Physical and Numerical Model Study of Montgomery Locks and Dam, Ohio River

Allen Hammack, Howard Park, Cecil Dorrell

Engineer Research and Development Center

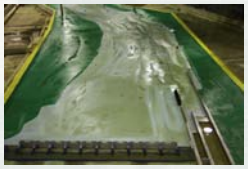
Coastal and Hydraulics Laboratory

US Army Corps of Engineers

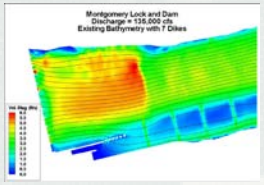
BUILDING STRONG®

This research focused on developing a device to protect spillway gates from runaway barges

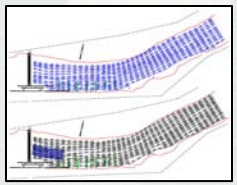
Project description



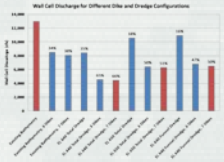
Initial physical modeling



Numerical modeling



Subsequent physical modeling



Conclusions

Montgomery Locks and Dam is located on the Ohio River in the northeast USA

In service since 1936

10 100-ft (30.5-m) gated spillways

2 fixed crest weirs

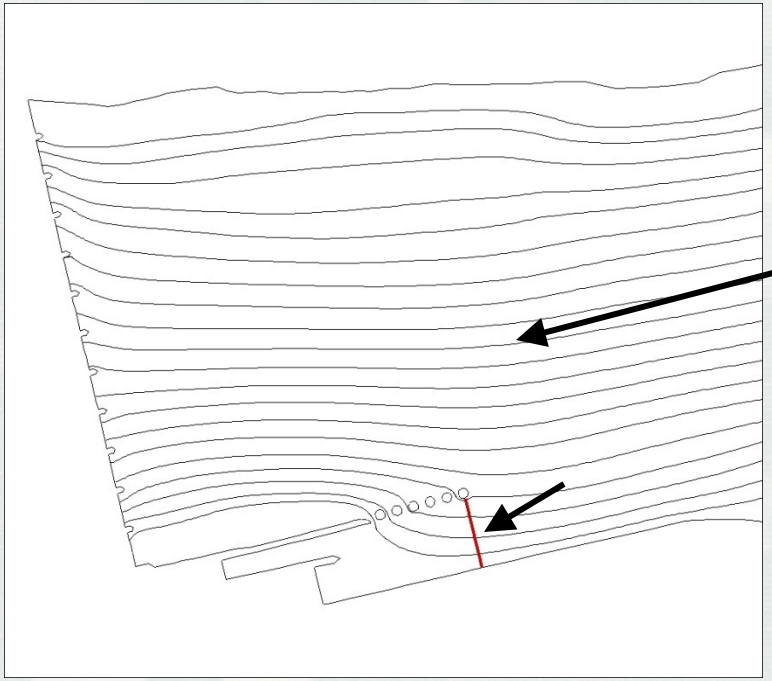
Two locks

- 110x600 ft (33.5x183 m)
- 56x360 ft (17x110 m)

Navigation problems on upstream approach

Aerial view from downstream side

The flow intercepted at the cell wall is referred to as the outdraft



The streamlines indicate the currents as the flow approaches the locks and spillway

Outdraft causes vessels to move away from the landside guide wall and out of alignment with the lock chamber

At the indicated line, the flow discharges were measured in the physical model to give an indication of the severity of the outdraft present

This model study is focused on the upstream lock approach

2.1 miles (3.4 km) upstream of the structure is modeled

Model scale – 1:100

Fixed bottom of concrete

7 flows modeled

- 42,000-303,000 cfs
- (1,000-8,600 m^3/s)
- Design flow – 135,000 cfs
- (3,800 m^3/s)

Tows modeled

- 15-barge flotilla – 105x975x9 ft (32x297x2.7) m
- 2-barge flotilla – 52x175x9 ft (16x53x2.7) m

Certain design constraints limited the river/structure features that could be changed

No changes to the existing structure (lock, dam, approach walls, etc.)

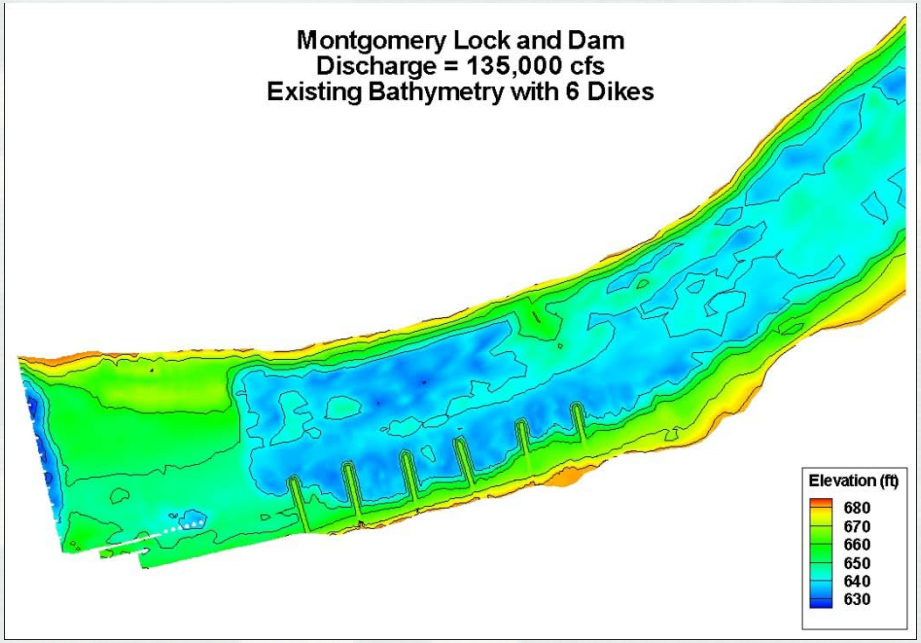
Due to foreseen lock replacement or extension

