VIMS | WILLIAM & MARY
VIRGINIA INSTITUTE OF MARINE SCIENCE

2017 Six-Year Plan – Part II
July 2018 Updates (in red)

A. Institutional Mission

The **Mission** of the Virginia Institute of Marine Science is to seek and broadly communicate knowledge in marine and coastal science to the Commonwealth of Virginia and the nation through research, education, and advisory service.

As a nationally and internationally recognized premier marine science institute, our overarching goals in the VIMS **Vision** are to (1) make seminal advances in understanding marine and coastal systems through research and discovery, (2) translate research findings into practical solutions to complex issues of societal importance, and (3) provide new generations of researchers, educators, problem solvers, and managers with a marine-science education of unsurpassed quality.

B. Strategies

Increase Graduate Financial Aid. As one of the top producers of marine science graduate-level degrees in the nation, the William & Mary School of Marine Science at VIMS has awarded over 1,000 degrees since VIMS was founded over 75 years ago. Our graduate students provide essential capacity in support of VIMS research programs and advisory services mandated in the *Code of Virginia*. Our alumni successfully compete for jobs in academia, federal and state agencies, K-12 education, non-profits, and marine-related businesses within the private sector. Many have gone on to become leaders in areas such as aquaculture, fisheries management, storm surge modeling, water quality research, and environmental management and restoration approaches for coastal and estuarine environments. Despite the quality and success of the program, we are increasingly concerned that the high cost to our faculty of supporting research-focused graduate students is putting VIMS at a competitive disadvantage and limiting program enrollment below capacity. Increased state graduate financial aid of $425,000 is vital to program stability and for increasing the competitiveness of VIMS' faculty in winning external grants and contracts by providing matching funds (also known as cost share). We have prioritized this request in order to reflect the very high value of the graduate program to VIMS, the Commonwealth, and the nation.

VIMS faces a challenge unknown at most of our peer institutions in Virginia and across the nation. Without an undergraduate marine science major, William & Mary is unable to provide the needed graduate student support that typically comes from teaching assistantships. This significantly disadvantages our institution relative to most of our peers that have greater need, and thus more opportunities, to engage graduate students in assisting with undergraduate courses. We also do not have the significant endowments of our peer private institutions. Therefore, the bulk of the financial aid provided to SMS students must be derived from competitive external grants and contracts to faculty. VIMS faculty currently provide more than $2 of non-general funding from external grants and contracts for every $1 of general funds used to provide tuition and assistantship support to graduate students. While the faculty will continue to aggressively pursue competitive federal, state, and private grants and contracts to assist in meeting student financial needs, traditional fund sources are virtually saturated, and in many instances, are being reduced. The funding requested is sufficient to cover one year of tuition for an incoming class of 25 students. During this first year, students

carry a heavy course load and are unable to contribute to grant-funded research in a meaningful way, and as such, faculty cannot justify expending grant funds on student financial aid. Without Virginia's financial commitment, VIMS will also be far less competitive for recruiting and retaining top-tier faculty who are attracted to VIMS, in part, because of the opportunity to work with talented graduate students.

Increase Base Operating Support. This strategy has now been met. The General Assembly in their 2018 session provided VIMS with $625,000 in each year of the biennium for operations and maintenance of new facilities coming online.

Increase Base Operating Support. This request supports much needed core base operating funds at the Institute given that the normal formulas the state uses to assess and supply base operating support to higher education institutions do not readily apply to VIMS and, thus, disadvantages the Institute. Specifically this request includes vital support for 1) service contracts for high tech scientific equipment purchased through the Equipment Trust Fund, 2) inflationary increases in general operating expenses, and 3) support for personnel services in support units.

Utilize Advanced Modeling and Assessment Technologies for Chesapeake Bay Water Quality Improvement. This strategy has now been met. The General Assembly in their 2018 session provided VIMS with $893,753, starting in FY 2020, for water quality improvement work. The funding includes $406,075 for on-going support, $84,678 for debt service costs under the Master Equipment Leasing Program (MELP) associated with the modeling and assessment technologies, and $403,000 for development of the State of the Elizabeth River Scorecard for pollution levels in the Elizabeth River.

Utilize Advanced Modeling and Assessment Technologies for Chesapeake Bay Water Quality Improvement. The need to assess and verify the effectiveness of public fund expenditures to restore water quality in Chesapeake Bay is critically important. Historically, the Commonwealth was largely dependent upon the EPA Chesapeake Bay Program model and monitoring data to assess progress towards meeting Bay water quality goals. In recent years VIMS, in collaboration with DEQ, has employed more advanced water quality modeling and assessment technologies in Virginia's tributaries to support efforts by the state and local governments to meet water quality goals. The EPA has now recognized the value of the higher spatial and temporal resolution provided by these technologies and has indicated their willingness to allow states to adopt a more focused approach towards meeting and assessing water quality goals, potentially resulting in significant savings to local governments and the state. VIMS is uniquely positioned with its expertise, state-of-the-art modeling capabilities, advanced assessment technologies and mandated role as the scientific advisor to the Commonwealth on marine and coastal natural resource issues to provide this critical need. The proposed program would build on these strengths to further develop and utilize models that more accurately represent conditions in Virginia waters and to couple these models with real-time water quality data to provide a comprehensive, high-resolution view of water quality that far exceeds the spatial extent, temporal coverage, and accuracy of the current monitoring program. Such information would furnish decision makers with the information necessary to make more informed decisions related to Bay restoration and TMDL (Total Maximum Daily Load) implementation.

