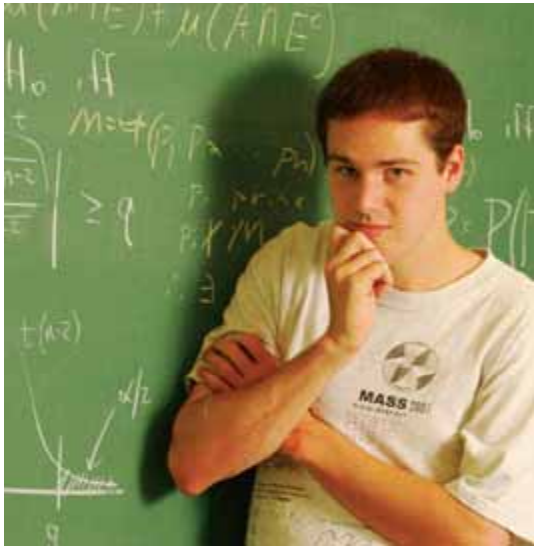
The College of WILLIAM & MARY

Hampton Roads Research Partnership
Energy Workshop
12 August 2009
A College of William & Mary Overview



The College of WILLIAM & MARY

HRRP Energy Workshop

- **Activities in several areas**
  - **Basic and Applied Research**
  - **Comparative Research**
  - **Energy Policy**
  - **Energy Regulatory Issues**

Research

- Super Capacitors
  - Electric vehicles
  - Energy harvesting
- Photo Voltaic Panels
  - Comparative (late term) research

The College of WILLIAM & MARY

HRRP Energy Workshop

Algal Biomass Fuel Study - VIMS

- Types of Algae
- Algal Assessment

Ocean Dead Zones

- Algal farms

Bio Diesel

- Operating facility at Keck Laboratory
- Create bio diesel from cooking oil
- Organized by Sharpe Community Scholars student team
- CWM graduate created palm oil facility in Philippines