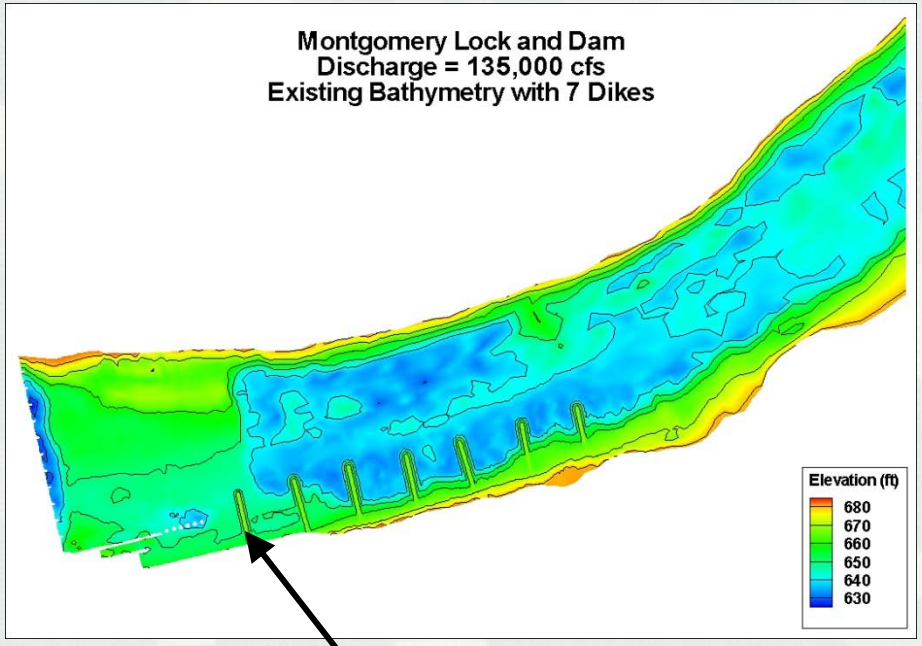
No changes to the spillway gate operation schedule

No negative impacts to the use of the mooring cells on left descending bank

Improvements should not interfere with industries in and around the area

Dike fields consisting of six and seven dikes were investigated



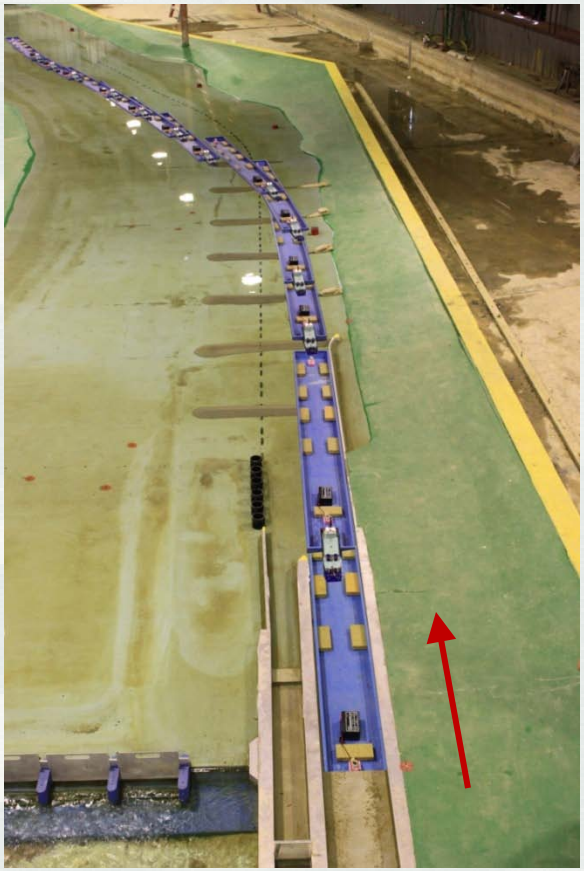


7th Dike

Dike geometry

- Crown elevation is 15 ft (4.6 m) below the water surface
- ~650 ft (198 m) long at about a 400-ft (122-m) spacing
- 10-ft (3-m) crown width, 1 v on 1.5 h side slopes