Advanced water quality assessment can be most effectively achieved with a Commonwealth Chesapeake Bay Observing System comprised of a network of buoys that can remotely obtain water quality data and transmit it to a central location for analysis. This system would expand and integrate VIMS' current technologies to produce a unified, state-of-the-art system. The system would integrate water quality and weather to allow for near real-time responses in support of environmental management with public health and economic consequences, such as harmful algal blooms and fishery impacts, as well as statewide tidal water quality assessments. As an example, Virginia's rapidly growing oyster aquaculture industry would benefit greatly from an advanced water quality assessment and early warnings of harmful algal blooms.

***Monitor* Bay Grasses.** Submerged bay grasses are a critical living resource in Chesapeake Bay that supports valuable fish and crab resources. Because bay grasses are dependent on good water quality they are being used as key indicators of water quality improvement in Chesapeake Bay by the Virginia Department of Environmental Quality. VIMS has conducted a bay-wide annual survey of bay grasses since 1987, with considerable support from EPA, NOAA and the state of Maryland. That support has declined in recent years as costs have risen. We are seeking to establish a stable funding base for maintaining the Virginia portion of this valuable survey.

The results of the annual survey are important to the Commonwealth for a number of reasons. (1) Bay grass acreage is embodied in Virginia's water quality standards; (2) the Virginia Secretary of Natural Resources must report annually to various Virginia House and Senate Committees on the status of bay grass abundance from the annual surveys (*Code of Virginia §2.2-220*); (3) bay grass acreage is an important component the blue crab fisheries management plan (*Code of Virginia §28.2-203.1*); (4) bay grass survey maps are used by the Virginia Marine Resources Commission in evaluating aquaculture lease applications; and (5) bay grass acreage is used as a metric for attainment of the restoration goals established by the Chesapeake Bay Program and its partners, including the Commonwealth of Virginia.

VIMS is uniquely qualified to provide this service, not only because of its experience in conducting the surveys, but because it has pioneered restoration techniques for bay grasses that are now used worldwide and is widely recognized for its scientific leadership in bay grass restoration.

Enhance Chesapeake Bay Environmental Technology. Natural economic benefits derived from the Chesapeake Bay are estimated to be valued at more than $100 billion annually, with the Bay supporting many economically important fisheries, including blue crabs, striped bass, and oysters. The Bay waters also enhance coastal property values and support a vital tourist economy, including nature-based recreation industries. However, urbanization and increased fertilizer usage have led to excessive nutrient inputs entering the Bay, negatively affecting the health of the Bay ecosystem and the economic services it provides. **For those economically invested in the Chesapeake Bay, there is an urgent need to implement the latest technology-based solutions to address major current and future environmental challenges**, including: (1) hypoxia ["dead zones"], (2) water clarity, (3) acidification, and (4) Harmful Algae Blooms [HABs] and pathogens. These challenges

facing the Bay are becoming increasingly critical each year, as temperatures rise, storms become more intense, and atmospheric carbon dioxide levels rise.

Fortunately, new technologies are making it feasible to use real-time data to produce short-term spatially extensive forecasts of hypoxia, water clarity, acidification metrics, and harmful algal blooms, resulting in improved decision support products for commercial and recreational anglers, watermen, beach managers, public health agencies, oyster hatcheries, and other shellfish growers. Addressing these Bay-wide challenges through forecasted information requires effective collaboration among business, education and government, and is only possible because of new technological advances in real-time data collection systems. Here we propose to leverage existing VIMS expertise in a novel *Chesapeake Bay Environmental Technology Initiative*, which will include: implementing state-of-the-art models that can ingest real-time Bay data, sensors that can collect and transmit data in real-time to improve forecast accuracy, and a new, targeted mobile platform that will improve stakeholder accessibility of this information. By promoting collaborative technological innovation among researchers, educators, entrepreneurs and government, this proposed initiative addresses multiple policy priorities of ***GO Virginia***, including *Innovation, Invention, Improvement and Infrastructure*. In addition, information garnered from this initiative will address Governor McAuliffe's policy priorities by allowing VIMS researchers to better understand how to "protect and improve the health of the Chesapeake Bay", and better "prepare the Commonwealth for the effects of climate change".

Boost Marine Aquaculture and Fisheries Health. Virginia is one of the nation's leaders in the aquaculture production of bivalves, particularly oysters and clams. Improvements in disease resistance, genetics, and management have led to major advances in shellfish production in the state. Yet, outbreaks of disease continue to damage economically important and ecologically sensitive marine resources in the Commonwealth and nation. Examples of these diseases include dermo and MSX in oysters, *Hematodinium* in blue crabs, mycobacteriosis in striped bass, morbillivirus in dolphins, and wasting disease in sea stars, to name just a few.

The pathogens responsible for these outbreaks often are not well known, their risks to marine life and risk of spread remain understudied, and their full ecological impacts have been difficult to assess. *To meet the challenge of conserving and improving aquaculture and fisheries industries, we propose an initiative to provide science-based guidance on the development of improved techniques in aquaculture and disease management.*

VIMS scientists have considerable expertise working with diseases of marine animals. We aim to leverage this expertise by augmenting training in aquaculture, identifying and liaising with key industry groups, serving as a clearinghouse for information to policy makers, establishing state and regional response protocols against diseases, and developing tools to enhance aquaculture production by mitigating the effects of disease outbreaks in our marine resources. Our goal is to build on existing and emerging aquaculture programs to augment fishery and aquaculture resources in the Commonwealth and Chesapeake Bay region.

Specifically, VIMS will:

- Enhance public outreach in aquaculture, environmental health, and marine animal health;

- Provide additional pathology services for industry and regulators;
- Establish surveillance protocols to facilitate identification, assessment, and prediction of emerging pathogens;
- Develop modeling tools to quantify epidemiological and ecological impacts of disease;
- Implement Response Planning Workshops to mitigate diseases in natural and cultured marine resources;
- Enhance technology transfer and training with the aquaculture industry; and
- Establish regular reporting to the VMRC and other agencies on status of new developments.

These objectives will build on VIMS' strengths in aquaculture and environmental sciences to provide cutting-edge science in support of efforts by resource managers, public health officials and industry to manage around marine diseases. Specific examples follow.

1. Shellfish aquaculture is a rapidly expanding economic sector that relies heavily on certification that seed shipped regionally and nationally is pathogen-free. We work closely with industry in this certification process, but the optimization and validation of newer molecular protocols is needed for rapid assessments, surveillance, and quality assurance. New advances in technology such as genetic manipulation, sample processing and automation, and sensor development will greatly facilitate this work.

2. Blue crab stocks fluctuate markedly due to fishing, predation, poor settlement, and disease; yet the latter (disease) remains understudied, even though several pathogens damage juvenile crabs in seasonal outbreaks.

3. Striped bass are susceptible to mycobacterial infections that show strong associations with increasing water temperature. The impact on fish populations has been difficult to quantify, but new modeling estimates indicate a significant increase in mortality due to this pathogen. The increased mortality from disease must now be factored into stock assessments and management plans for crabs and striped bass.

This strategy will provide guidance on the management and mitigation of existing and emerging disease threats to vital fishery and aquaculture resources in the Commonwealth and Chesapeake Bay region. The health of our marine resources is fundamental to the growth of local industries and to the revitalization of coastal communities that dependent upon them.

Establish a Molecular Core Facility. Rapidly advancing technology has led to a revolution in the realm of molecular biology and genomics, giving scientists much greater power to address complex problems in marine and estuarine systems. This revolution offers the opportunity for VIMS to improve its capabilities in fulfilling its advisory mission to the Commonwealth in the areas of fisheries and aquaculture, environmental health, and coastal ecology. Extremely large amounts of data can be generated in a relatively short period of time using this technology, offering unparalleled opportunities to create more sustainable environments, bolster regional economies, and protect human health.

Currently, VIMS researchers in within three different departments use molecular approaches to address important research questions related to resource management and public health issues in Virginia, including fisheries and aquaculture management, harmful algae blooms, and shellfish health and safety. Key pieces of heavily used shared equipment are scattered across campus and are rapidly becoming outdated. VIMS' ability to accommodate this research, which requires massively high-throughput sequencing, digital PCR, transcriptomics and single cell genomics, is limited by the absence of a centralized facility with support. *Now is the time for VIMS to establish a consolidated Marine and Aquaculture Molecular Core Facility.*

We are seeking to upgrade critical instruments and to add technical expertise in advanced bioinformatics analyses, and dedicated technical staff to operate and coordinate the use of specialized equipment, and to advise researchers on appropriate strategies and approaches to answer their research questions. Almost all top-tier marine research institutions, including Woods Hole Oceanographic Institute, Scripps Institution of Oceanography, Rosenstiel School at University of Miami, University of Rhode Island, University of Washington, and others, support these types of core facilities with state of the art equipment and technical expertise. VIMS needs this facility to remain competitive in the 21st Century and to provide the Commonwealth with state-of-the-art, science-based advice.

This initiative requests funds to consolidate, and update where necessary, existing equipment, thereby expanding VIMS' capacity for high-throughput sequencing, and staffing the facility with a technician and bioinformatician. Over the past five years, VIMS has leveraged its existing molecular genetics capabilities for over $5 million dollars in extramural research funds. Enhancing our capabilities further would expand our capacity to leverage even more extramural money in support of our research, education and advisory missions.

Develop an Oyster Biosecurity Plan. The majority of cultivated oysters in the mid-Atlantic and increasing numbers elsewhere are triploid; that is, they contain an extra set of chromosomes rendering them sterile. In Virginia, triploid oysters account for approximately 90% of the oyster aquaculture production. These triploids are made by crossing tetraploid oysters, those that contain four sets of chromosomes, with diploid oysters, those that contain the normal two sets of chromosomes. VIMS is the major producer of tetraploid oysters, with other commercial companies currently developing the capacity for growing tetraploids also. While triploid oysters are reproductively sterile, tetraploids are fertile. Citing concerns about their reproductive capability, the state of South Carolina has recently taken steps to limit the deployment of tetraploid oysters in state waters. As the number of tetraploid oysters being held in Chesapeake Bay waters has increased, there is a critical need to evaluate the risks that these oysters may or may not pose to wild oyster stocks. The specific risk of concern is that, were a feral population of tetraploid oysters to become established in Virginia waters, tetraploid oysters might then be able to mate with native, wild diploid oysters resulting in some portion of the wild population being sterile triploids. VIMS' objective is to **develop a biosecurity plan based on the scientific assessment of risks of holding tetraploid oysters in the Bay**. We intend to assess the environmental concerns regarding the use and grow out of tetraploid oysters, for example, issues of health, reproduction, and population genetics, in order to inform a biosecurity plan. The ultimate goal is to assure that the use of these oysters in aquaculture is done in an environmentally responsible fashion and ultimately, make

recommendations to the VMRC Commissioner for establishing guidelines for the use of tetraploid oysters in Virginia waters.

Accelerate Economic & Community Impacts from Coast & Marine Science and Technology.
This proposed program leverages Virginia Sea Grant's (VASG) coastal community development funding ($50,000 annually) and graduate research and workforce development fellowship program ($40,000/year/fellow), VIMS' legacy services in economic impact analysis, Fisheries Resource Grant program and coastal and marine science and technologies, and partnerships with members of the VASG seven-university partnership (e.g., Virginia Tech Seafood Agriculture Research and Education Center and Office of Economic Development; William & Mary's Public Policy Program and Mason School of Business) to:

- Facilitate greater university-community and public-private partnerships that fast-track scientific discoveries and streamline the process of turning those discoveries into innovations that accelerate economic and community development in Virginia; and
- Meet pressing economic development analysis needs in coastal communities that inform local economic and community development decisions and planning.

This initiative contains three elements: 1) sector-specific Research & Development (R&D) plans; 2) collaborative public-private partnership-led graduate research and workforce development fellowships; and 3) economic impact analysis to support local and state economic and community development planning.

First, the program would establish partnerships with coastal and marine industries (e.g., aquaculture farms, hatcheries, seafood processors, coastal engineering and construction firms, marina, boat-building, etc.) and facilitate sector-specific R&D strategic plans to identify priority R&D needs that are currently limiting economic growth. Based upon the R&D strategic plans, VASG, VIMS, and our academic partners will advance opportunities to seed-fund product and market development activities (e.g., NOAA Small Business Innovation Research, Virginia Research Investment Fund, Fisheries Resource Grant, Virginia's National Disaster Resilience Competition award). In collaboration with industry and academic partners, VASG would further leverage technical assistance from the Virginia Business Higher Education Council, GO Virginia, regional Economic Development Organizations, and other business incubators. For example, VASG has partnered on a grant with RISE, a non-profit organization establishing innovative resilience initiatives as part of the Virginia's HUD National Disaster Resilience Competition grant. RISE's mission is to test innovation and facilitate partnerships and collaboration in the resilience and coastal adaptation fields that lead to economic growth. RISE, in partnership with the global startup incubator 1776, will lead the Resilience Campus in Norfolk to enhance entrepreneurship skills and build highly scalable businesses. RISE has start-up seed funding available.

Second, new public-private partnerships will co-fund graduate research and workforce development fellowships working directly with the private sector and university advisors to advance coastal and marine science, innovations and new technologies. For example, VASG has partnered on grant proposals with five environmental engineering firms to co-fund graduate

research fellows in resilience design and currently co-sponsors a summer resilience design fellow with Clark Nexsen, developing innovative flood and water management strategies, designs and technologies with market potential throughout Virginia, the nation and world. VASG is working with RISE to explore commercialization potential of these innovations.

Third, VASG and VIMS will provide economic impact analysis to local communities to inform economic and community development decisions and planning with the best available scientific information. These local and state community plans and policies are essential to enable commercialization from innovations. For example, VASG and VIMS are working closely with several new local and state-wide economic development programs, including GO Virginia, the Rural Coastal Virginia Community Enhancement Authority, and the Middle Peninsula Alliance Board.

***Implement a post-graduate Commonwealth Coastal and Marine Fellowship program in collaboration with the Virginia Sea Grant (VASG) program that has been housed at VIMS since 2008*.** This proposed program would be modeled after the highly successful national Sea Grant Knauss Marine Policy Fellowship and similar state fellowship programs operated by state Sea Grant programs in Washington and California. The goal of the Commonwealth Coastal & Marine Policy Fellowship is to develop and support exceptional post-graduates by partnering them with an agency mentor where they receive on-the-job training, and hone their professional skills, while improving the stewardship of the Commonwealth's coastal and marine resources. The program increases the capacity of the host agencies by supporting fellows who are working on mission-relevant programs, and leveraging the knowledge and capacity of Virginia's academic institutions. The program enhances retention of Virginia's best coastal and marine science graduates in careers within the Commonwealth.

Continue to operate as a year-round facility. As an independent state agency that is heavily involved in research and graduate education, VIMS also provides advisory service to the Commonwealth in the form of expert scientific advice on marine-related issues throughout Chesapeake Bay and the coastal ocean. All three of our missions, the graduate program, research and advisory programs, are heavily operational for the entire 12-month calendar year, and in fact, all of our faculty hold 12-month appointments. Field research is most active between April and October, but most other activities occur equally throughout the year. For example, throughout calendar year 2016, VIMS offered a total of 362 outreach programs reaching nearly 25,000 citizens. More than 50% of those programs were held on VIMS' main campus. These were in the form of campus tours, after hours lecture series, discovery labs, summer camps for children in grades 1-8, workshops, training programs, and more. VIMS always has been, and will continue to be, a year-round operation.

Virginia Research Investment Fund. VIMS submitted two Letters of Intent to the VRIF for consideration. The project summaries are as follows:

Expanding tetraploid technology for improved yields of oyster aquaculture in Chesapeake Bay

Virginia leads the east coast in aquaculture production of clams and, more recently, oysters. These developments have come from transfer of contemporary technologies from public

institutions, such as, the Virginia Institute of Marine Science. In fact, VIMS has become a world leader in shellfish aquaculture technologies. One of those technologies has been a force in driving oyster aquaculture to the forefront: tetraploid technology. Tetraploid oysters are used by commercial hatcheries to produce sterile (spawnless) *triploid* oysters, which comprises >90% of farmed oysters in Virginia, and increasingly, east coast states. This technology is part of the IP portfolio of the Aquaculture Genetics and Breeding Technology Center at VIMS.
This proposed project will focus on expanding our mastery of tetraploid technology through several objectives:

- We will expand the development of tetraploid "lines" by developing new genetic material for release to industry.
- We will test this new material during this project through collaboration with several strategically located oyster farms, including one in Maryland where a new market for tetraploid technology is rapidly developing. Such expansion will benefit Virginia hatcheries.
- We will recruit and train a Tetraploid Technologist who will specialize in the practical breeding of tetraploid material for the benefit of commercial aquaculture. This position will be absorbed into operations at ABC after the grant period.
- Using the genetic materials at hand, we will continue our investigations into triploid mortality that have arisen in the last several years.

Commercialization of low-cost underwater sensor platform for animal-borne and 'crowd-sourced' environmental monitoring in the Chesapeake Bay and beyond

Understanding the changes that our aquatic and marine environments are undergoing requires data collection, but we do not have sensors deployed in the majority of places due to high costs and logistical challenges. At the same time, our waters are continually plied by a variety of species than can carry electronic sensor tags, as well as by fishermen and other ocean users who could deploy them. Off-the-shelf electronic sensor tags have become reliable but are very costly and measure only a few variables. Fishermen are typically equipped with only thermometers, if anything, for environmental data collection.

We propose to commercialize the low-cost animal-borne sensor platform we have developed for shark behavior studies, and extend it to measure variables of interest for environmental monitoring and fisheries (e.g. dissolved oxygen, nutrient concentration). Several oxygen sensors are now available with long term stability (i.e. no short term drifts, frequent calibration not required). Pairing these stable oxygen sensors with our platform would enable tagged animals to function as autonomous vehicles, sampling the water column through their movements. In the Chesapeake Bay, additional oxygen measurements would be extremely valuable. The Bay suffers from eutrophication, which causes hypoxia, so there are episodes in which certain parts of the Bay's waters become degraded as fish and shellfish habitats, causing harm both to diverse wildlife and to Virginia's important fishery industry.

In addition to attaching the device to animals, it can be attached to a fishing pole for collection of vertical profile data. By pairing the device with the user's smartphone, the collected temperature, oxygen or other profile data could be uploaded to a server along with GPS

coordinates, generating a large amount of new in situ measurement effort. This would become a 'crowd-sourced' oceanographic dataset with far greater spatial and temporal coverage than what could be accomplished by research cruises and other science platforms. Both NASA and NOAA presently have citizen science portals to accept crowd-sourced data. In conjunction with the hardware, we propose to provide the data analytics platform for interpretation of the sensor measurements by end users, immediately on their smartphones, as well as on the internet.

Our team has developed an inexpensive arduino-based accelerometer animal tag over the past two years and deployed it on captive sharks, so we have many of the building blocks in place. We have expertise in small low-power surface mount electronics development and microcontroller programming. We have substantial operational experience with animal tag application and recovery. We will provide a means to locate and recover the tag after timed release based on GPS and cellular uplinked location information.
This project will focus on commercialization and adaptation of our product to the target market. We anticipate that researchers, fishermen, boaters and other ocean users will be customers.

C. Financial Aid – Not Applicable

D. Evaluation of Previous Six-Year Plan Strategies

Graduate Financial Aid. VIMS faculty continue to aggressively pursue grant support from federal agencies and private donors, and recognize that meeting the need for graduate financial aid will require multiple sources of funds. For example, the VIMS administration made an internal reallocation of $175,000 to graduate student support beginning in Fall 2013 and William & Mary's Provost allocated up a total of eighteen tuition waivers annually beginning in Fall 2014 for enrollment of top doctoral program students. In addition, the state awarded just under $80,000 for Graduate Financial Aid beginning in FY17.

