E-7

MAYNORD

MICROMODEL EVALUATION
(POWER POINT PRESENTATION)

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Micro-model Evaluation

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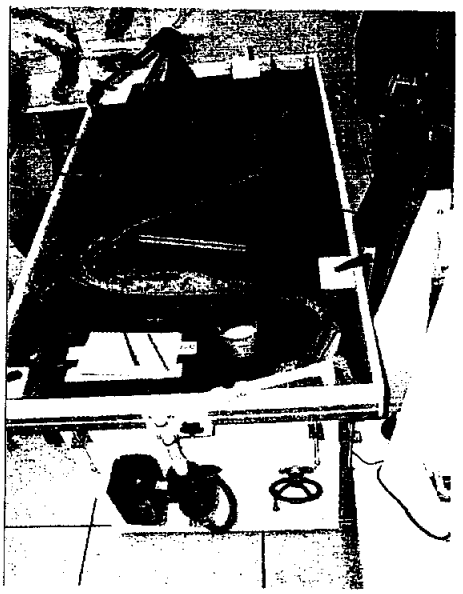
Today's Topics

- Describe micro-model
- Describe previous movable bed models
- Compare micro-model to previous models
- Describe Evaluation Team and Approach
- Focus on micro-model/prototype comparisons
- Conclusions

Micro-model Characteristics

- Extremely small-scale physical river model.
- Moveable bed- sediment recirculation, varying discharge
- Developed by Rob Davinroy, MVS, in 1994. 18 published reports.



Vicksburg Front Micro-Model, 1:14400 horizontal, 1: 1200 vertical

Micro-model Characteristics cont'

- 0.9 m wide by 2 m long table
- Minimum channel width of 1.5 inches in main channel and 0.5 inch in side channels
- Fixed free overfall at downstream end

Micro-model Characteristics, cont'

- Vertical channel banks
- Porous screen used to simulate dikes or bendway weirs.
- Bed material- plastic– SG=1.48, 1.0 mm
- Slope about 1% or 100 times Mississippi River

Micro-model Calibration

- No bed molding
- Calibration adjustments:
  - Flow variation- high Q versus low Q, ratio about 3
  - Flow duration- 3-5 minutes per cycle
  - Downstream overflow weir elevation and shape
  - Amount of material in model
  - Inflow distribution vanes, baffles, etc
  - Flume slope
  - Vertical scale and datum

Micro-model Calibration cont'

- Bed surveyed with 3D Laser
- Model run to equilibrium: survey A = survey B
- Morphological similarity- Model Bathymetry compared to applicable prototype surveys for correct trends

Previous Movable Bed Models

Graf (1971)

- Rational (semi-quantitative)
- Empirical (qualitative)

Rational Movable Bed Models

Graf (1971)

- Rational :
  - Most rigorous- sediment transport model
  - semi-quantitative
  - Low vertical scale distortion
  - Low Froude number exaggeration
  - Model Shields parameter = prototype Shields parameter
  - Einstein and Chien, Yalin, DHL
  - Huge models- 30 ft wide

Empirical Movable Bed Models

Graf (1971)

- Empirical:
  - Less rigorous than rational- bathymetry model
  - qualitative
  - Modest vertical scale distortion and Froude number exaggeration
  - Model Shields parameter less than prototype Shields parameter, objective is to get general bed movement
  - WES models, some European models
  - Large models- 10 ft wide

Are Empirical Models Valid ?

- Shields parameter is the most fundamental parameter in sediment transport
- Mississippi River SP > 1, typical empirical model SP < 0.1
- My conclusion- valid for bathymetry studies

Further Characteristics and Some Differences Between the Micro-model and Most Previous Empirical MBMs

Differences

Small Size: one to two orders of magnitude smaller than most empirical models.

Large Distortion: distortion ratios are about twice that in most empirical models.

Vertical scale and vertical datum determined as part of the calibration/verification

Differences (continued)

No correspondence of stage and discharge in micro-model and prototype.

Micro-model maximum stages are about 2/3 of bankful.

Verification of micro-model based on equilibrium bed.

Differences (continued)

Small size of micro-model and relatively heavy bed material results in steep slopes which significantly exaggerate the Froude number. Fm=3.5&6.0*Fp

Extreme distortion of relative roughness.

Similarity of friction is not present in the micro-model.