A 15-barge tow can successfully enter and exit the main chamber with seven dikes

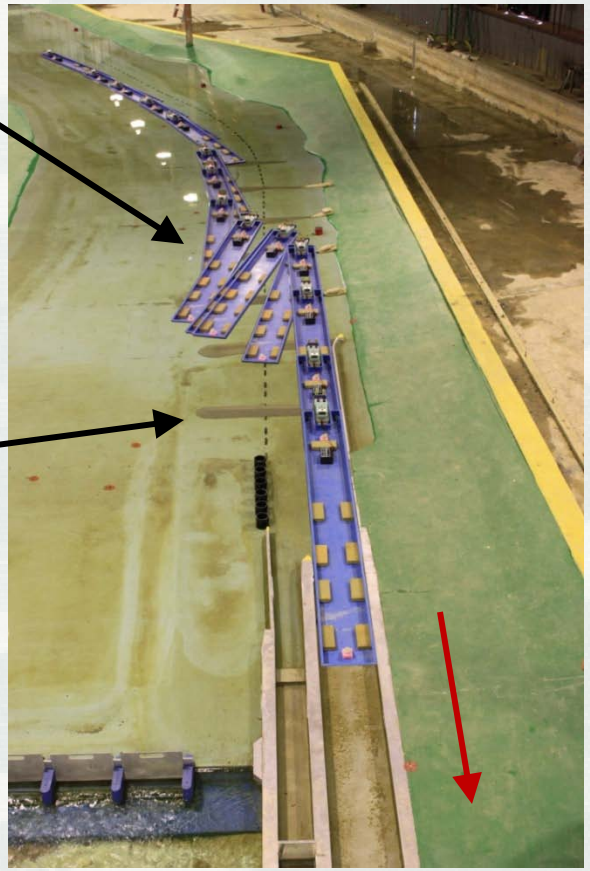


Flanking maneuver

7th Dike

Upbound

Downbound

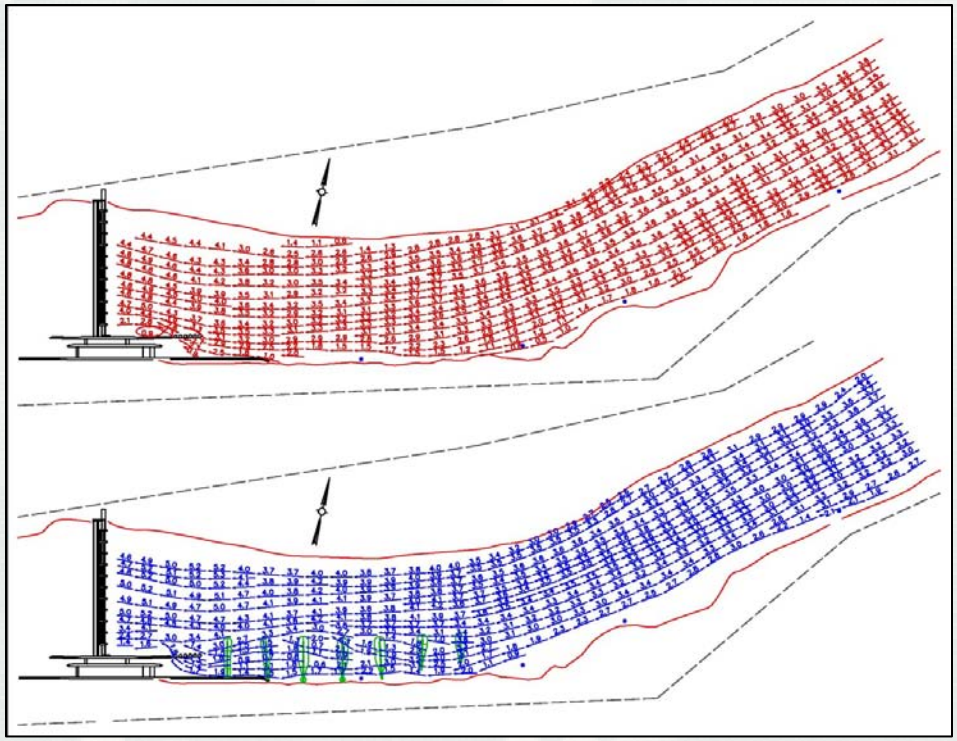


The downbound tow can flank to and maintain alignment with the landside guide wall and enter the main chamber – an <u>improvement</u> on existing conditions

The dike field reduces the currents and subsequently the outdraft by about 40%

No Dike Field

Dike Field



Surface currents

To minimize the impacts of the outdraft, dikes were added to reduce the flow into the immediate lock approach

How could navigation conditions be improved even more?

Would dredging alone be sufficient? Would both dredging and dikes be better?

With the physical model time and budget constraints, thorough testing of dredge/dike combinations would be costly and time prohibitive

Is there another tool readily available that could help?

Numerical model (2D Adaptive Hydraulics)

- Shorter turn-around time per configuration
- Test multiple configurations and flow conditions simultaneously

Adaptive Hydraulics (AdH) is a USACE flow solver maintained by ERDC

Developed by ERDC-CHL and ERDC-ITL

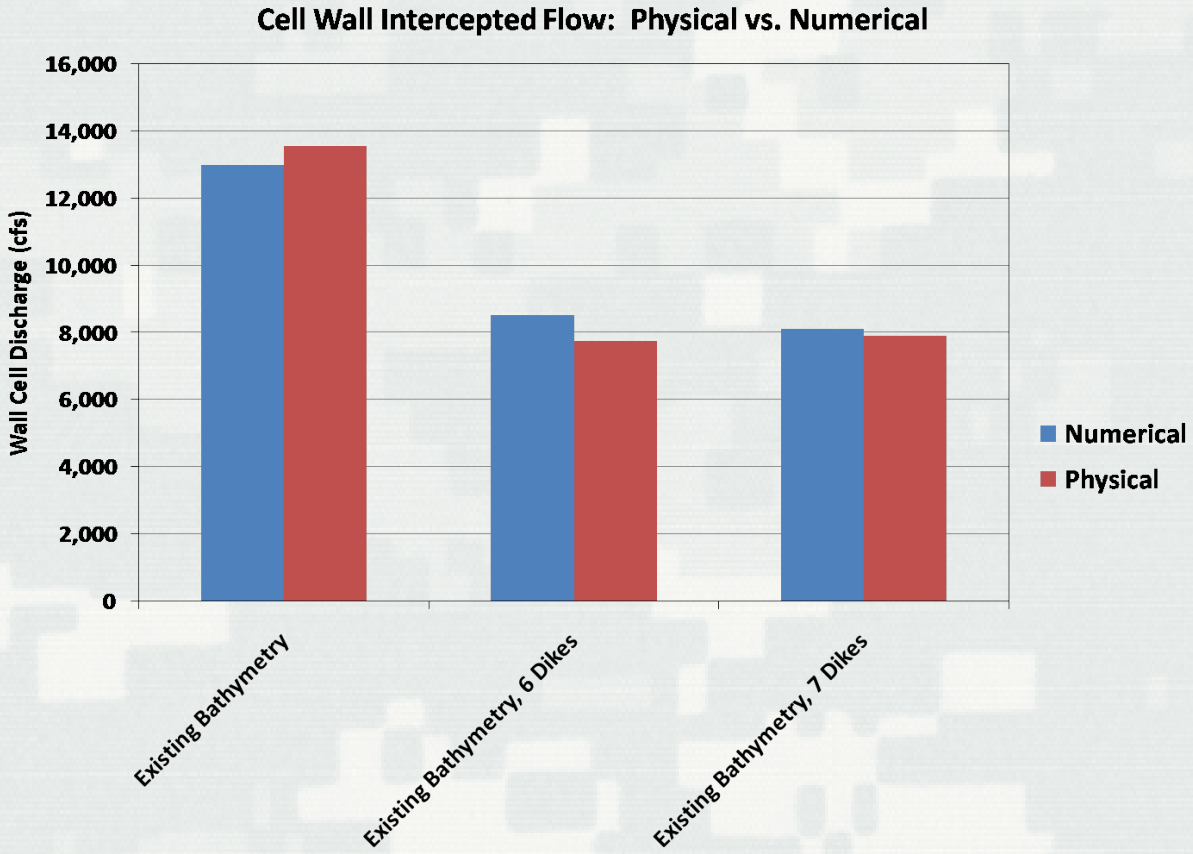
Can model closed-conduit, groundwater, and open-channel hydraulics