These efforts have reversed a trend of decreasing enrollment in our doctoral program from a low of 38 in Fall 2012 to 50 in Fall 2016. Additional state support is a critical element if we are to maintain our historic leadership in graduate education in marine science and take advantage of our strategic institutional goal of further increasing enrollment via a professional master's degree program.

Enhance Chesapeake Bay Water Quality Modeling and Monitoring. This strategy has now been met. The General Assembly in their 2018 session provided VIMS with $893,753, starting in FY 2020, for water quality improvement work. The funding includes $406,075 for on-going support, $84,678 for debt service costs under the Master Equipment Leasing Program (MELP) associated with the modeling and assessment technologies, and $403,000 for development of the State of the Elizabeth River Scorecard for pollution levels in the Elizabeth River.

Increase Base Operating Support. This strategy has now been met. The General Assembly in their 2018 session provided VIMS with $625 K in each year of the biennium for operations and maintenance of new facilities coming online.

Management of Marine Diseases. VIMS has over $467,000 in active grants during FY17 to conduct research related to understanding and managing marine diseases. The state support that

we are now seeking is to more effectively put the knowledge that we gain through this research into use in monitoring and outreach programs to assist industry.

***Monitoring* Bay Grasses.** VIMS obtained a small amount of one-time money during FY17 from the EPA to continue this monitoring program. However, these funds are not available in FY18 and the program has been forced to lay-off one person. Our current federal dollars are not sufficient to sustain this program at levels needed to provide DEQ and VMRC with up-to-date monitoring that they require for water quality standard evaluation and aquaculture permitting, respectively.

Develop and support new management and policy approaches at state and local government levels. The Commonwealth Center for Recurrent Flooding Resiliency, a joint partnership between VIMS, ODU, and W&M, provided partial support for this strategy centered around the topic of flooding.

Implement a Post-Graduate Commonwealth Coastal and Marine Fellowship Program. With pilot funding from VIMS, VASG, the Virginia Environmental Endowment, and three state host agencies (VA Department of Environmental Quality, VA Department of Conservation and Recreation, and VA Marine Resource Commission), three Fellows were placed in 2017. Six outstanding candidates applied for the three available host positions. VASG conducted all recruitment and pre-screening, fiscal management, and Fellow oversight and technical assistance. The host agencies developed and oversee the Fellow's job tasks and activities, interviewed candidates, and serve as professional mentors for the 12-month duration of the Fellowship. While one-time seed funding was provided and minimal leveraged funding exists (e.g., $10,000/year from VEE), long-term support is needed for the Commonwealth Coastal and Marine Fellowship program.

E. Tuition Rate Increases

Although the W&M School of Marine Science (SMS) resides at VIMS, we do not set the tuition and fees for the students in this graduate program. Those rates are set by the W&M Provost, Senior VP for Finance and Administration, with ultimate approval by the Board of Visitors. Unfortunately, the recent increases in graduate tuition and fees for marine science have negatively affected enrollment at the SMS. We aspire to have 120 students, yet our Fall 2016 headcount was 91. This is due to a combination of increasing tuition and fees and level, or even reduced, funding from external granting sources such as NOAA and NSF. The Director and Dean of VIMS has requested that W&M hold the SMS tuition and fees at current levels for fiscal years 2019 and 2020.

F. Contributions to Economic Development

a. University-led or public private partnerships in real estate and/or community redevelopment
   VIMS has engaged in conversations over the last several years with Gloucester County's Economic Development Authority (EDA), a private developer, and W&M's Real Estate Foundation to explore the possibility of a mixed-use development contiguous to VIMS' Gloucester Point campus that would provide food, retail, and housing. VIMS does not have any auxiliary services, such as dormitories or food service. In fact, VIMS does not even have a campus center. While VIMS does not have the funds to put toward such a redevelopment, we do have approximately 450 faculty, staff, and students who would be very pleased to have

these types of amenities contiguous to our campus with the majority willing to be patrons, if the price points are set favorably.

We learned from the EDA, in June 2018, that a prominent local restaurant owner was buying property within a short walking distance of VIMS for redevelopment into a restaurant, retail shops and, possibly, several apartments. The EDA has offered to bring VIMS into the conversation after the closing on the property so that we can convey our thoughts with regard to redevelopment.

Also in June, 2018, Gloucester County produced a video promoting economic development that featured in one segment its relationship with VIMS under the heading "where inquiring minds come to learn." VIMS is one of the county's economic drivers and maintains a strong relationship with the Director of Economic Development, always with an eye towards mutually-beneficial partnerships.

Finally, VIMS is located in GO Virginia Region 6, and the VIMS Dean and Director is a voting member of the Region's Council. The Region 6 Council awarded a planning grant in April, 2018 to Virginia Sea Grant, housed at VIMS, to explore developing a partnership that would focus on flooding, resiliency, and research commercialization in the Middle Peninsula. The intent is to determine the most appropriate approach for submitting a larger collaborative project.

b. State industries to which the institution's research efforts have direct relevance
There are several industries in which VIMS' research efforts have had a direct impact. Examples include:

- Oyster and Clam Aquaculture Industry. In 2017, the farm gate value for Virginia's shellfish aquaculture industry was $56.6 million, of which $38.1 million was attributed to Hard Clams and $18.5 million to Oysters. This is an all-time high for the shellfish aquaculture industry. The research conducted at VIMS by our faculty and staff over the last 50 years has led to this economic success. Specifically, VIMS researchers provide genetically superior oyster brood stock to industry without charge, and provide guidance to industry on the leading diseases that impact shellfish to provide guidance to industry.
- East Coast Off Shore Scallop Industry. In the early 1990s, the scallop fishery along the U.S. Atlantic seaboard was on a sharp downward slide. Commercial fishermen were having to spend more and more time at sea, up to 240 days per year, but were catching fewer and smaller scallops. Today, that fishery is the second most valuable commercial fishery on the East Coast, with more than $400 million in scallops landed in 2014. Virginia alone unloaded $33.6 million in scallops in that year, generating an additional $21 million in economic activity in the Commonwealth for a total impact of over $50 million. A large part of the recovery and growth of the East Coast scallop fishery is due to a long-term collaboration between scallopers, fishery managers, and scientists at VIMS. Our scientists have spent thousands of days on commercial scallop boats and research vessels during the last decades, testing and refining dredge

equipment to maximize sustainable scallop harvests while minimizing bycatch of yellowtail flounder and sea turtles.

- Agriculture Industry. The Eastern Shore of Virginia is home to tomato farms and, increasingly, chicken farms. VIMS' researchers work with the state and local municipalities to understand the potential impacts of these industries on water quality, and assist in developing mitigation strategies to reduce the impacts.
- Environmental Industry. VIMS researchers developed state-of-the-art biosensors that have early detection functionality for oil spills, rapid quantification in real-time of polycyclic aromatic hydrocarbons (PAHs) concentration (EPA considers PAHs highly toxic and lists 17 as suspected carcinogens), and other contaminants.

c. High-impact programs designed to meet the needs of local families, community partners, and businesses

- Oyster Aquaculture Training Program. The Oyster Aquaculture Training program is a popular five-month hands-on program that focuses on the principles of oyster aquaculture. Participants learn and work alongside researchers during our oyster hatchery season from April to August. They receive a stipend for the duration of their involvement. To ensure a one-on-one experience, we accept a maximum of only 3-5 participants. During the five-month program, participants rotate through various stages of oyster aquaculture, from our hatchery and field grow-out operations, to our laboratory. Working through these rotations provides a sound understanding of all phases of the oyster life-cycle. Participants also work in the field, learning the importance of seawater flow rates, sieve and bag sizes, and oyster seed sizes and densities. They learn various field grow-out methods, such as suspended culture and rack and bag techniques. By the end of the program, participants have a clear understanding of all areas of oyster aquaculture and are highly qualified and confident in their ability to perform tasks in both oyster hatchery and field operations. Although there are only a small number of participants in any given year, the impact of the program is high and community and industry relations are enhanced.
- Community Outreach. VIMS and its federal partners offer a wide variety of free public programs both on VIMS' campuses in Gloucester Point and Wachapreague, as well as throughout Hampton Roads and the lower Chesapeake Bay region. In calendar year 2017, VIMS offered more than 350 outreach programs that reached nearly 25,000 citizens. Our programs include After Hours Lecture Series, Discovery Labs, Annual Open Houses at Gloucester Point and Wachapreague, Public Tours, Seafood Symposia, Speakers Bureau, Technical Training and Workshops, Summer Camps for K-8th graders, Field and Classroom Experiences, and booths at local Fairs and Festivals.

d. Business management/consulting assistance

As the state's mandated advisor on a wide range of natural resources management and use issues, VIMS plays a truly unique role as an institution of higher education. In fact, VIMS is a model for the nation in this regard because our advisory services mission is so significantly different from traditional university service to the community, and it shapes VIMS in a most fundamental way. VIMS is identified in 36 sections of the *Code of Virginia*, and as such we are

on call and expected to provide advice based on the highest quality science when requested by the Governor, the General Assembly, state agencies, marine industries, and citizens. The charge put forth to us in the *Code of Virginia* is an asset, an advantage, and a vibrant part of our institutional culture. Advisory service is in many ways the public face of VIMS.

Currently, there are eight to ten major projects ranging from municipal surface water intakes, to Dominion Virginia Power river crossings, to the Chesapeake Bay Bridge Tunnel

expansion. Expectations from stakeholders are high and we have a long history of furnishing advice of unsurpassed quality. Many of these projects require multiple permits and are complicated, time-consuming and often controversial. VIMS brings, at no charge, an objective voice that ultimately results in better policy and management decisions, and that help sustain the environment and protect public health.

The Commonwealth Center for Recurrent Flooding Resiliency (CCRFR), a partnership between Old Dominion University, W&M Law School's Virginia Coastal Policy Center (VCPC) and VIMS, was established in 2016 to bring university-based expertise to the growing challenge of recurrent flooding. The CCRFR conducts studies, provides training and offers a variety of services in the area of recurrent flooding resilience, and is currently working with local governments and state and federal agencies throughout Tidewater Virginia to enhance the region's resiliency to flooding. Examples include: 1) working with the City of Virginia Beach to assess resilience in the tourism industry and assemble policy recommendations; 2) collaborating with Newport News and Norfolk to install low cost-water level-monitors to enhance prediction and visualization tools; 3) assisting the City of Portsmouth in incorporating resilience to future storms in their comprehensive plan; 4) evaluating the effectiveness of various risk communication methods; 5) mapping local land subsidence rates; 6) contributing to the development of easy-to-use data portal, *Adapt Virginia*, that provides a wide range of technical and policy decision support for building resilience; 7) providing leadership in addressing storm water concerns in rural Tidewater, and; 8) developing an improved version of *TideWatch*, which currently predicts water levels at selected tide gauge stations 36 hours in advance, and will soon provide flood inundation predictions up to 48 hours in advance.

G. Capital Outlay

VIMS has 11 proposed capital projects over the Six-Year Plan period; however, there are three projects that are the top priorities for VIMS in the upcoming biennium and that will have a significant impact on several of the strategies listed in our Six Year Plan. They are (1) Construct an Oyster Research Hatchery, (2) Replace Fisheries Science Building, and (3) Expand and Renovate Watermen's Hall.

Relocate and Construct an Oyster Research Hatchery. The current hatchery is nearly four decades old and was originally designed as a production facility for planting large numbers of seed oysters in the Chesapeake Bay. The new hatchery will be 22,000 square feet and constructed on the north side of campus, out of the flood plain, and be specifically purposed for oyster aquaculture research, oyster restoration, industry and economic development, and educational and training space. This research hatchery supports the Virginia Plan Goals 3 and 4 and TJ 21 Objective D5. VIMS'

Aquaculture Genetics and Breeding Technology Center (ABC) will be housed in the new hatchery. The 1997 General Assembly established ABC in recognition of the role that genetic research and selective breeding play in aquaculture development. ABC is the first genetics program to focus on oysters and one of the first dedicated Centers for breeding marine species. ABC's mission is to continuously improve oyster aquaculture through the manipulation and control of the genetics and culture of the oyster. These improvements, through application of cutting edge research, have and will continue to have regional impact and worldwide application. Most importantly, aquaculture is one of the leading economic development opportunities for Chesapeake Bay. ABC addresses industry requirements for a more profitable enterprise by running a breeding and applied research program, which comprises a research hatchery, labs, and farms that are staffed with technicians, students, and trainees. ABC does not sell seed or larvae, but enables industry to meet this demand by providing the best available brood stock.

Replace Fisheries Science Building. Currently, the Department of Fisheries Science is housed in three different buildings across campus, Nunnally Hall/Fisheries Science Building, Chesapeake Bay Hall, and Andrews Hall. Nunnally Hall/Fisheries Science Building, that houses 80 percent of the department, is 27 years old and has had three additions in order to accommodate the expanded needs of office, laboratory, and storage space. The building is one story, of VB type construction, and has reached its maximum allowable size according to state building code. This proposed project will demolish the current Nunnally Hall/Fisheries Science Building and construct a new 34,000 square-foot multi-level research laboratory building.
The Department of Fisheries Science provides critical scientific information and objective technical advice on resource management to the Commonwealth (via VMRC), the nation, and the international community. Fisheries faculty and staff have extensive experience and knowledge on the biology and status of fishes, molluscs, and crustaceans, applying both classical skills and novel approaches to enhance our understanding of these animals in their estuarine and marine environments. The research conducted by members of this department informs society and is often the basis for resource policy. This combination of research and advice provides a rich environment for graduate education. Fisheries students integrate into department research, actively participating in VIMS' advisory function. Graduates find employment as teachers, researchers, and resource managers at universities, in local, state, national and international agencies, and in private corporations. This project supports the Virginia Plan Goals 2, 3 and 4 and TJ 21 Objective D5.

Expand and Renovate Watermen's Hall. This project consists of expanding and renovating the 1984 vintage Watermen's Hall. This renovation and expansion is critical to meeting the programmatic, technological, and instructional needs of graduate marine education and public outreach at VIMS. The project includes renovation of existing classrooms, and an 11,800 square foot addition for an educational center with classrooms, conference rooms, convertible meeting rooms, and an informal lounge.

Watermen's Hall is a multipurpose building that houses the Institute's administration, advisory services, main research library, classrooms, and an auditorium. Not only does Watermen's Hall provide essential functions and act as the nerve center for the Institute's faculty, staff, and students, but it is the main building where the Institute and the public interface. The building has been well maintained and improvements have included a handicapped accessibility project, re-roofing

project, and partial face lift to the McHugh Auditorium, and mechanical equipment replacement as part of an energy performance contract. However, the building is 31 years old, has never been renovated, and is showing its age. Moreover, VIMS is unable to host regional and national conferences due to lack of proper facilities and class scheduling conflicts. The proposed addition would allow VIMS to hold workshops for 50-100 people with breakout rooms for small discussion groups and improve VIMS' ability to provide advisory services to state and local governments and the general public through outreach training workshops. This project supports the Virginia Plan Goals 2, 3 and 4 and TJ 21 Objective D5.

H. Restructuring – Not Applicable