The College of WILLIAM & MARY

HRRP Energy Workshop

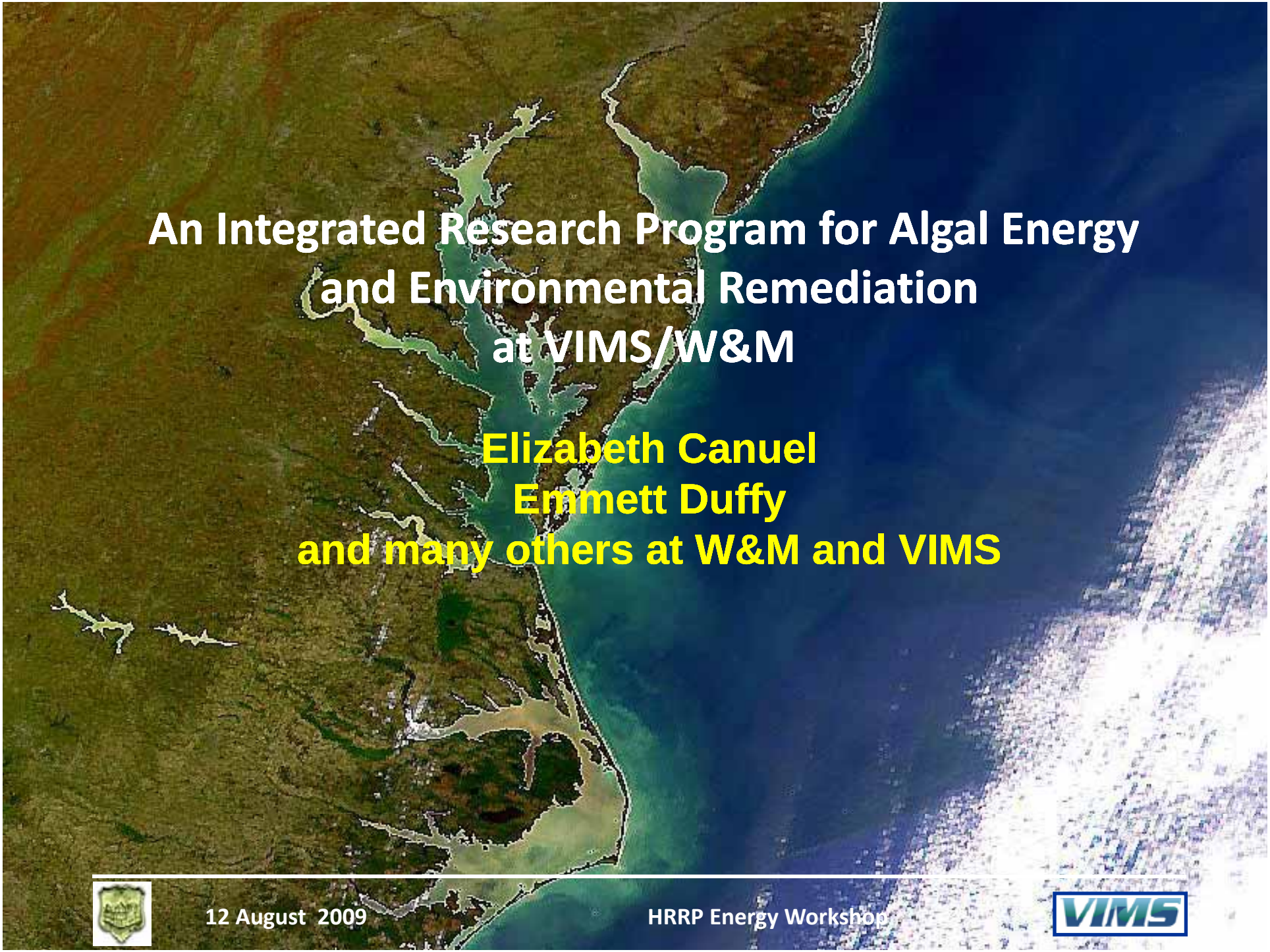
- **Programs --** Applied Science and related fields of Physics, Chemistry, Computational Science, Biology, Computer Science, Mathematics

  www.wm.edu/research/index.php

- **Specialized Resources**
  - 17.6 tesla NMR magnet
  - SciClone computational science cluster
  - Visualization laboratory for computational modeling
  - Hitachi field emission scanning electron microscope (FESEM)
  - Zeiss confocal microscope
  - Femto-second lasers and other optical resources
  - SQUID ultra-low magnetic measurement laboratory
  - X-ray diffractometer
  - Deposition Suites (evaporative and sputter coaters; PECVD and CVD)
  - 3-wavelength Raman spectrometer
  - Multi-analysis chamber (Auger, XPS, TDS, and Fowler-Nordheim)

Policy and Other Publications

- Wind Farms
- Continental Shelf Impacts
- Off-Shore Issues
- Economics of Space Reflector Power Sources



An Integrated Research Program for Algal Energy and Environmental Remediation at VIMS/W&M

Elizabeth Canuel
Emmett Duffy
and many others at W&M and VIMS

VIMS/W&M Algal Energy Plan: General Objective

We propose to turn pollution into fuel

Algae link two of society's most pressing problems:

"the source problem"—dwindling fossil fuel supplies

"the sink problem"—fouling of the global environment

VIMS/W&M Algal Energy Plan: Context

Renewables are the future of the fuel industry

Fossil fuels are running out while demand accelerates

Source problem: fuels must be renewable

Sink problem: fuels must avoid degrading the environment

Wild algae uniquely solve both source and sink problems

Fastest-growing, high-quality biofuel feedstock

Capture *and* store solar energy (solves the "battery problem")

Sequester—rather than releasing—nutrients and carbon

Linking fuel production to clean-up may be key to profitability

Carbon & nutrient credits can enhance value of algal biofuel

Why algae? High oil Content

Comparison of some sources of biodiesel

Crop	Oil yield (L/ha)	Land area needed (M ha)[a]	Percent of existing US cropping area[a]
Corn	172	1540	846
Soybean	446	594	326
Canola	1190	223	122
Jatropha	1892	140	77
Coconut	2689	99	54
Oil palm	5950	45	24
Microalgae[b]	136,900	2	1.1
Microalgae[c]	58,700	4.5	2.5

[a] For meeting 50% of all transport fuel needs of the United States.

