RESOLUTION TO APPROVE OF MASTER OF SCIENCE (MS) IN WATER RESOURCES

Academic Area: Graduate School

Requested initiation: Fall 2025

The Graduate School will administer this degree program however, faculty across 3 colleges will collaborate and teach in the program: CNRE (Department of Forest Resources and Environmental Conservation and Department of Geography), COS (Department of Geosciences), and CALS (School of Plant and Environmental Science).

This degree program will prepare students to protect, analyze, and improve water quality, watershed ecosystems, and water resources. Students will learn to use sophisticated computer software to collect, analyze, and interpret hydrologic data such as the physical, chemical, biological, and anthropogenic factors impacting water quality and flow paths. Graduates will be prepared to conduct, collect, and analyze hydrologic data using advanced computer modeling and advise policymakers, engineers, and public officials about water resources, challenges, and management.

RECOMMENDATION:

That the resolution to establish the Master of Science (MS) in Water Resources in the Graduate School be approved and the proposal forwarded to the State Council of Higher Education for Virginia (SCHEV) for approval.

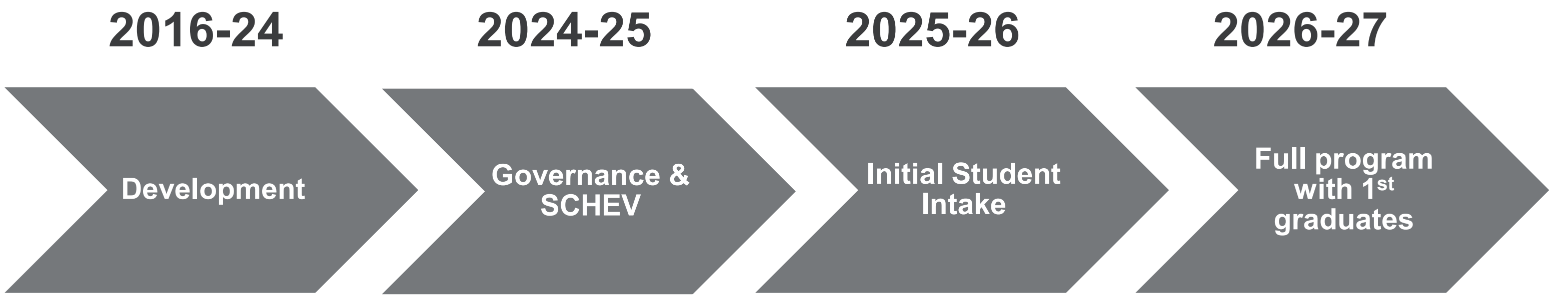
November 19, 2024

M.S. in Water Resources

Presenter: Dr. Kevin McGuire, Director of the Virginia Water Resources Research Center

Description: new M.S. degree in Water Resources at VT will provide students with a foundation in water science, assessment, and management, offering both thesis and non-thesis options to prepare graduates for diverse career paths and further doctoral studies.

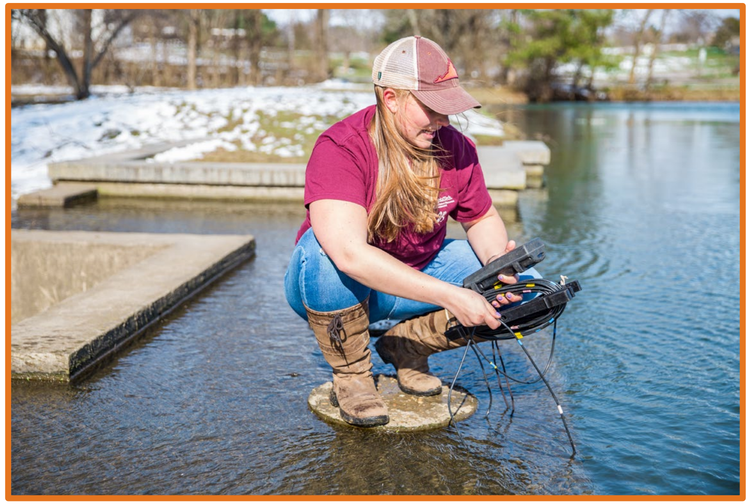
Timeline:



Support & Resources:

- Builds on existing strengths in faculty, courses, & VT's successful B.S. degree in water
- Support from 14 departments and 8 colleges at VT; >75 faculty at VT with water expertise
- Jointly administered by the Graduate School and Water Center
- 0.5 FTE Program Coordinator

M.S. in Water Resources



Justification

1. **Addressing Complex Water Challenges:** The program equips future leaders to tackle the most pressing issues and prepares them to meet these challenges locally and globally.

2. **Interdisciplinary and Comprehensive Training:** By integrating water science and social perspectives, the program prepares graduates for leadership roles in water research, policy, and management, fostering sustainable solutions.

3. **Unique & Innovative:** As the only M.S. degree program of its kind in Virginia, it positions VT at the forefront of innovative water resources education in preparation of the workforce.

4. **Employment and Mission Alignment:** The program meets the growing demand for water-related jobs and supports VT's mission by preparing students to serve communities, enhance economic competitiveness, and improve quality of life.

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Description of the Proposed Program

Program Background

Virginia Polytechnic Institute and State University requests approval to initiate a Master of Science (M.S.) degree program in Water Resources. The proposed degree program would be located in the Graduate School. The anticipated initiation is fall 2025.

The purpose of the proposed M.S. in Water Resources degree program is to prepare students to protect, analyze, and improve water quality, watershed ecosystems, and water resources. Students will learn how to use sophisticated computer software to collect, analyze, and interpret hydrologic data such as the physical, chemical, biological, and anthropogenic factors impacting water quality and flow paths. The program will provide students with an advanced understanding of the physical, policy, and management factors affecting water volume, water properties (e.g., pollutants, pH), and the water cycle of urban and natural environments. The program will educate students to conduct water risk assessments using advanced computer modeling to make decisions regarding watershed management, water hazards, and sources of water- and vector-borne diseases. Coursework will develop students' knowledge and skills in the human, environmental, and ecological impacts on water issues such as erosion, floods, and water treatment. The program will educate students in historical and current policy initiatives related to water resources including rivers, groundwater, lakes, and man-made stores such as dams and reservoirs. The program will also emphasize ethical issues related to water such as accessibility, safety, affordability, and sustainability for people and animals. Graduates of the proposed program will be prepared to conduct, collect, and analyze hydrologic data using advanced computer modeling and advise policymakers, engineers, and public officials about water resources, challenges, and management.

The proposed degree program responds to the current needs of Virginia, the nation, and abroad. The increasing complexity of water-related issues has created a significant demand for professionals with advanced graduate-level training in water science and resource management. The availability of adequate, clean water for domestic use is a critical need and a continuing challenge across the globe. Although the United Nations General Assembly adopted a resolution to recognize "the right to safe and clean drinking water and sanitation as a human right"[1] on July 28, 2010, it remains an ongoing challenge for many communities. "In 2020, 26% of the world's population (2 billion people) did not have access to safely managed drinking water services; 46% (3.6 billion) lacked access to safely managed sanitation."[2] Complex water challenges have a high economic and environmental toll on the people, land surfaces, and wildlife affected by water extremes such as flooding and drought. From 2000-2019, the economic loss worldwide is estimated at $650 billion from flooding and nearly $130 billion from droughts.[3] Further, "higher temperatures and more extreme, less predictable, weather conditions are projected to affect availability and distribution of rainfall, snowmelt, river flows and groundwater, and further

[1] Geneva Environment Network. The Water Cycle and the Role of Geneva. Human Rights to Water and Sanitation. https://www.genevaenvironmentnetwork.org/resources/updates/water-and-the-environment/
[2] UN World Water Development Report 2023. Facts and Figures. https://www.unesco.org/reports/wwdr/2023/en
[3] Ibid.

deteriorate water quality."[4] Addressing these challenges requires professionals with sophisticated analytical skills and comprehensive knowledge to develop sustainable solutions. Graduates of the proposed program will be prepared to analyze, interpret, and manage water data to address challenges such as water scarcity, pollution, and infrastructure resilience.

In addition, these scientific data and research findings must be translated into practical, implementable strategies that address diverse and often conflicting water needs. In 2015, the Joint Audit and Review Commission (JLARC) was directed by the General Assembly of Virginia to study Virginia's water resources, management activities, and planning activities at the local, regional, and state levels with a particular focus on eastern Virginia.[5] The resulting 2016 report indicated several alarming findings including an insufficient groundwater supply for eastern Virginia and a lack of clarity and specificity in water planning across the state. The group reported "Virginia's state and local water plans are not sufficiently specific or aligned with water location and use. As a result, the state lacks a clear plan for addressing its most pressing sustainability challenges."[6] The proposed degree program will address such issues by preparing students with skills in policy development and stakeholder engagement, enabling them to develop actionable strategies that balance competing demands, such as economic productivity and environmental sustainability.

A market demand exists for professionals with the knowledge and skills to collect, analyze, and interpret data on the factors impacting water resources, as well as synthesize this scientific knowledge into actionable strategies that balance competing demands to solve water-related challenges. The proposed M.S. in Water Resources will train students to meet these water challenges in Virginia, nationally, and abroad. Students will be able to critically evaluate existing water issues and support engineers, policy groups, and local officials in developing sustainable, actionable strategies to address water challenges. Graduates of the proposed degree program will have the advanced knowledge and skills needed to perform risk assessments, collect and analyze water data using computer programming, and evaluate the impacts of water challenges on communities, animals, and the environment. This advanced training is essential for professionals to effectively navigate the intricate relationships between water, ecosystems, and human needs, and to implement integrated solutions that ensure water security for both current and future generations.

Institutional Mission

The mission of Virginia Tech is as follows:

> "Inspired by our land-grant identity and guided by our motto, *Ut Prosim* (That I May Serve), Virginia Tech is an inclusive community of knowledge, discovery, and creativity dedicated to improving the quality of life and the human condition within the Commonwealth of Virginia and throughout the world."

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[4] Geneva Environment Network. The Water Cycle and the Role of Geneva. Water and Climate Change. https://www.genevaenvironmentnetwork.org/resources/updates/water-and-the-environment/

[5] Joint Audit and Review Commission. Effectiveness of Virginia's Water Resource Planning and Management. https://jlarc.virginia.gov/water-2016.asp

[6] Ibid.

The proposed M.S. in Water Resources degree program aligns with the mission of Virginia Tech. The proposed program will educate students who can "improve the quality of life" in "Virginia and throughout the world" through watershed risk assessments, protecting water resources, and helping to solve water challenges. Students will be prepared to use computer modeling and hydrological data to create new "knowledge" and analyze water data to solve complex water challenges through "discovery and creativity."

The proposed M.S. in Water Resources is included in Virginia Tech's 2024 Six-Year Plan.

Curriculum

The proposed Master of Science (M.S.) in Water Resources will require 30 credit hours. A project and report (non-thesis option) or a thesis will be required.

The curriculum will provide students with a foundation in water science and watershed assessment and management. Core coursework will educate students on the hydrological processes that affect the origin, cycling, and flow of water within watersheds and the physical, chemical, biological, and anthropogenic (i.e., human-influenced) factors that affect quality and contaminants in water. Students will also be educated on the hazards of water to human (infrastructure, economy) and ecological (rivers, groundwater) systems in the context of disease, climate change, and eutrophication (i.e., the excessive enrichment of water with nutrients, leading to oxygen depletion and zones devoid of aquatic life). Students will learn about protecting and improving watershed ecosystems. They will learn how to conduct watershed risk assessments and develop monitoring and modeling approaches to analyze digital terrain, as well as spatial and temporal hydrologic data. The courses will train students in computerized decision tools and water treatment and management technologies to make informed, ethical decisions about water treatment and management.

The proposed program will require students to complete either a project and report (non-thesis option) or a thesis (thesis option). Students who select the non-thesis option will complete a project and report. The project and report will allow students to pursue a research project under the supervision of a faculty advisor.

The thesis option will be available for students who want to prepare for research careers in water resources. Students will also be prepared to pursue doctoral level education in areas such as hydrology, water quantity, water quality, water treatment, water law, policy, and management, and watershed management.

All new courses are denoted with an asterisk.

Program Requirements

Core Courses: 15 credit hours
CSES 5314: Water Quality for Professionals (3 credits)

GEOG 5134/GEOS 5844: Advanced Interdisciplinary Issues and Ethics in Water Resources (3 credits) *
FREC/CSES 5144: Watershed Hydrology (3 credits)
FREC/WATR 5244G: Advanced Hydroinformatics (3 credits)
WATR 5004: Seminar in Water Science and Society (1 credit) *
WATR 5614G: Advanced Watershed Assessment, Management, and Policy (2 credits)

Electives Courses: 6-12 credits
Students will work with their advisor to select elective coursework that aligns with their professional goals.

Capstone Requirement: 3-9 credit hours
Students will be required to complete a project and report (non-thesis option) or a thesis.

Project and Report: 3-6 credit hours
GRAD 5904: Project and Report (variable credit)

Thesis: 6-9 credit hours
GRAD 5994: Research and Thesis (variable credit)

Total: 30 credit hours

Description of Project and Report
The project and report will entail a research project under the supervision of a faculty advisor (for example, evaluating the effectiveness of water conservation policies or water allocation strategies in a particular watershed, or assessing the ecological benefits of wetland restoration projects on water quality and biodiversity in a degraded watershed). Students will be required to complete a minimum of 3 credit hours and a maximum of 6 credit hours for their project and report. This may entail any number of semesters during their program. They will be expected to give a final presentation of their project and report to their faculty advisor and a committee of at least two (2) additional faculty members. If they do not pass their project and report presentation, they will have a second opportunity to present in order to meet graduation requirements. A second failure will result in dismissal from the degree program.

Description of Thesis
Students will be allowed to register for thesis credits with approval from their thesis advisor. Students will be required to complete a minimum of 6 credit hours for their thesis. For the thesis, students are required to work with a committee of at least three (3) faculty members, including their thesis advisor. At least one of the committee members must be a faculty in the department of the thesis advisor. It is the responsibility of the student to form a thesis committee. The committee must be formed at least two semesters before the desired graduation.

Students must conduct a research project incorporating an original design and independent study, resulting in a final written thesis. The topic must fall within one of the areas of water-related expertise of their thesis advisor, including hydrology; hydroinformatics; water supply; water quality; water treatment; water law, policy, and management; or watershed management.

Students must develop a proposal and have it approved by their graduate committee and by the appropriate university committees, such as the Institutional Biosafety Committee, Institutional Review Board, Human Research Protection Program, Institutional Animal Care and Use Committee, before undertaking the project. Students must demonstrate competence in independent research and the ability to write a thesis paper. Students will present a public oral defense to their thesis committee members. The defense will cover the thesis and knowledge area related to the student's area of interest. The thesis manuscript will be required to follow requirements set by the faculty advisor's department, college, and the university. If students do not receive a passing grade, they will be allowed one time to revise or retake a failed portion. A second failure will result in dismissal from the degree program.

See Appendix A for a sample plan of study.
See Appendix B for course descriptions.

Faculty Resources

The College of Natural Resources and Environment Department of Forest Resources and Environmental Conservation has 33 full-time faculty members and will provide two (2) existing faculty members to teach required courses in the proposed degree program. The faculty have doctoral degrees in Hydrology and Forest Resources and Environmental Conservation.

The College of Natural Resources and Environment Department of Geography has 22 full-time faculty members and will provide one (1) existing faculty member to teach required courses in the proposed degree program. The faculty member from the Department of Geography has a doctoral degree in Geography.

The College of Science, Department of Geosciences has 39 full-time faculty members and will provide one (1) existing faculty member to teach required courses in the proposed degree program. The faculty member from the Department of Geosciences has a doctoral degree in Geology.

The College of Agriculture and Life Sciences, School of Plant and Environmental Sciences has 81 full-time faculty members and will provide two (2) existing faculty members to teach required courses in the proposed degree program. The faculty members from the School of Plant and Environmental Sciences have doctoral degrees in Water Resources Engineering and Soil Chemistry.

The faculty have over 50 years of combined teaching and research experience in the field. Collectively, they have published 386 scholarly articles in professional journals, served as textbook reviewers and manuscript reviewers for scholarly journals, and made 674 presentations at professional conferences.

No adjunct faculty members will be utilized for the proposed program.

See Appendix C for faculty curriculum vitae (abbreviated).

Student Learning Assessment

Every student who completes the proposed M.S. in Water Resources degree program will have mastered a set of skills that are needed to analyze and interpret data from hydrological systems; plan, develop, and implement strategies to sustainably manage water resources; and assess the impacts of water policies and management practices on diverse stakeholders.

Students will be assessed in each course through various mechanisms that include (1) projects, (2) homework assignments, (3) term papers, and (4) exams. The project and report or thesis will provide an opportunity for assessment of the combined learned skills obtained throughout the program.

The project and report or thesis will be used to assess student learning of the combined learned skills obtained throughout the program. Students will be assessed using several evaluations and measures. These include graduate committee meetings occurring each semester, a final written thesis or research project, and a final oral presentation of the thesis or research project.

The learning outcomes for the degree program are specific to graduate-level knowledge, skills, and abilities that students should acquire in the proposed degree program.

<u>Learning Outcomes</u>
Students will be able to:

- Quantify physical processes that affect age, origin, cycling, and flowpaths of water within watersheds.
- Predict how soil, vegetation, geologic materials, and land use affect flows of water within and from watersheds.
- Interpret the physical, chemical, and biological aspects of water quality.
- Appraise the impact of natural processes and anthropogenic activities on water quality.
- Assess how contaminants are transported within water systems.
- Justify the significance of maintaining water quality for sustainability of ecosystems at multiple spatial scales.
- Use computer programming to calculate and analyze measures of hydrologic behavior with respect to watershed function.
- Apply appropriate visualization techniques and other strategies to communicate results of hydroinformatics analyses to experts and non-experts.
- Address water-related issues (e.g., dams, eutrophication, water-and vector-borne diseases, and social vulnerability) in an ethical way.
- Demonstrate concepts of scale, spatial distribution, interconnectivity, and place- and systems-based approaches to the intersection of water resources with socio-ecological systems.
- Evaluate how local social, ecological, and built/engineered environments play a role in how water and humans interact.
- Work with a team to address a watershed issue by applying innovative watershed assessment, management, and policy concepts to a case watershed through a team project and facilitate discussion on critical assessment of water research findings

- Critically evaluate current and historical research on issues in water science, policy, and management across water-related disciplines.
- Evaluate effects of water policy and management outcomes on a diverse community of stakeholders.

Curriculum map for M.S. in Water Resources

Learning Outcomes	**Core and Required Courses**	**Assessment Measures**
Quantify physical processes that affect age, origin, cycling, and flowpaths of water within watersheds.	FREC/CSES 5144: Watershed Hydrology	Formative: In-class exercises and homework (for example, hydrological modeling to explore physics affecting the movement and storage of water in watersheds) Summative: Course exams (for example, an item on the exam may ask students to construct a model of water flowpaths within a watershed)
Predict how soil, vegetation, geologic materials, and land use affect flows of water within and from watersheds.	FREC/CSES 5144: Watershed Hydrology	Formative: In-class exercises and homework (e.g., use of soil hydrological properties and modeling to explore and predict land use and vegetation effects on rainfall-runoff processes) Summative: Course exams (for example, an item on the exam may ask students to compare surface stormwater flows from watersheds supporting primarily urban vs. agricultural vs. forest land uses)
Interpret the physical, chemical, and biological aspects of water quality.	CSES 5314: Water Quality for Professionals	Formative: End-of-chapter open-note exams and homework (for example, identify harmful aquatic microorganisms (e.g., algae, bacteria) in water samples)

		Summative: Course midterm and final exams (for example, an item on the exam may ask students to describe a sampling regime (i.e., number of samples and frequency of sampling) to determine chemical properties of streamwater)
Appraise the impact of natural processes and anthropogenic activities on water quality.	CSES 5314: Water Quality for Professionals	Formative: End-of-chapter open-note exams and homework (for example, covering potential water-quality impacts of turfgrass management on golf courses that use pesticides and fertilizers) Summative: Course midterm and final exams (for example, an item on the exam may ask students to compare expected effects of flooding and droughts on streamwater salinity)
Assess how contaminants are transported within water systems.	CSES 5314: Water Quality for Professionals	Formative: End-of-chapter open-note exams and homework (for example, covering environmental fate and transport of microplastic contaminants in water systems) Summative: Course midterm and final exams (for example, an item on the exam may ask students to trace dissolved pharmaceuticals emitted from a sewage treatment plant outflow in downstream water and sediment samples

		at varying distances from the treatment plant provided in a dataset for their evaluation)
Justify the significance of maintaining water quality for sustainability of ecosystems at multiple spatial scales.	CSES 5314: Water Quality for Professionals	Formative: Course individual assignments (for example, students will be responsible for end-of-chapter open-note exams and homework covering the importance of water quality to global ecosystem sustainability) Summative: Course midterm and final exams (for example, an item on the exam may ask students to suggest expected changes in benthic macroinvertebrate communities in an urban stream vs. a forested stream in relation to specific water quality variables in each stream)
Use computer programming to calculate and analyze measures of hydrologic behavior with respect to watershed function.	FREC/WATR 5244G: Advanced Hydroinformatics	Formative: Class assignments and quizzes (for example, covering the importance of computer programming to measure hydrologic processes important to watershed function) Summative: Course midterms and final exams (for example, an item on the exam may ask students to use a hydrologic model introduced in the class and a dataset to estimate rainfall-runoff relationships in a watershed)
Apply appropriate data visualization techniques and other strategies to	FREC/WATR 5244G: Advanced Hydroinformatics	Formative: Course individual assignments (for example,

communicate results of hydroinformatics analyses to experts and non-experts.	WATR 5004: Seminar in Water Science and Society	students will be responsible for lecture activities and quizzes covering the importance of using appropriate data visualization techniques for hydrologic information) Summative: Course midterms and final exams (for example, an item on the exam may ask students to compare pros and cons of two currently-used data visualization techniques to demonstrate effects of climate change on flooding in a given watershed to a non-expert audience)
Address water-related issues (e.g., dams, eutrophication, water-and vector-borne diseases, and social vulnerability) in an ethical way.	GEOG 5134/GEOS 5844: Advanced Interdisciplinary Issues and Ethics in Water Resources	Formative: In-class discussions on ethical and non-Western considerations of water-related issues (for example, water quality, dams, eutrophication, water-borne diseases, and social vulnerability) Summative: Final research paper and presentation to the class (for example, researching and presenting about effects of and solutions to dam construction, eutrophication, water-borne diseases or intersection of vulnerability and water-related issues within actual communities)
Demonstrate concepts of scale, spatial distribution, interconnectivity, and place- and systems-based approaches to the intersection of water	GEOG 5134/GEOS 5844: Advanced Interdisciplinary Issues and Ethics in Water Resources	Formative: Written reflections on the intersection of water resources with socio-ecological systems (for example, scale, spatial

resources with socio-ecological systems.		distribution, interconnectivity, and place- and systems-based approaches) <u>Summative:</u> Final research paper and presentation to the class (for example, researching and presenting about effects of water quality, dam construction, eutrophication, or presence of water-borne diseases upon actual socio-ecological systems)
Evaluate how local social, ecological, and built/engineered environments play a role in how water and humans interact.	GEOG 5134/GEOS 5844: Advanced Interdisciplinary Issues and Ethics in Water Resources	<u>Formative:</u> In-class discussions on how local social, ecological, and built/engineered environments play a role in how water and humans interact (for example, evaluating role of social capital and local stakeholder groups on establishment and maintenance of neighborhood stormwater best management practices) <u>Summative:</u> Final research paper and presentation to the class (for example, evaluate the role of local social, ecological, and built/engineered environments in how water and humans interact relative to water quality, dam construction, eutrophication, or presence of water-borne diseases)
Work with a team to address a watershed issue by applying innovative watershed assessment, management, and policy	WATR 5614G: Advanced Watershed Assessment, Management, and Policy	<u>Formative:</u> Quizzes, case studies, oral presentations (for example, covering watershed assessment, management,

concepts to a case watershed through a team project and facilitate discussion on critical assessment of water research findings.		and policy at varying spatial and political scales) <u>Summative:</u> Final oral and written report that integrates scientific, engineering, and technological advances with socio-economic factors on a case study watershed (for example, develop a watershed management plan integrating science, engineering, and socio-economic factors for a stream and surrounding watershed that has been designated as impaired because of degraded water quality)
Critically evaluate current and historical research on issues in water science, policy, and management across water-related disciplines.	FREC/CSES 5144: Watershed Hydrology GEOG 5134/GEOS: 5844 Advanced Interdisciplinary Issues and Ethics in Water Resources WATR 5004: Seminar in Water Science and Society CSES 5314: Water Quality for Professionals	<u>Formative:</u> Class assignments (for example, identifying research objectives and/or hypotheses for assigned articles) <u>Summative:</u> Course exams and final projects (for example, students may be asked to place final project in historical context related to previous approaches to managing water resources that were successful)
Evaluate effects of water policy and management outcomes on a diverse community of stakeholders.	WATR 5614G: Advanced Watershed Assessment, Management, and Policy WATR 5004: Seminar in Water Science and Society	<u>Formative:</u> Class assignments (for example, participating in a role-playing exercise that involves diverse backgrounds and viewpoints to develop watershed management decisions) <u>Summative:</u>

		Final oral and written report that integrates scientific, engineering, and technological advances with socio-economic factors on a case study watershed (for example, evaluate stakeholders and present innovative practices to incorporate their involvement in developing and participating in a watershed management activity for a case study watershed)

Employment Skills

The proposed M.S. in Water Resources degree program will offer graduates knowledge, skills, and abilities for professional employment opportunities in hydrology, water research, and water resources management.

Graduates of the proposed M.S. in Water Resources degree program will be able to:

- Determine data requirements, identify appropriate technical approaches, and evaluate data quality for the assessment of water resources.
- Analyze water resource properties (e.g., flow rate, pH, and contamination levels) to develop strategies for managing a region's water supply.
- Analyze surface water systems like rivers and lakes to understand their flow patterns and potential impacts on the environment.
- Use computer models and data analysis to predict events like floods, droughts, and changes in water supply.
- Design systems to improve water quantity and quality, manage water resources, and address issues like water scarcity, pollution, and environmental impact (e.g., stormwater management systems).
- Evaluate the feasibility of water-related projects, such as hydroelectric power plants, irrigation systems, and wastewater treatment facilities.
- Assess the impacts of climate change, dams, and other large-scale projects on water resources.
- Evaluate the effectiveness of watershed management and policies on sustaining water resources.
- Provide technical advice and guidance to engineers, scientists, and other professionals working on water-related projects.
- Prepare reports, give presentations, and communicate analyses and recommendations on water-related projects to managers, policymakers, and stakeholders.

Relation to Existing Programs

Virginia Tech offers five (5) degree programs that are related to the proposed degree program: 1) the Master of Science (M.S.) in Crop and Soil Environmental Sciences; 2) the Master of Science (M.S.) in Geography; 3) the Master of Science (M.S.) in Geosciences; 4) the Master of Natural Resources (M.N.R.) in Natural Resources; and 5) the Master of Science (M.S.) in Environmental Sciences and Engineering. The M.S. in Crop and Soil Environmental Sciences is located in the College of Agriculture and Life Sciences, School of Plant and Environmental Sciences. The M.S. in Geography and the M.N.R. in Natural Resources are located in the College of Natural Resources and Environment. The M.S. in Geosciences is located in the College of Science. The M.S. in Environmental Sciences and Engineering is located in the College of Engineering.

All five (5) existing degree programs share related interests in aspects of the natural environment, which includes topics related to water. However, there are distinct differences in the purpose and focus of the programs. There are also distinct differences in the knowledge and skills of the graduates of the degree programs.

The M.S. in Crop and Soil Environmental Sciences degree program emphasizes agronomy, crop breeding and genomics, and the impacts of soil and water on managed landscapes and ecological restoration. Students take courses in agroecosystem productivity and agronomic crops such as soybeans, small grains, and forages. Students develop knowledge and skills related to plant, animal, and microbe interactions with soil and water in intensively managed and degraded ecosystems. Graduates are prepared to serve in roles such as agronomist, crop advisor, and soil scientist. There are no common core or required courses between the two degree programs. Students in the proposed program are required to take one course that is cross-listed with Crop and Soil Environmental Sciences (CSES), FREC/CSES 5144: Watershed Hydrology, as part of the required core coursework, however, this course is not required for the Crop and Soil Environmental Sciences program. Students in the proposed program are required to take one CSES course, CSES 5314: Water Quality for Professionals, as part of the required core coursework, however, this course is not required for the Crop and Soil Environmental Sciences program. The proposed program emphasizes water as a scientific discipline and includes water resources, risk assessment, and computerized decision tools for watershed management. Graduates of the proposed program are prepared to serve as hydrologists, water specialists, and water resource managers.

The M.S. in Geography focuses on analyzing and interpreting spatial and temporal processes and research in the field. Students take courses in geography research methods, the analysis of spatial data, geographic information systems (GIS), and remote sensing. Students develop knowledge and skills related to the collection and analysis of geographic data, mapping of different landscapes, and conducting field work to better understand a given region's physical landforms, features, and inhabitants. Graduates are prepared to serve in roles such as geographers, cartographers, and geography researchers. There are no common core or required courses between the two degree programs. Students in the proposed program are required to take one course that is cross-listed with Geography (GEOG), GEOG 5134/GEOS 5844: Advanced Interdisciplinary Issues and Ethics in Water Resources, as part of the required core coursework, however, this course is not required for the Geography program. The proposed program focuses on collecting and analyzing hydrologic data, conducting water risk analyses, and protecting water resources. Graduates of the proposed program are prepared to serve as flood risk assessors, water research specialists, and hydrologists.

The M.S. is Geosciences degree program focuses on the physical aspects of Earth and all aspects of its composition, history, and active processes, at a scale that ranges from atomic to planetary. Students develop knowledge and skills about the Earth's materials, physical attributes, and natural hazards, such as volcanoes. Students in the program can choose to conduct research on water as a component of the geological fluid systems present on Earth. In this context, students can learn about the fundamental linkages between the thermal, hydraulic, chemical, and mechanical processes that drive fluids throughout the Earth, and apply this knowledge to understand geologic processes and hazards from nano- to continental-scales. Graduates are prepared to serve in roles such as geoscientists, geoscience researchers, and project managers in industry sectors such as mining, oil, and gas. There are no common core or required courses between the two degree programs. Students in the proposed program are required to take one course that is cross-listed with Geosciences (GEOS), GEOG 5134/GEOS 5844: Advanced Interdisciplinary Issues and Ethics in Water Resources, as part of the required core coursework, however, this course is not required for the Geosciences program. The proposed program focuses on conducting water risk analyses, protecting water resources, and water as a scientific discipline. Graduates of the proposed program are prepared to serve in roles such as hydrologists, watershed risk managers, and water research scientists.

The M.N.R. in Natural Resources degree program focuses on environmental sustainability from a global perspective including natural resource systems, such as water, food and agriculture, climate, and energy. Students develop knowledge and skills about the impacts that climate, agriculture, energy, poverty, urbanization, global material flows, and biodiversity can have on sustainability efforts for different regions. Students learn about water as one of many elements of the climate and natural resource system of an area that should be considered as part of sustainability efforts. Graduates are prepared to serve in roles such as sustainability specialist, natural resource manager, and environmental scientist. There are no common core or required courses between the two degree programs. The proposed program focuses on water as a scientific discipline of study and includes training in advanced methods of data analysis of hydrologic data as well as risk-based watershed assessment and water as a hazard on human (e.g., infrastructure, economy) and ecological (e.g., rivers, groundwater) systems. Graduates of the proposed program are prepared to serve as watershed field managers, flood risk assessors, and hydrologists.

The M.S. in Environmental Sciences and Engineering focuses on preparing undergraduates with a physical science or life science background to work with engineers in various fields. The objective is to provide students with an exposure to engineering with technical training that is intermediate between the sciences and engineering. There is a non-thesis/coursework-only option and a thesis option. Students develop knowledge about chemical, physical, biological, and mathematical modeling fundamentals and how to apply these principles, along with their previous scientific training, to the solution of environmental problems. Students take courses in environmental chemistry, fluid mechanics, environmental engineering principles, and foundational water resources. Graduates are prepared to work in consulting firms, regulatory agencies, municipalities, and industry. There are no common core or required courses between the two degree programs. This existing program differs from the proposed program in that the existing program has an emphasis on engineering, whereas the proposed program does not. The proposed program emphasizes protecting water resources, watershed management, and water as a scientific discipline. Graduates of the proposed program are prepared to serve as watershed risk managers, water research scientists, hydrologists, and flood risk assessors.

Effect on Existing Degree Programs

The proposed M.S. in Water Resources will not affect or negatively affect any existing degree programs. No degree programs will close as a result of the initiation and operation of the proposed degree program.

Justification for the Proposed Program

Response to Current Needs
(Specific Demand)

Water is the earth's most precious resource and has no substitutes. Ensuring equitable access to clean water resources for all living beings requires effective water resources management strategies. In 2010, the United Nations General Assembly explicitly recognized the human right to water and sanitation.[7] Yet in 2024, "2.2 billion people still live without access to safely managed drinking water and 3.5 billion lack access to safely managed sanitation."[8] "In addition to health impacts, inadequate water access also poses an enormous financial burden on individuals and families as they experience higher rates of illness and lose work time…According to recent analysis, water insecurity [inadequate or inequitable access to clean, safe and affordable water[9]] also costs the U.S. economy approximately $8.58 billion annually in lost labor and productivity, reduced household earnings and higher healthcare costs."[10]

In Virginia, a 2015 Joint Audit and Review Commission (JLARC) report[11] on the effectiveness of the Commonwealth's water resource planning and management found that Eastern Virginia has insufficient groundwater to meet demand and noted the state water plan "does not adequately define the state's water challenges and lacks detailed and actionable strategies to address those challenges." In addition to growing demand issues, climate change is expected to have

[7] United Nations. (2015). *International decade for action "water for life" 2005-2015*. https://www.un.org/waterforlifedecade/human_right_to_water.shtml
[8] United Nations. (2024, March 22.). *Water crises threaten world peace (report)*. https://www.un.org/sustainabledevelopment/blog/2024/03/un-world-water-development-report/
[9] Schimpf, C., & Cude, C. (2020). A Systematic Literature Review on Water Insecurity from an Oregon Public Health Perspective. *International Journal of Environmental Research and Public Health*, *17*(3), 1122. https://doi.org/10.3390/ijerph17031122
[10] O'Neill, R. (2023, March 22). *Addressing a growing water crisis in the U.S.* CDC Foundation. https://www.cdcfoundation.org/blog/addressing-growing-water-crisis-us
[11] Joint Legislative Audit and Review Commission (n.d.) *Effectiveness of Virginia's water resource planning and management*. https://jlarc.virginia.gov/water-2016.asp

significant impacts on water resources. Increased temperatures and changes in precipitation patterns will likely lead to more frequent and intense droughts and floods, straining water supplies and infrastructure.[12] Sea level rise will cause saltwater intrusion into coastal aquifers and increased flooding in coastal areas, like Virginia's Hampton Roads area. These impacts threaten drinking water supplies, agriculture, ecosystems, and infrastructure.[13] Virginia's 2020 State Water Resources Plan notes the importance of developing alternative water supply sources on the Eastern Shore and in the Eastern Shore Groundwater Management Area; "the location and extent of demand growth in the next twenty years will ultimately determine where these measures may be most necessary."[14]

According to the U.S. Geological Survey, "as we experience increased stress on our Nation's water resources, the need to understand and protect them will require highly trained and skilled individuals in the fields of water resources and water management."[15] There is a current need for professionals with the knowledge, skills, and expertise to analyze and interpret water data, evaluate the impacts of water resource issues on communities and the environment, and develop sustainable strategies to effectively address water-related challenges.

The proposed M.S. in Water Resources degree program responds to the current need for experts with an advanced understanding of water science and water resource management. The current needs in Virginia, the nation, and abroad include: 1) industry demand for professionals with knowledge and skills in water science who can collect, analyze, and interpret data on the factors impacting water resources 2) industry demand for professionals with the skills to turn scientific knowledge into actionable strategies that balance competing demands to solve water-related challenges.

<u>Water Science / Factors Impacting Water Resources</u>
Developing a comprehensive understanding of water science and systems is foundational to effectively managing water resources. Water systems are impacted by a multitude of factors, both natural (e.g., erosion and sedimentation) and human-induced (e.g., pollution from sources like industrial waste, agricultural runoff, sewage discharge, and environmental contaminants). Aging infrastructure and ineffective treatment methods can also strain water supplies and degrade quality. "As changing climate patterns, biological and chemical contaminants, and aging water infrastructure systems threaten the availability and quality of water, communities and aquatic ecosystems will increasingly rely on advances in science and technology for resilience."[16]

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[12] National Geographic. (2022, August 18). *How climate change impacts water access*. https://education.nationalgeographic.org/resource/how-climate-change-impacts-water-access/

[13] Virginia Department of Conservation and Recreation. (n.d.). *Virginia coastal resilience master plan*. https://www.dcr.virginia.gov/crmp/plan#plan

[14] Virginia Department of Environmental Quality. (2022, January). *Virginia state water resources plan: A report of Virginia's water resources.* https://www.deq.virginia.gov/home/showpublisheddocument/16134/637991887436000000, p. xxxvii

[15] U.S. Geological Survey. *The U.S. geological survey water resources research act program—meeting local, state, and national needs for water resources science and training*. (2024, January). https://pubs.usgs.gov/fs/2023/3031/fs20233031.pdf

[16] U.S. Environmental Protection Agency. (2013, September 19). *Water research*. https://www.epa.gov/water-research

The United Nations Educational, Scientific and Cultural Organization (UNESCO)'s Intergovernmental Hydrological Programme (IHP)[17] has identified scientific research and innovation as one of its 2022-2029 priority areas. "The development of hydrological science and research has provided practical knowledge and information for society about water fluxes, transport and management, however ever increasing and uncertain environmental changes demands for a continued effort on research innovation and application. Scientific research incorporating human interactions with nature in the context of complex water sciences and management problems provide fundamental feedback for water resources management, along with the application of new tools, approaches and technologies."[18] As noted in Virginia's 2020 State Water Resources Plan, "in order for science based or evidence based decision-making to be valid, the science and data that drives [water] resource management decision making must remain current and relevant."[19]

Water science involves collecting, analyzing, and interpreting complex data sets to solve water-related challenges (e.g., assessing flood risks, locating sustainable groundwater sources).[20] This work requires scientific knowledge of the water cycle, mathematical modeling, and leveraging computing power to make sense of large volumes of hydrologic data. Water scientists and hydrologists gather quantitative measurements and qualitative observations about water supply, quality, flow dynamics, and interactions with the environment. This work requires graduate-level training in advanced analytical techniques, statistical methods, and computer simulations to study this data, identifying trends, forecasting scenarios, and evaluating the impacts of human activities or potential mitigation strategies.[21] For example, a water scientist could lead a study to understand how climate change is affecting water quality in a particular region or watershed. This may involve monitoring changes in water temperature, pH, dissolved oxygen levels, nutrient loads, and the presence of contaminants over time. The scientist could also model how factors like increased precipitation, droughts, sea level rise, and extreme weather events might exacerbate water quality issues. Additionally, they could assess the vulnerability of water infrastructure and ecosystems to these changes. The findings from this research could inform strategies and policies to protect water resources and public health.

Water utilities, environmental consultants, government agencies, and research institutions rely on expertise in water science to inform sustainable management strategies and policies safeguarding water security.[22] As pressures on water resources intensify, the need for comprehensive data and scientific knowledge will only escalate, driving demand for water science professionals. Virginia

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[17] United Nations Educational, Scientific and Cultural Organization. (2022). *Intergovernmental hydrological programme*. https://www.unesco.org/en/ihp
[18] United Nations Educational, Scientific and Cultural Organization. (2022). *IHP-IX: Strategic plan of the intergovernmental hydrological programme: Science for a water secure world in a changing environment, ninth phase 2022-2029*. https://unesdoc.unesco.org/ark:/48223/pf0000381318
[19] Virginia Department of Environmental Quality. (2022, January). *Virginia state water resources plan: A report of Virginia's water resources.* https://www.deq.virginia.gov/home/showpublisheddocument/16134/637991887436000000, p. 112
[20] Water Science School. (2019, May 23). *What is hydrology?* U.S. Geological Survey. https://www.usgs.gov/special-topics/water-science-school/science/what-hydrology
[21] Ibid.
[22] Ibid.

Tech's proposed M.S. in Water Resources will produce graduates that will be trained to collect, analyze, and interpret data on the factors impacting water resources to inform sustainable solutions.

Water Resource Management / Balancing Competing Demands

According to the Word Bank's Water Security and Integrated Water Resources Management Global Solutions Group (GSG), "the complexity of relationships between water and households, economies, and ecosystems, requires integrated management that accounts for the synergies and tradeoffs of water's great number uses and values." [23] Water resource management involves translating data and scientific knowledge into actionable strategies that balance competing water demands (e.g., economic productivity vs. environmental sustainability, current vs. future needs, local interests vs. system-wide priorities, and water quantity vs. quality considerations).[24] [25]

Communities grapple with aging infrastructure, water scarcity, contaminant management issues, and lack of funding for necessary upgrades and improvements. They must also adapt to uncertainties from climate change impacts like droughts, floods, and water quality degradation. Balancing competing demands requires integrated technical, policy, stakeholder engagement, and locally-tailored solutions.[26] For example, a water resource manager in a rapidly urbanizing watershed may be tasked with providing adequate water supplies to meet growing municipal demands while also mitigating water quality impairments from urban stormwater runoff and pollution. Increasing water withdrawals could degrade aquatic habitats, but limiting withdrawals could constrain the ability to meet future urban water needs. The manager must work with stakeholders to develop integrated strategies that expand municipal water supplies (e.g., though reuse, stormwater capture, and conservation), while simultaneously implementing policies and practices to mitigate runoff impacts on water quality (e.g., stormwater regulations, green infrastructure, and pollution prevention). Navigating tradeoffs between competing demands, environmental priorities, and water quantity and quality is key to achieving sustainable water management solutions guided by water science. For example, Virginia's 2020 State Water Resources Plan notes the Department of Environmental Quality is working on "new ways to simulate the complex inputs and outputs in Virginia's surface and groundwater resource systems, visualize effects on these systems, make trade-offs among beneficial water uses more transparent, and provide the underlying data to those that want to build on the analysis."[27]

As water-related issues grow in importance and complexity, there is a critical need for highly trained professionals who understand and can synthesize the technical and policy aspects of water resources to ensure the efficient allocation and sustainable management of water resources,

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[23] World Bank Group. (2022, October 5). *Water resources management*. https://www.worldbank.org/en/topic/waterresourcesmanagement#2
[24] EnvironmentalScience.org. (n.d.). *What is an integrated water resources manager?* https://www.environmentalscience.org/career/integrated-water-resources-manager
[25] RTI International. (2023, August 18). *Water resources management.* https://www.rti.org/focus-area/water-resources-management
[26] Loucks, D.P. & van Beek, E. (2017). Water resources planning and management: An overview. *Water resource systems planning and management*, 1-49. https://doi.org/10.1007/978-3-319-44234-1_1
[27] Virginia Department of Environmental Quality. (2022, January). *Virginia state water resources plan: A report of Virginia's water resources.* https://www.deq.virginia.gov/home/showpublisheddocument/16134/637991887436000000, p. xl

mitigate risks associated with water scarcity, pollution, and flooding, and evaluate policies aimed at preserving water quality and quantity for both human and ecological needs.[28] Graduates of the proposed degree program will be trained to work with stakeholders to translate scientific knowledge into actionable strategies that balance competing demands to address water resource challenges.

Employment Demand

Graduates of the proposed M.S. degree program in Water Resources will be qualified to serve as hydrologists, water specialists, water project managers and coordinators, and water researchers. Graduates will be prepared to work in governmental agencies such as the U.S. Geological Survey or the Virginia Department of Environmental Quality, industry sectors such as water associations or consulting firms, universities, nonprofits, and extension agencies.

The U.S. Bureau of Labor Statistics (BLS) does not currently have a separate category for water specialists, water project managers and coordinators, or water researchers. The BLS does have a separate category for hydrologists and other relevant employment categories including environmental scientists and specialists, and natural science managers.

Hydrologists

According to the U.S. Bureau of Labor Statistics (BLS), a 1% growth in employment demand is predicted for hydrologists from 2022-2032. The BLS states:

> "Despite limited employment growth, about 500 openings for hydrologists are projected each year, on average, over the decade. Demand for the services of hydrologists will stem from ongoing human activities such as mining, construction, and hydraulic fracturing. Environmental concerns, especially global climate change that may contribute to flooding and drought, are likely to increase demand for these scientists. Hydrologists will be needed to assess threats to local, state, and national water supplies and to develop comprehensive water management plans. However, the development and use of integrated technology and review systems may limit the need for some hydrologists."[29]

While the BLS notes that "hydrologists typically need a bachelor's degree for entry-level jobs," it also states that "some employers prefer to hire candidates who have a master's degree.[30]

Environmental Scientists and Specialists

According to the U.S. Bureau of Labor Statistics (BLS), a 6% growth in employment demand is predicted for environmental scientists and specialists from 2022-2032. The BLS states:

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[28] Loucks, D.P. & van Beek, E. (2017). