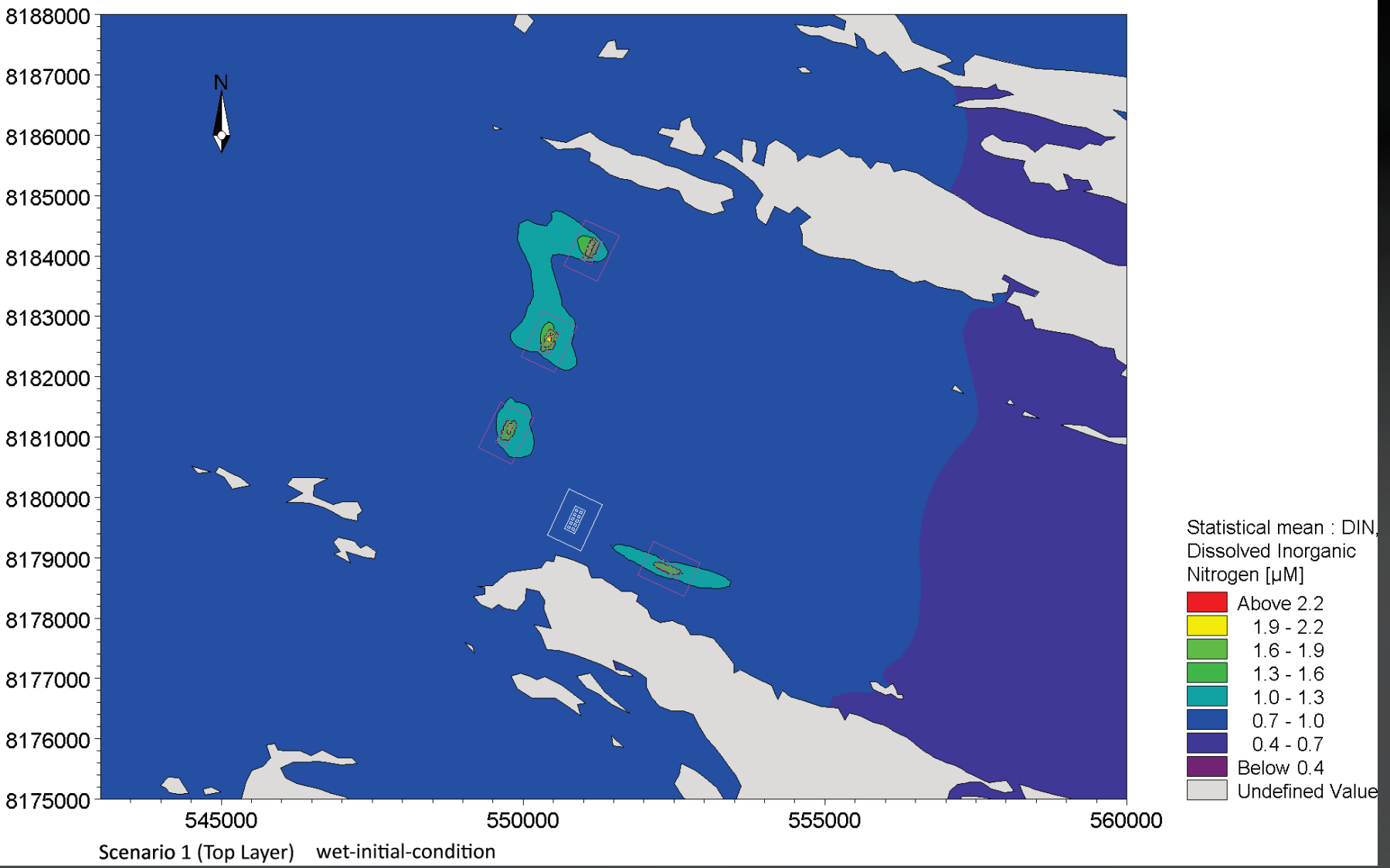




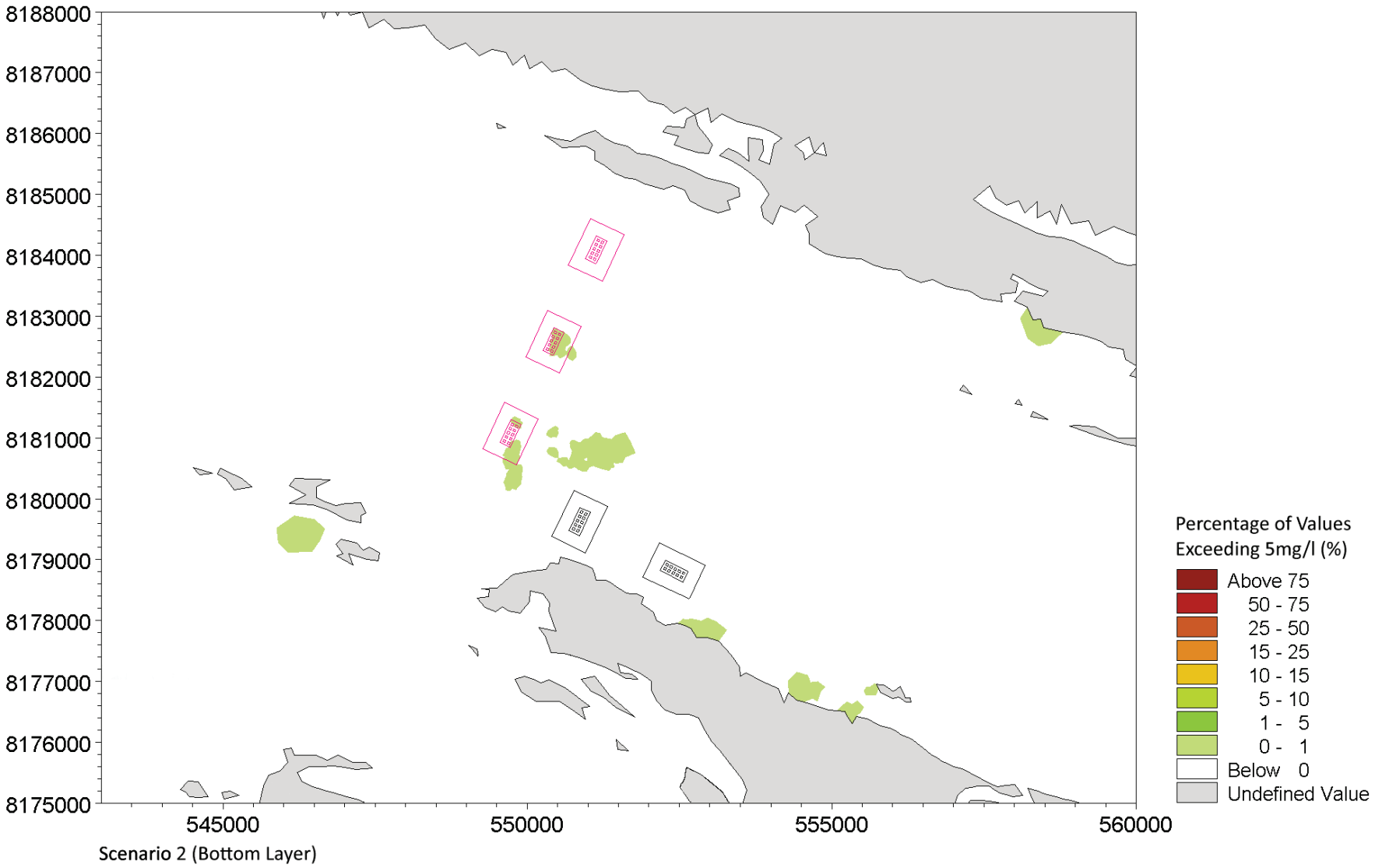
Ammonium


5316300
5316200
5316100
5316000
5315900
5315800
5315700
5315600
5315500
5315400
5315300
5315200
5315100
5315000
5314900
5314800
5314700
5314600
5314500
5314400
360800
361000
361200
361400
361600
361800
362000
362200
362400
9:00:00 19-Jun-02 Time Step 0 of 0. Sigma Layer No. 1 of 1.
Depth
-2m to -4m
Statistical maximum NH4
Total ammonium [mg/l]
Above 0.18
0.16 - 0.18
0.14 - 0.16
0.12 - 0.14
0.10 - 0.12
0.08 - 0.10
0.06 - 0.08
0.04 - 0.06
0.02 - 0.04
Below 0.02
Undefined Value

Ammonium


8188000
8187000
8186000
8185000
8184000
8183000
8182000
8181000
8180000
8179000
8178000
8177000
8176000
8175000
N
545000
550000
555000
560000
Statistical mean : DIN, Dissolved Inorganic Nitrogen [µM]
Above 2.2
1.9 - 2.2
1.6 - 1.9
1.3 - 1.6
1.0 - 1.3
0.7 - 1.0
0.4 - 0.7
Below 0.4
Undefined Value
Scenario 1 (Top Layer) wet-initial-condition

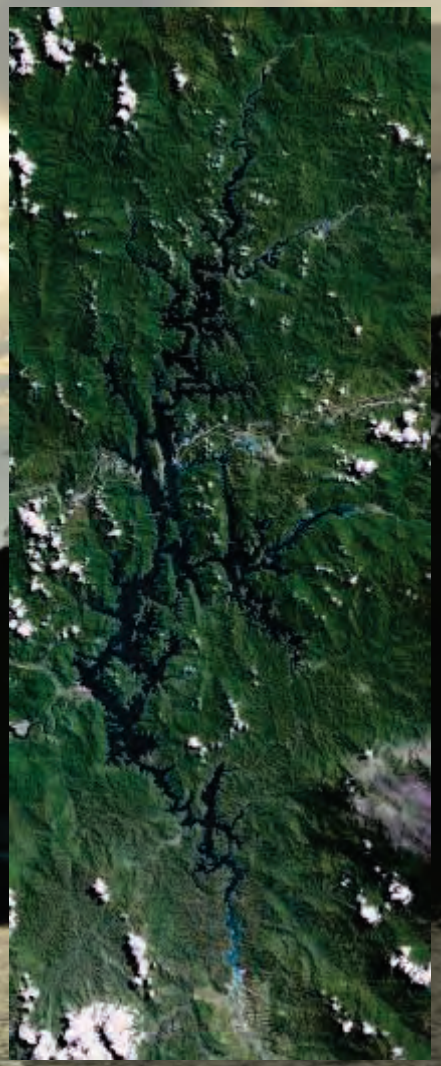
Trigger values



Start up to around 5,000 tons

Site selection and carrying capacity

TRAPIA



Who I have worked with

Nissu	(Salmon)
Sealord	(Grouper, ASB, Salmon, Trout)
Darden	(Lobsters)
Tassal	(Salmon)
Regal Springs	(Tilapia)
Huon	(Salmon, Trout)
Sanford	(Salmon)
BAE Systems	(Grouper)
Maritek	(Grouper, ASB)
Genomar	(Tilapia)
Lobster harvest	(Lobsters)
Skretting	Feed
INVE	Feed and health products

THE FUTURE what do I see …

THE FUTURE Small scale but $$$$

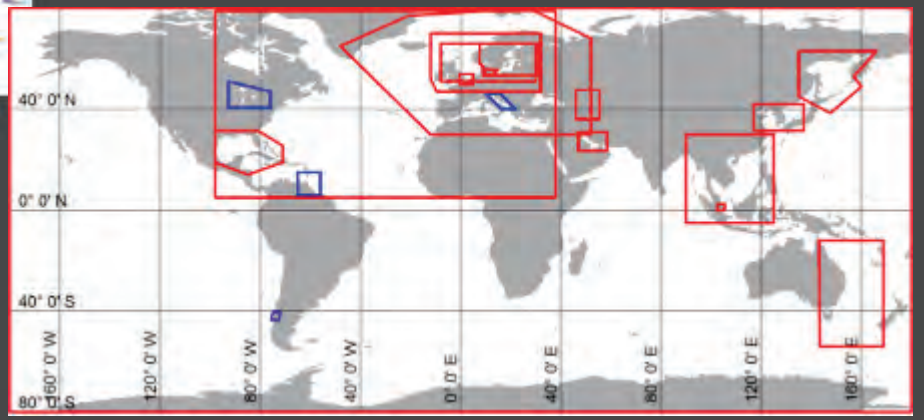

15/03/2013

Big scale

Finally if we get there.. How to manage?

The best of both worlds, combining either or both:

- Data collection (automated or not)
- Modelling



FINAL COMMENT

- Need proper studies.. Hopefully where we can all come in ☺ site selection , carrying capacity and then management.