[b] 70% oil (by wt) in biomass.

[c] 30% oil (by wt) in biomass.

Low oil yield

High oil yield

Chisti (2007) Biotechnol. Adv. 25: 294–306

Why algae? Low land requirement

Comparison of some sources of biodiesel

Crop	Oil yield (L/ha)	Land area needed (M ha)[a]	Percent of existing US cropping area[a]
Corn	172	1540	846
Soybean	446	594	326
Canola	1190	223	122
Jatropha	1892	140	77
Coconut	2689	99	54
Oil palm	5950	45	24
Microalgae[b]	136,900	2	1.1
Microalgae[c]	58,700	4.5	2.5

Large area

Small area

[a] For meeting 50% of all transport fuel needs of the United States.

[b] 70% oil (by wt) in biomass.

[c] 30% oil (by wt) in biomass.

Chisti (2007) Biotechnol. Adv. 25: 294–306

Why algae? Additional environmental benefits

- **Thrive in brackish and saline waters:** *do not compete with fresh water demands*
- **Can consume nutrients from sewage and wastewaters (nitrogen, phosphorus)**
- **Take up CO_2 from power plants or other sources**
- **May be able to consume metals and organic contaminants**

Challenges: Biofuels from algae

- **High (current) algal oil production costs**

  ~$200 / barrel at productivity 20 g m^{-2} d^{-1} and 24% algal lipid yield.

- **Developing algal strains with a high lipid content and fast growth rate** (monocultures or genetically-modified organisms)

- **Cost-prohibitive cultivation & harvesting systems** (e.g., photobioreactors)

- **Scale-up to fuel conversion**

Approach: the Algal Turf Scrubber (ATS®) system

***Simple*:** low-tech, low-labor operations for growth and harvesting
no bioreactors, little or no filtration

***Inexpensive*:** simple, widely available materials

Adaptable: natural algal *communities* adapted to local conditions
Nature selects algae best adapted to application
useable in a range of situations

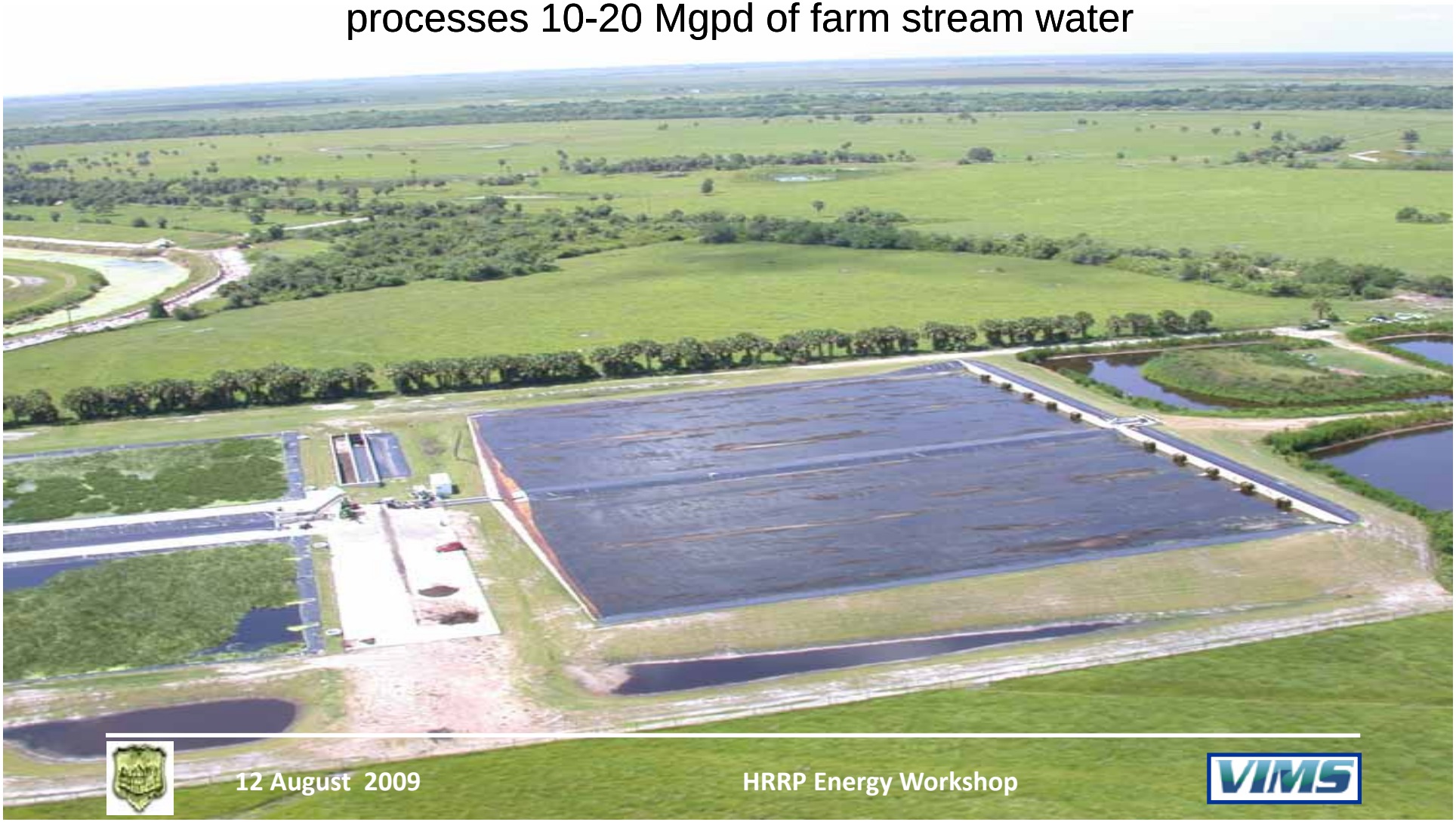
***Resilient*:** diversity provides stability, as in a stock portfolio
diverse algae resist challenges (disease, changing conditions)

Safe: no invasive species threats, no GMO escape risk
no threat to surrounding ecosystems

The Algal Turf Scrubber approach

2.5 acre ATS test system

processes 10-20 Mgpd of farm stream water



Pilot Algal Floway at VIMS

Land-based algal floway

reference data for saline env't

4 ft x 80 ft

Weekly harvest and sampling

dissolved nutrients

algal species composition

algal biochemical composition

Education opportunities

student projects over summer

Developing collaborations

contaminants (Unger, VIMS)

2nd generation biofuel production

Pilot Algal Floway at VIMS: Research Goals

Characterize basic production parameters

- algal growth, productivity
- seasonal variation
- variation with temperature, light, etc.
- saline conditions