Sediment and other constituent modeling techniques are being developed

Automatic adaptive meshing – based on a single user-supplied value

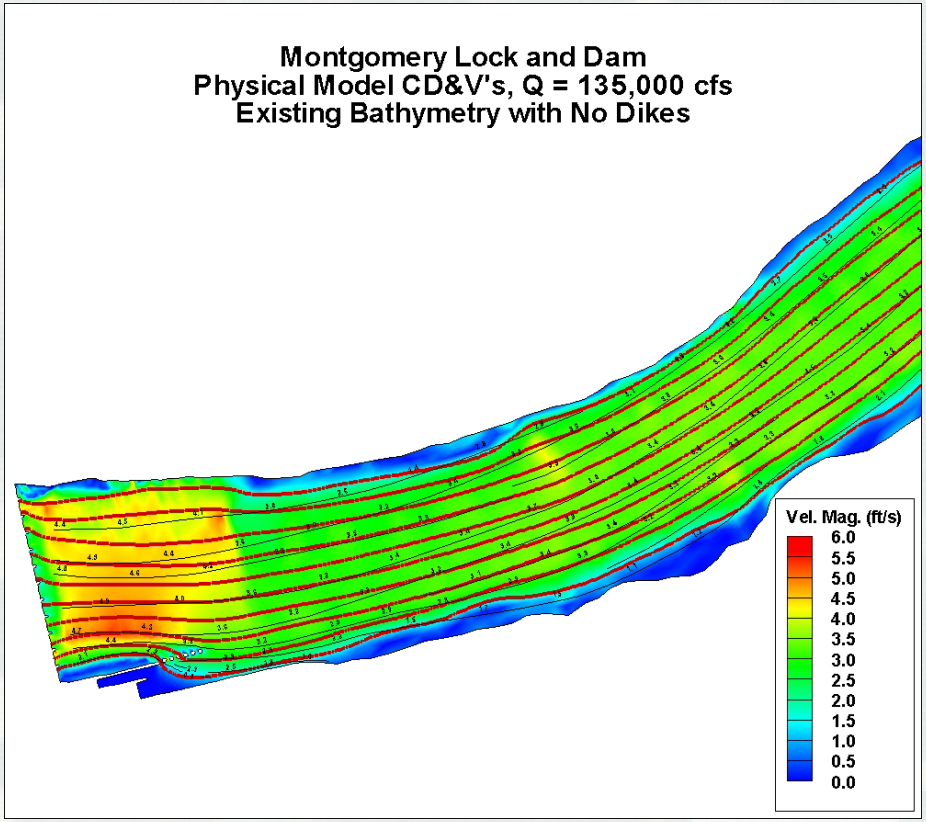
2D depth-averaged flow module considered for this study

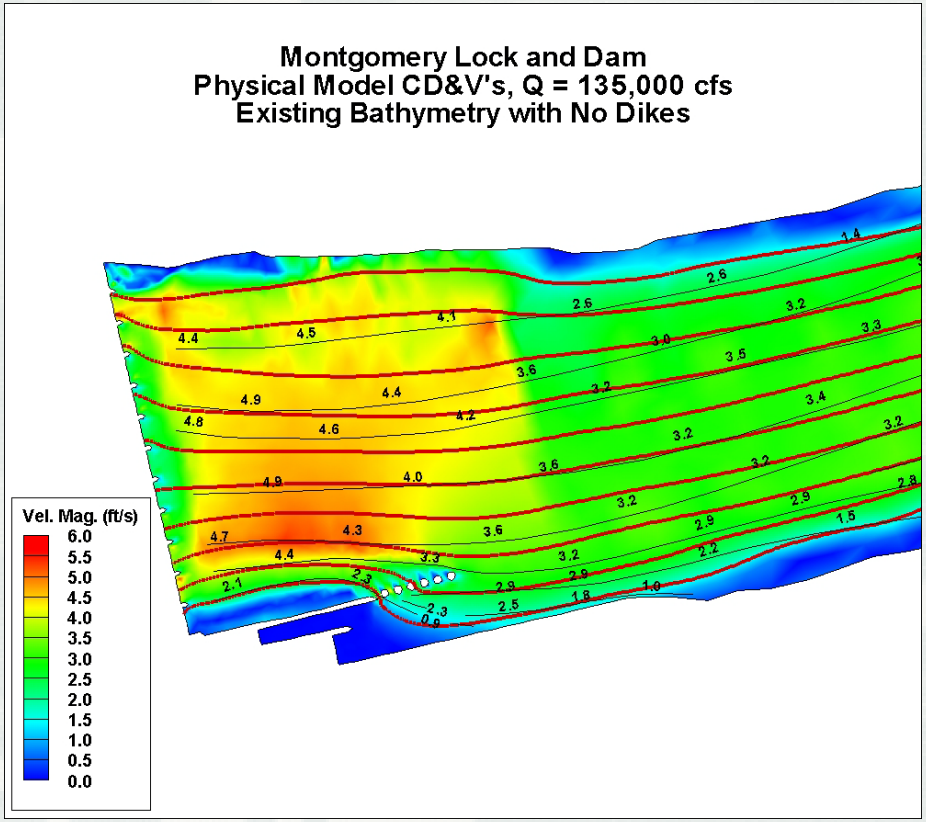
Is a 2D model appropriate for replicating flow effects of a dike field?