3 Types of Movable Bed Models

Model Type	Similarity criteria	Need for good model/ prototype comparison
Rational	Small deviations allowed	Modest
Empirical	Significant deviations exist	Strong
Micro-model	Extreme deviations exist	Critical

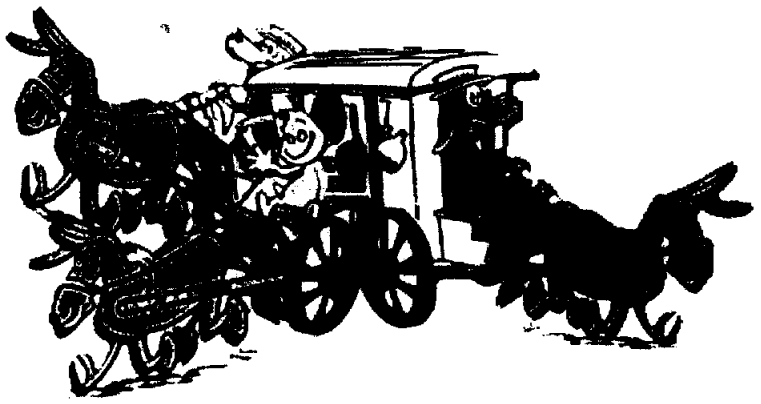
Verifications

- 2 step- adjust model to match prototype, declare ready for prediction
- 3 step- Vernon Harcourt (1886) empirical model
  - Adjust model to match prototype
  - Compare model to known changes
  - If satisfactory in hindcast, declare ready for prediction.

Evaluation by the US Army Corps of Engineers

- Two extremes- Good for everything or good for nothing
- Is Micro-model
  - Quantitative ?
  - Qualitative ?
  - Demonstration Tool ?
- CE Evaluation not just USACE

Evaluation Team- MVS, MVM, and ERDC



Evaluation Categories

- Demonstration, education and communication
- River Engineering – Qualitative
- River Engineering – Quantitative
- Navigability/Hydraulic Structures/Flow Patterns

Evaluation Approach

- Consultants
- Generic Flume Studies
- Comparison to prototype

Consultants

- One Day- M.S. Yalin- "Just because water flows downhill doesn't mean you have a model."
- Short Term- Gary Parker, Warren Mellema, Rob Ettema, and Charlie Elliot
- Long Term- Rob Ettema

Flume Studies

- U of Missouri- (Gaines, 2002)- movable bed
- U of Iowa- (Ettema and Muste, 2002) – fixed and movable bed

Comparison to Prototype

- Micro-model Proponents- Similitude criteria and generic flume studies are not convincing. The issue is how well the micro-model compares to the prototype.
- My position- Test their hypothesis- Compare model/prototype verification and **prediction**

One of the Bottom Line Issues

- Use of the MM beyond a demonstration tool requires that the following question be answered:

  After being calibrated to existing conditions, can the micro-model be used to predict changes to the system?

Another Bottom Line Issue

- Micro-model proponents want to compare the micro-model to previous coal bed models conducted at ERDC. Proponents are determined to conclude "MM has same capabilities as ERDC coal bed models."
- Proponents often look for weakest coal bed model as their standard. Comparisons of ERDC and MM are based only on the verification.
- My position- The only valid standard is comparison of the micro-model to the prototype.

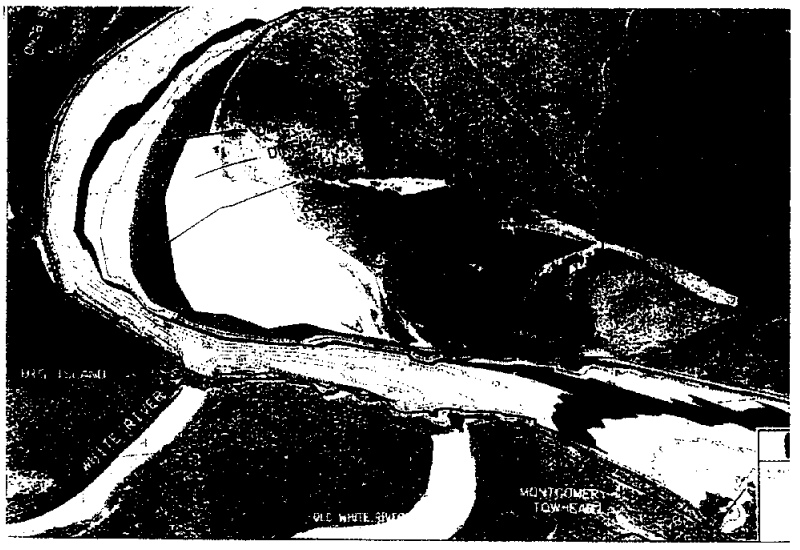
Comparison to Prototype cont'