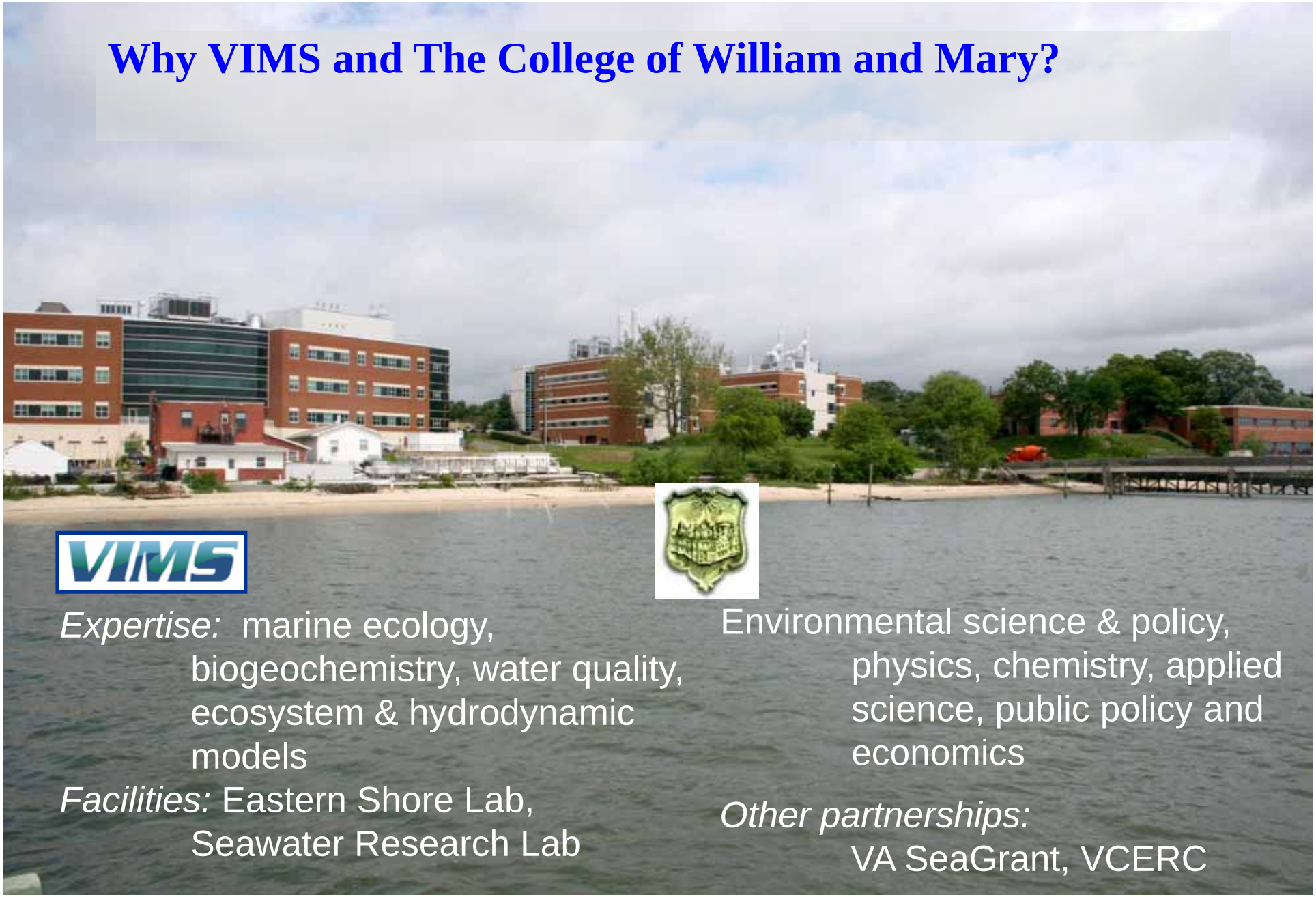
Environmental remediation potential

- resource (N and P) use
- contaminant sequestration

Understand factors influencing variability

- algal community
- gross biochemical composition
- lipid content and composition

Why VIMS and The College of William and Mary?



Expertise: marine ecology, biogeochemistry, water quality, ecosystem & hydrodynamic models

Facilities: Eastern Shore Lab, Seawater Research Lab

Environmental science & policy, physics, chemistry, applied science, public policy and economics

Other partnerships: VA SeaGrant, VCERC


QUESTIONS?

Contacts:

Bill Bean
Director – Technology Business Center
webean@wm.edu
757-221-7825

Elizabeth Canuel
Professor, VIMS Physical Sciences
ecanuel@vims.edu
804-684-7134