With the existing bathymetry, the numerically calculated discharges differ from the physical data by no more than 10%

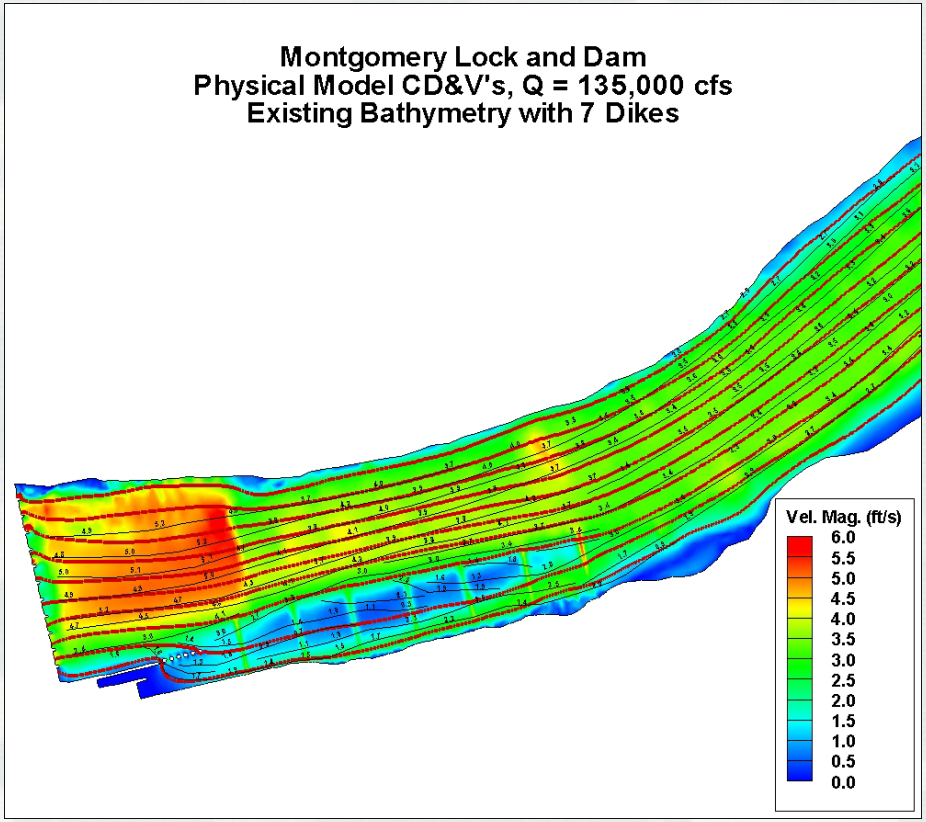
The numerical model was validated using physical model results

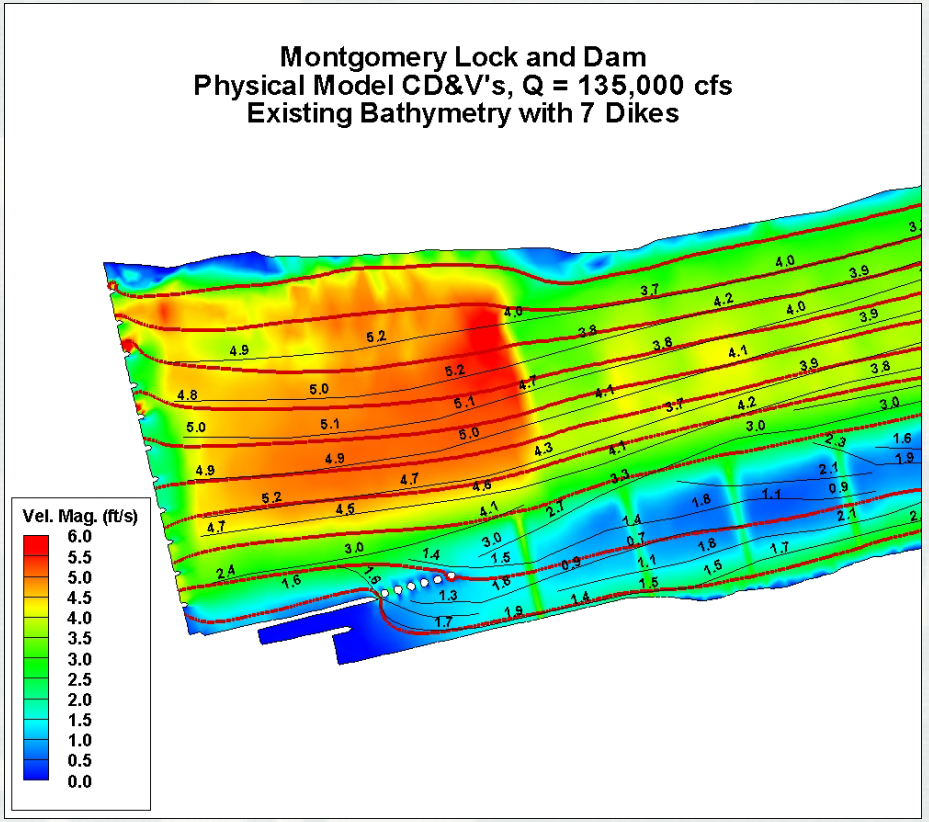




For the existing conditions, physical model flow traces (black lines) compared well to the numerical streamlines (red lines)

The models also compared well when the dikes were added

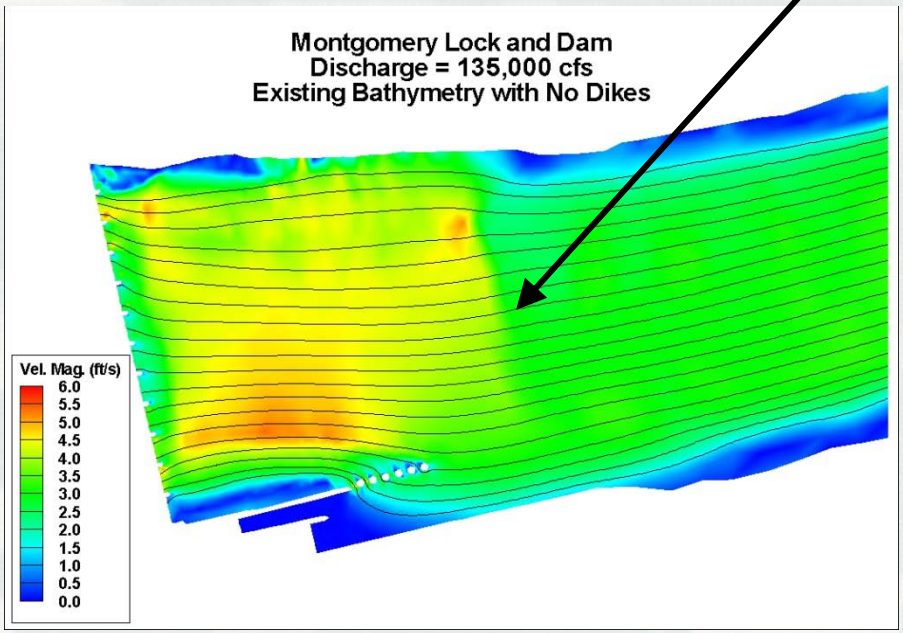


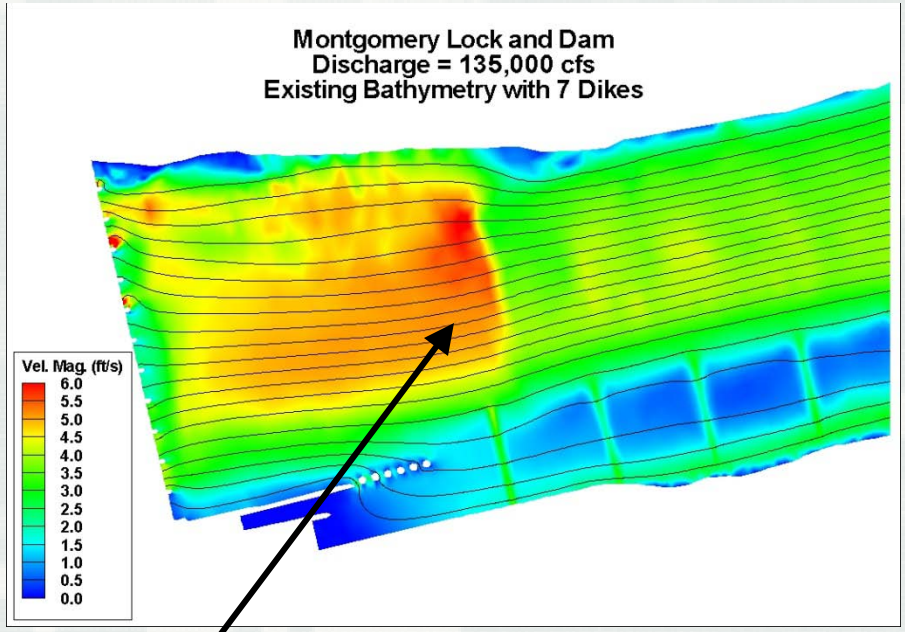


Some discrepancies between the models are expected near the dikes because of the sudden changes in bathymetry

The bathymetry upstream of the dam possibly reduces the effectiveness of the dikes

The flow velocity increases sharply near the bathymetric shelf immediately upstream of the spillway





The flow velocity increase is magnified when the dike field is added to the upstream approach

The bathymetry upstream of the dam possibly reduces the effectiveness of the dikes

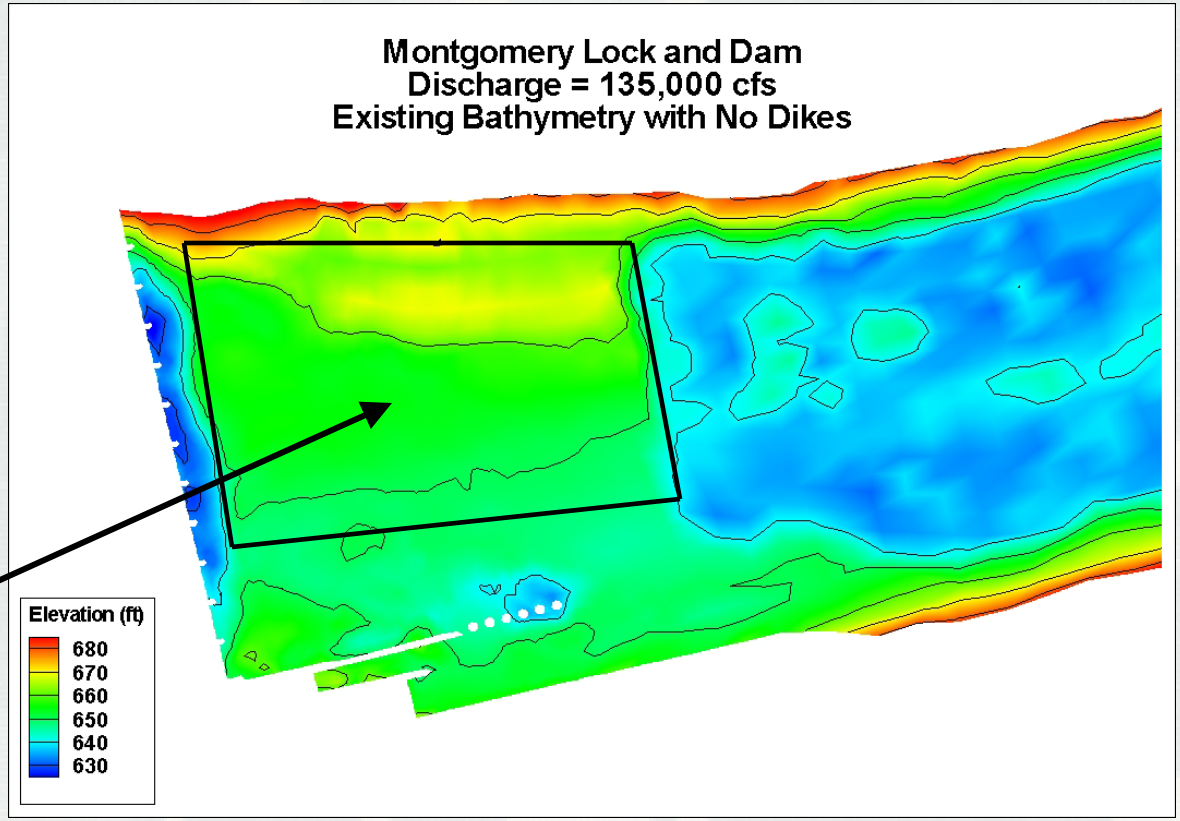
Direct flow to spillway

Above EL 640

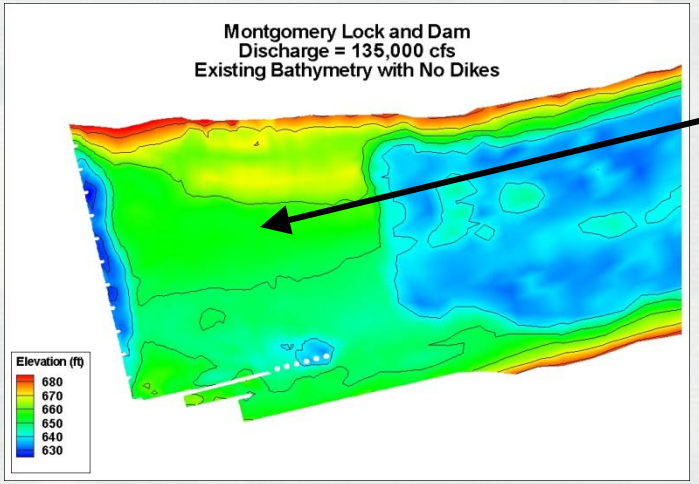
Three dredges

- EL 640 Total Dredge
- EL 650 Total Dredge
- EL 640 Funnel Dredge

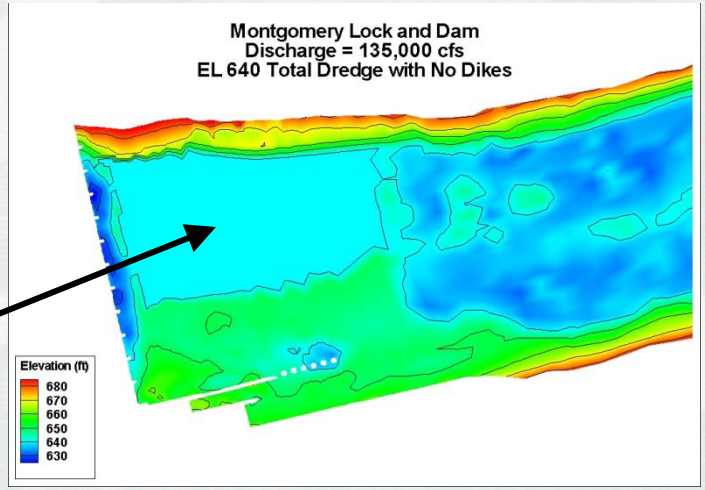
Dredge focus area



The three dredges vastly alter the bathymetry upstream of the dam



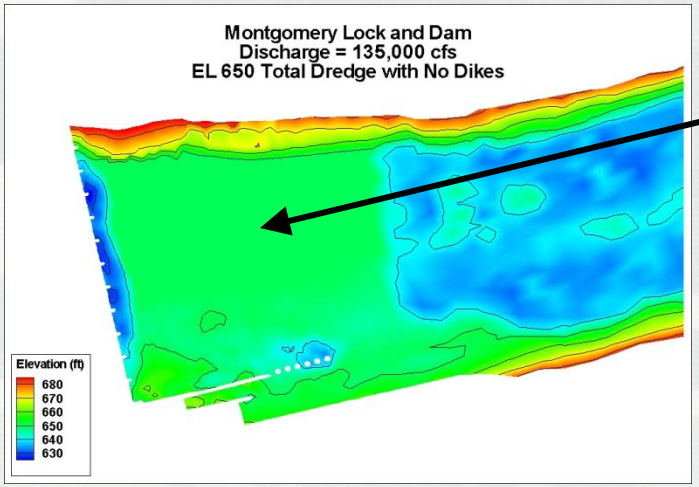
Existing



EL 640 Total

~540,000 yd^3

(413,000 m^3)



EL 650 Total

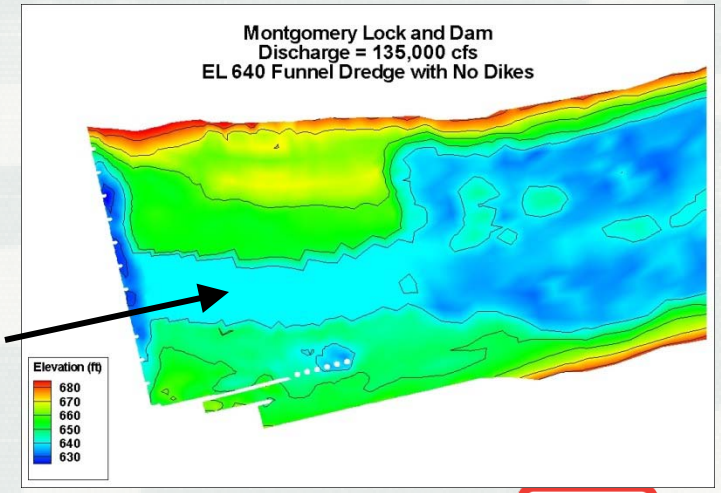
~220,000 yd^3

(168,000 m^3)

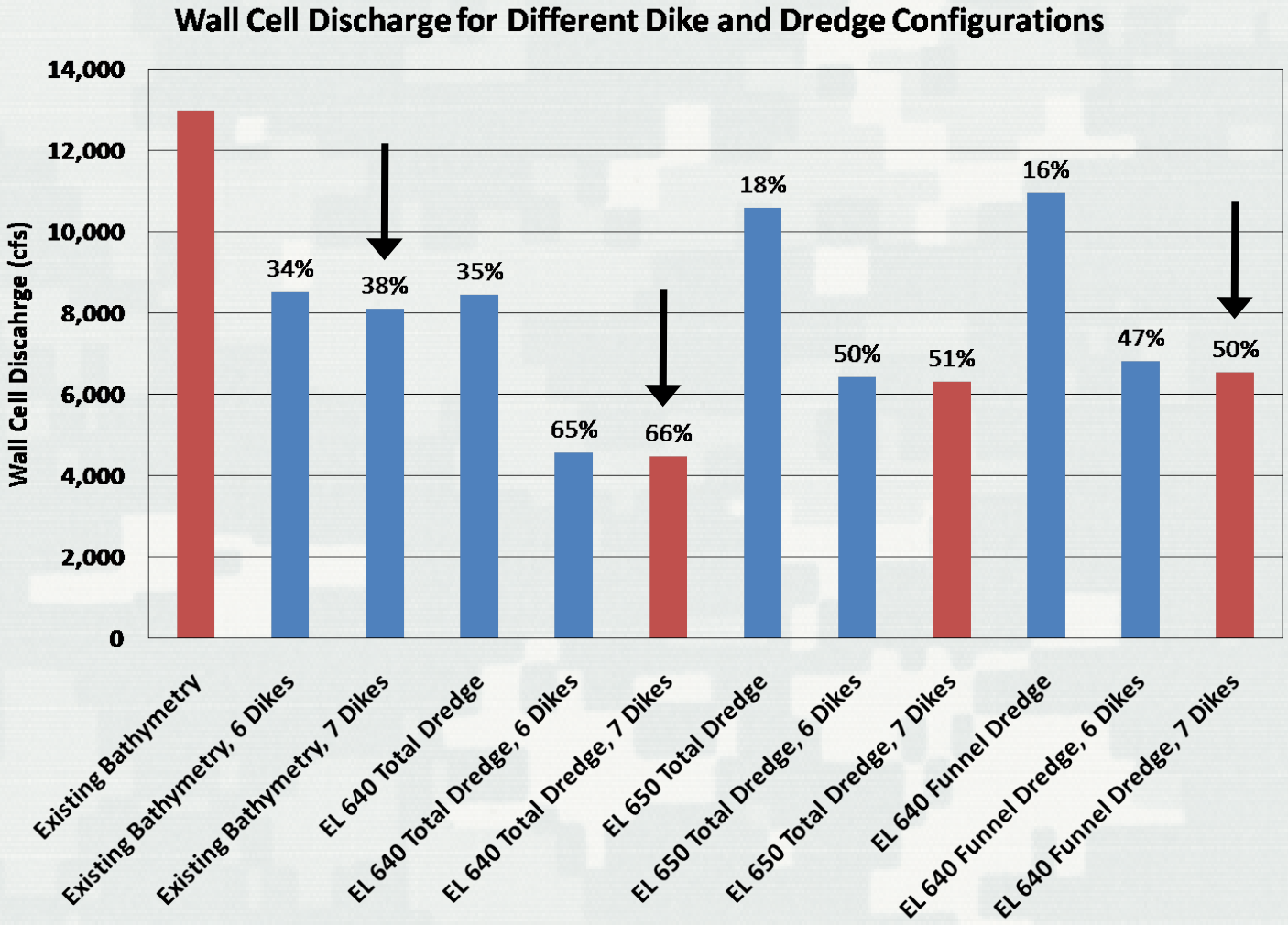
EL 640 Funnel

~160,000 yd^3

(122,000 m^3)



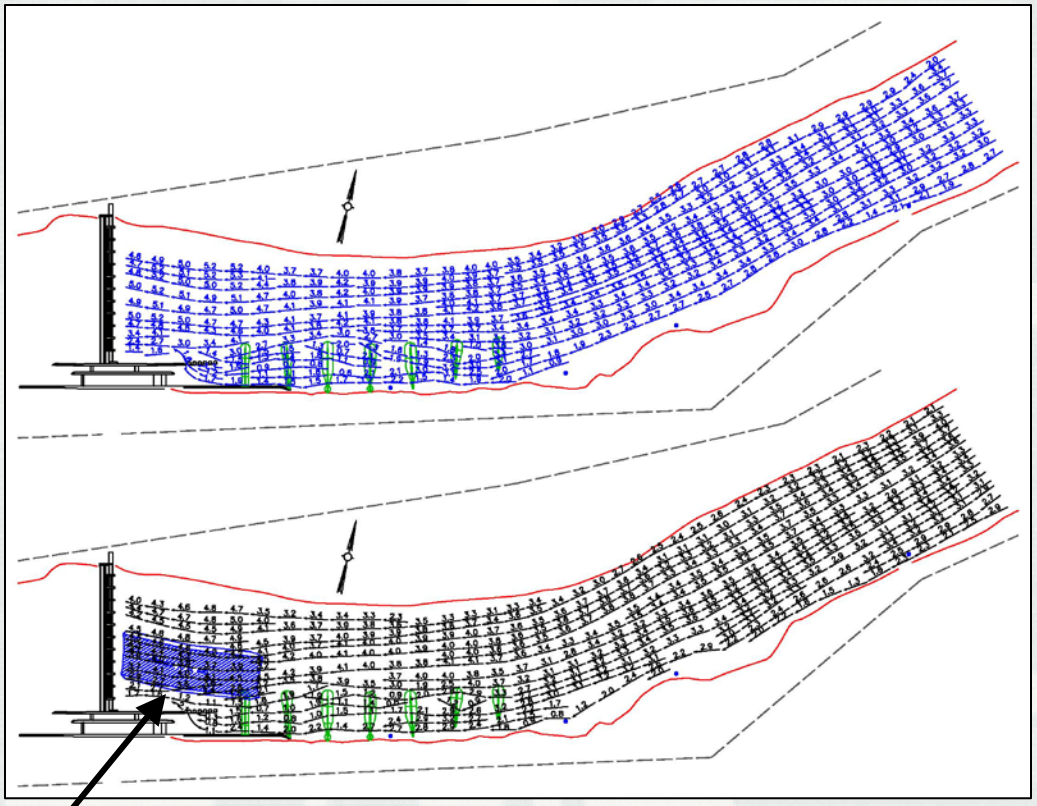
Twelve possible dredge/dike combinations were investigated in the numerical model



The funnel dredge was added to the physical model for barge tow runs

Existing bathymetry

Funnel dredge



Dredge

Surface currents

General conclusions from this model study

A dike field alone in the upstream lock approach significantly improves the navigation conditions

A 2D numerical model can be used to model the flows around a dike field sufficiently for navigation models

Using 2D numerical models to test bathymetric changes will significantly reduce the modeling time (~50-75% reduction)

Thanks for your attention!

Any questions?