- Three Comparisons of micro-model and prototype:
  - Mouth of White River
  - Vicksburg Front
  - Kate Aubrey

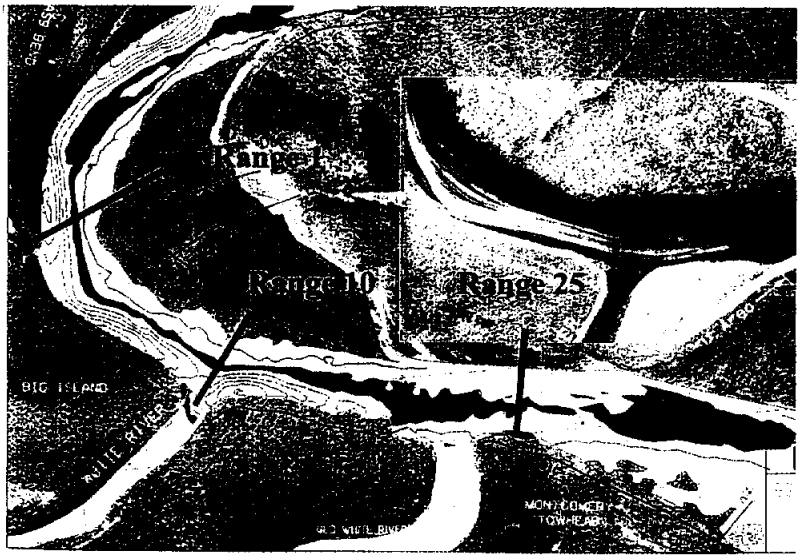
Mouth of White River

- "The primary goal was to evaluate the impacts of these measures on the resultant bed configuration (sediment transport response) and hydrodynamic response (flow patterns) within the study reach."

1997 Prototype



Micro-model Verification



Hydraulic Depth, ft

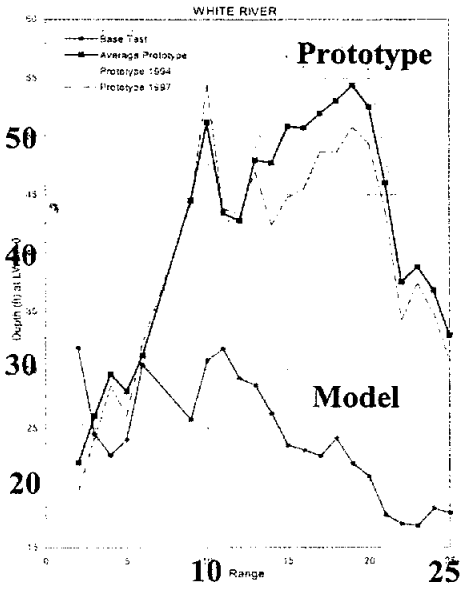
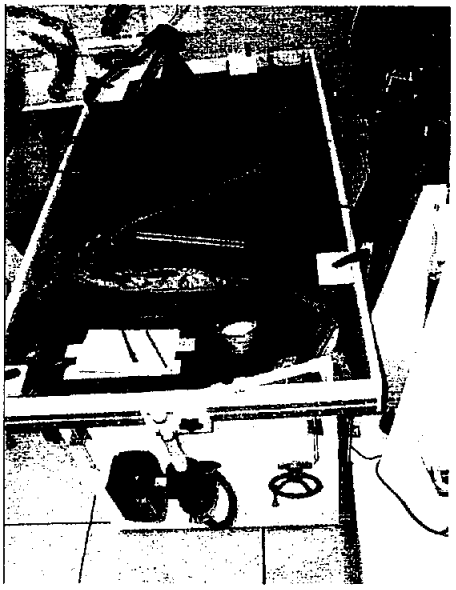


Figure B-10.2d Hydraulic Depth by Range, White River Confluence with Mississippi River

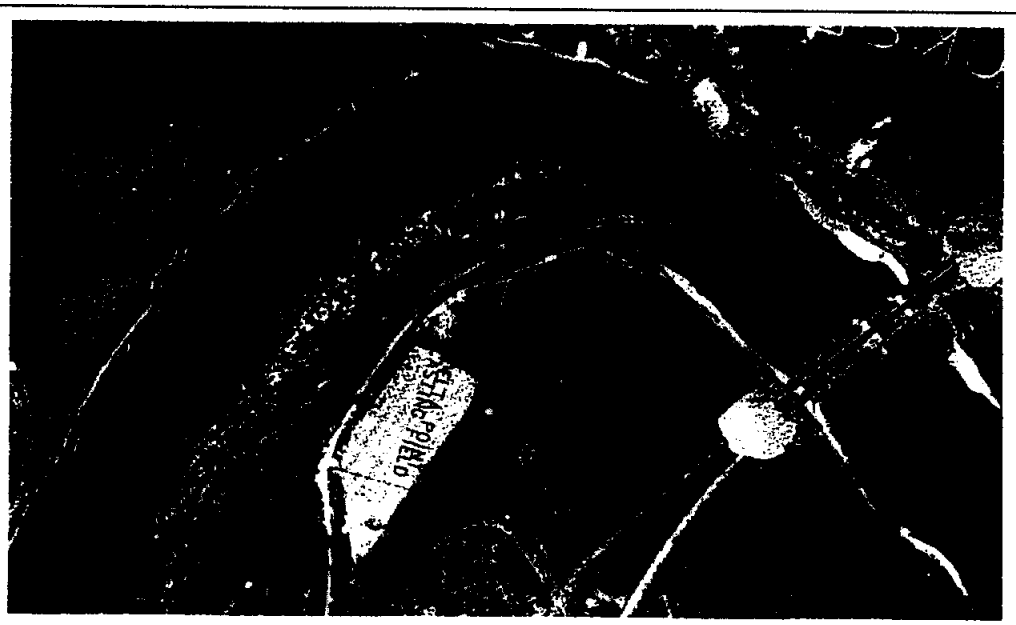
Vicksburg Front Model- Comparison of surface velocity

- Previous ADCP and ice flow comparisons with confetti have not been convincing regarding correct flow patterns in micro-model.

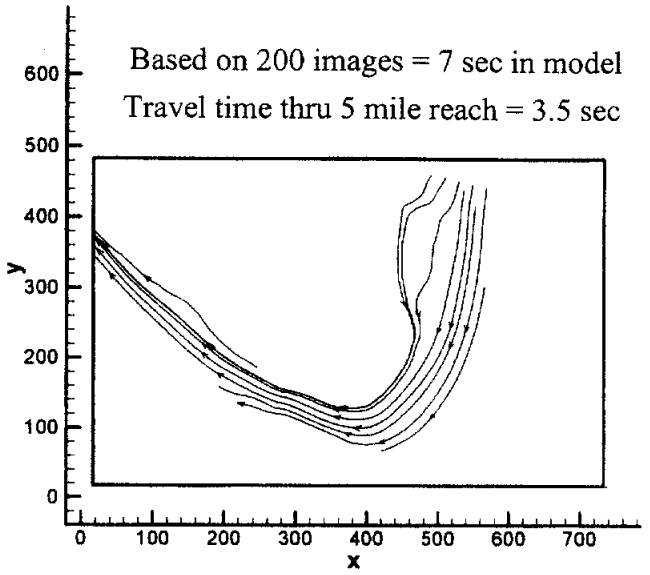


Vicksburg Front, 1:14400 horizontal, 1: 1200 vertical, distortion=12

Calibration – ". . . after a long series of successive hydrographs, there was a tendency for the side channel at Delta Landing to start to fill in with sediment . . ." (Davinroy, Gordon, Rhoads, and Abbott – 2000)

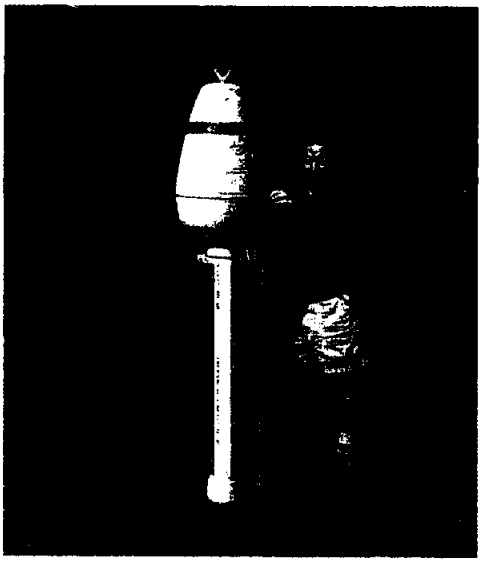


Pathlines from confetti streaks at high flow, 0.5-1.0 sec



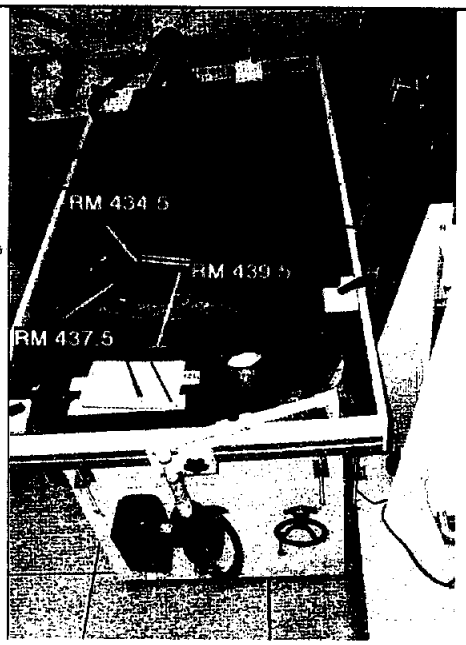
Pathlines from Vicksburg micro-model PIV

Float used in GPS, prototype

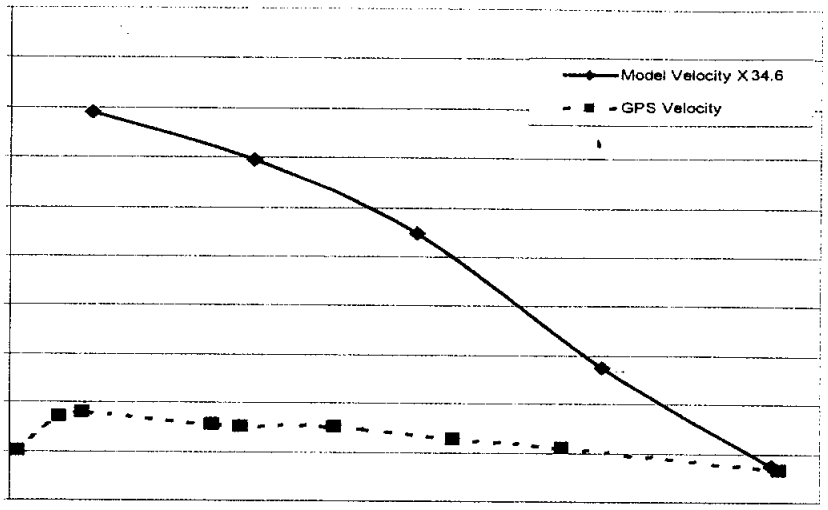


Comparison of Surface Velocity at Cross Sections from GPS and PIV

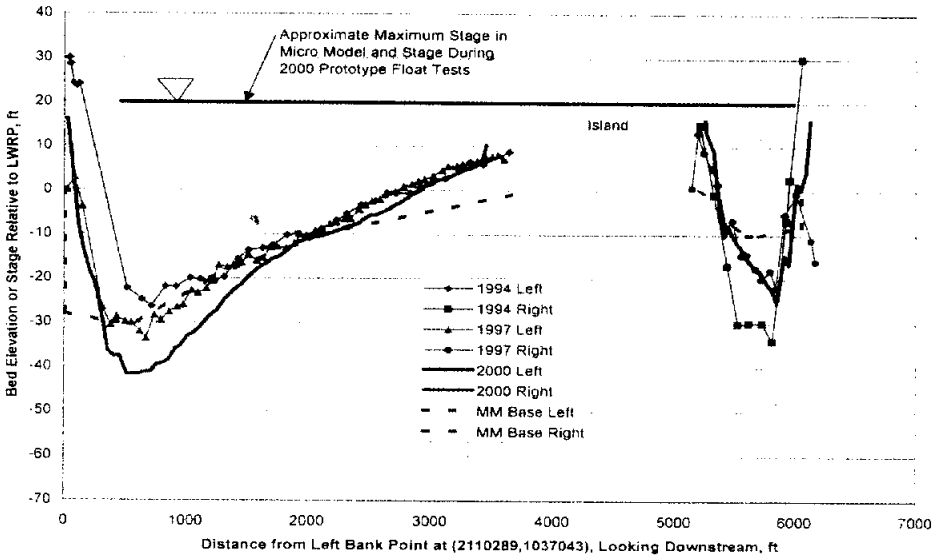
- GPS – Global Positioning Float in Prototype
- Average Stage = 19.3 ft LWRP vs 19.5 ft in MM PIV
- Discharge = 530,000 cfs
- Data collected over 4 days in May, 2000
- Travel time thru 5 mile reach = 5000 sec



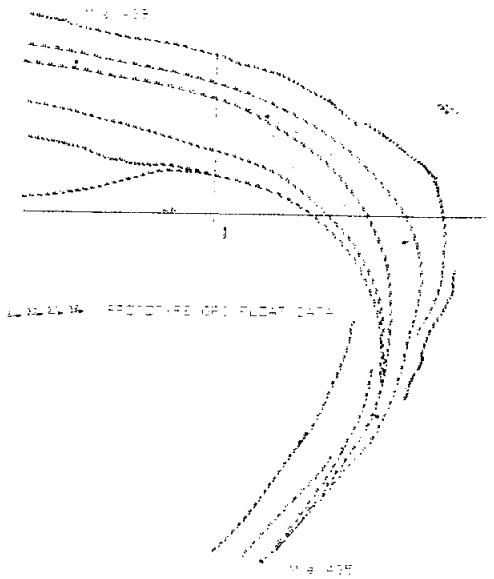
Location of Cross Sections



GPS Velocity (Field) versus PIV Velocity (Model), River Miles 439.5



Cross Section at River Mile 439.5



Comparisons of PIV in Micro-Model and GPS in Prototype

Vicksburg Summary

- Confetti, PIV, and GPS Floats are different techniques but allow comparison of trends.
- What does the complete picture say?
  - **Cross section velocity from PIV vs GPS show model flow concentrated on left bank**
  - **Incorrect deposition of right bank side channel in MM**
- Both show incorrect velocity distribution in MM. Affects ability of model to reproduce prototype bathymetry.

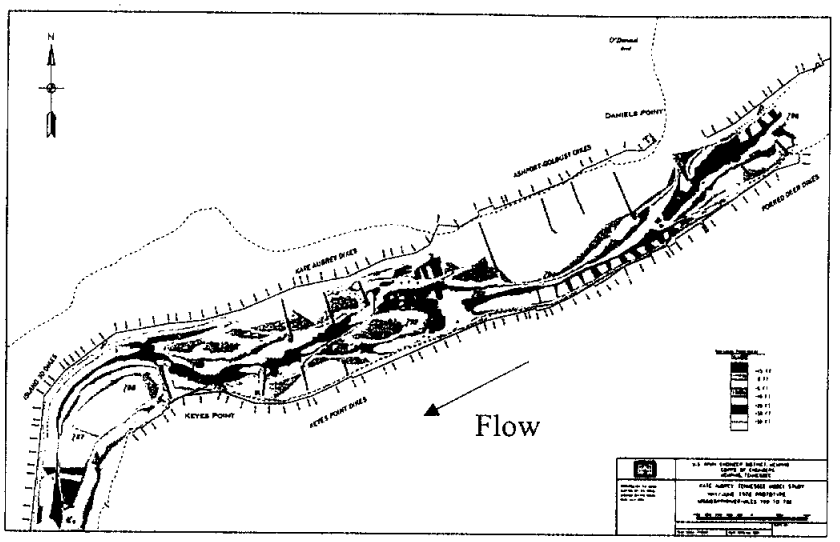
MVS Rebuttal

- Confetti and GPS different- both are pathlines but have different lengths
- Not enough GPS floats
- GPS floats released at different times cross paths- nature of unsteady flow in rivers, hopefully present in MM
- GPS float velocity magnitude too low- average channel velocity from Vicksburg gage = 0.86 * average float velocity
- Use ADCP Velocities- Q(ADCP) = 0.44*Q(floats or PIV or confetti), not comparable
- ADCP transect Velocities not generally accepted for model comparisons

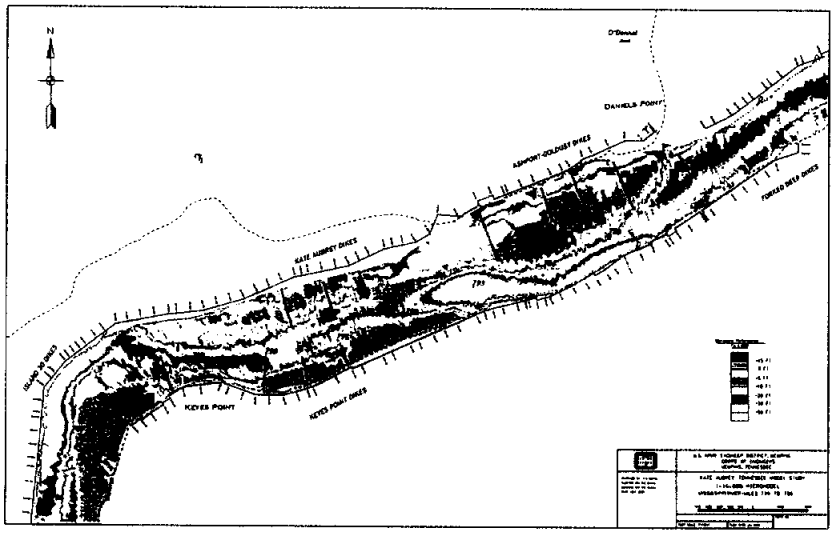
Kate Aubrey

- Primary Component of Evaluation
- Two models built, 1:16000 (traditional) and 1:8000 (2X)
- Verifications compared to 1975 and 1976.
- Plan tests compared to 1998.
- **Only predictive comparison with detailed bathymetry**

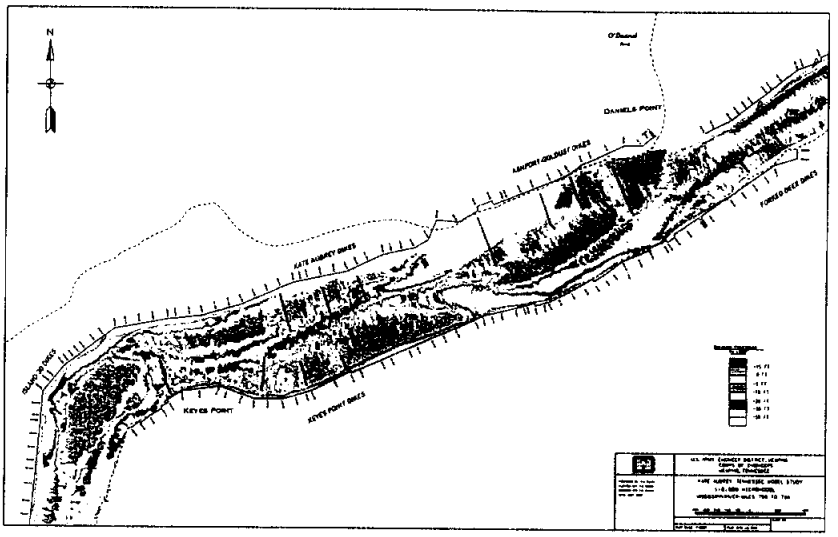
1976 Prototype Bathymetry



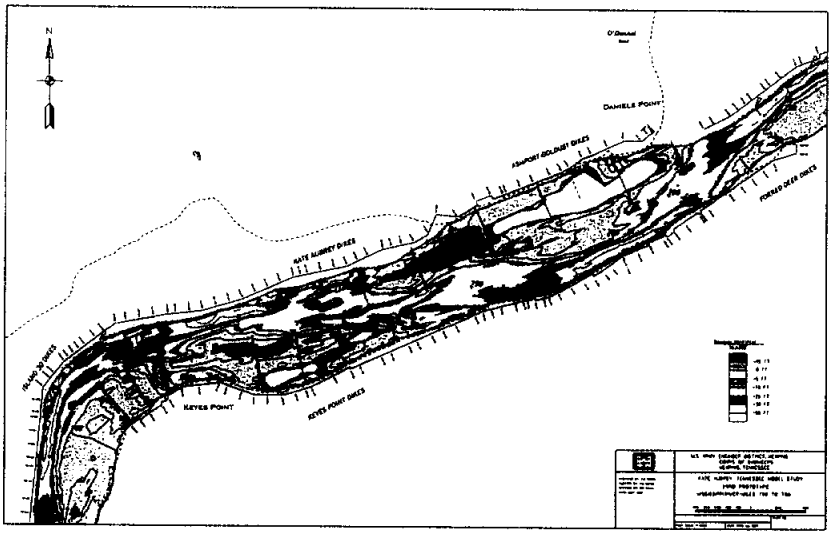
Verification Bathymetry, 1:16000 micro-model (traditional)



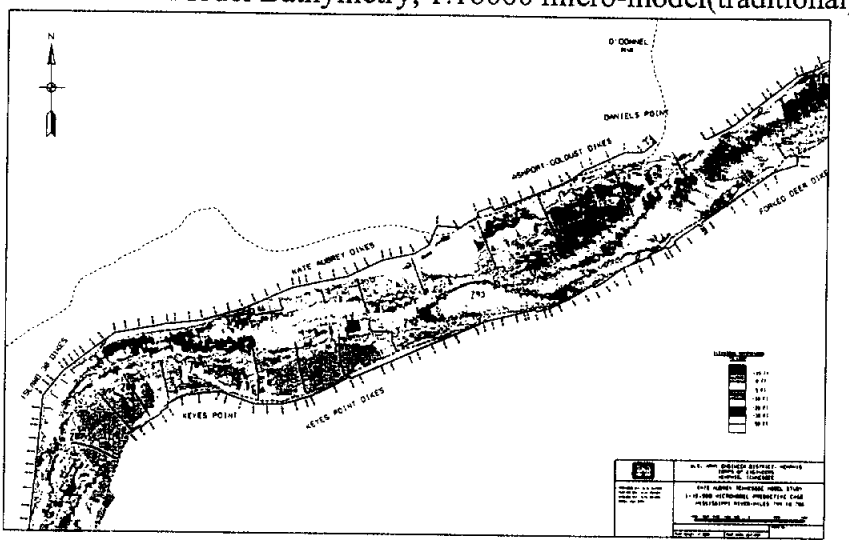
Verification Bathymetry, 1:8000 micro-model(2X)



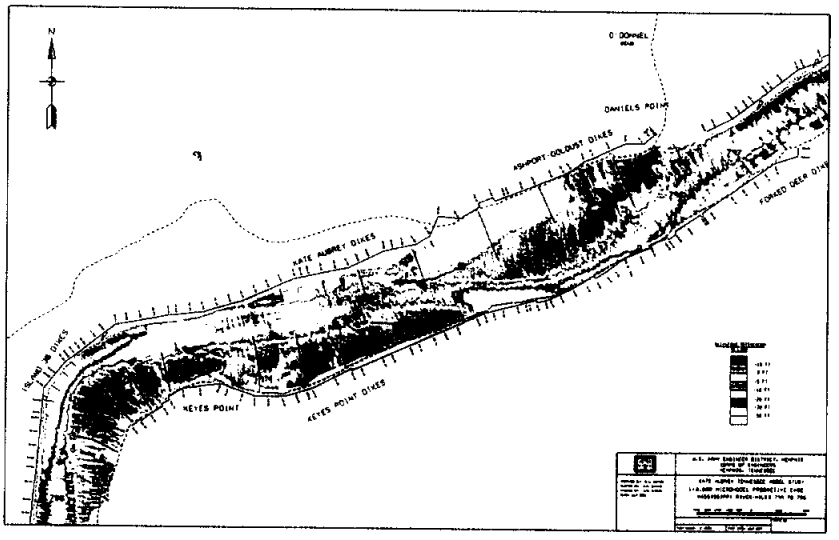
1998 Prototype Bathymetry



Predictive Model Bathymetry, 1:16000 micro-model(traditional)



Predictive Model Bathymetry, 1:8000 micro-model(2X)



Kate-Aubrey Summary

Verification similar to prototype in 1:8000 and 1:16000 MM

Plan is not similar to prototype in 1:8000 and 1:16000 MM

Conclusion: Achieving an adequate verification does not mean the MM is ready for prediction.

M.S. Yalin (1999)- "I regret such a 'model' can not be recommended for predictive purposes."

Overall Summary of Model/ prototype comparisons

- Some Micro-models have been verified to acceptable level.
- Based on the only comparisons of predicted bathymetry in a verified micro-model and the prototype, verification does not mean the model can predict.

Overall Conclusions based on 4 categories

- Micro-model is an excellent tool for demonstration, education, communication.

Overall Conclusions cont'

2) Micro-model should not be used for category 3, "River Engineering, Quantitative" or category 4, "Navigability, Hydraulic Structures, Flow Patterns" due to:
   - Lack of agreement of Kate Aubrey MM predictions
   - Lack of agreement of flow patterns in Vicksburg MM
   - Inability to achieve adequate verification in some previous MM
   - No correspondence of stage and discharge in model/proto
   - Large vertical scale distortion and Froude number exaggeration
   - Consultants/experts recommendations

Overall Conclusions cont'

3) Category 2, "River Engineering, Qualitative" is use of the micro-model as a screening tool. A screening tool is used to separate likely solutions from unlikely solutions.

- Pro: Good verifications in some previous MM
- Con: Kate Aubrey predictive tests not adequate, Poor verifications in some previous MM, no similarity criteria
- My recommendation- use MM in Category 2 if successful in a Vernon-Harcourt calibration.
- 3-step calibration- calibrate, test prediction, predict

Overall Conclusions cont'

- River Engineers have a major need in this area.

  - USACE needs to pursue both numerical and physical approaches in this area.

  - Numerical efforts underway

  - Physical- We went from 10 ft wide empirical models to 2" wide micro- models. Need to look at 1-3 ft wide models that eliminate extreme distortions yet achieve reasonable study time.

Acknowledgements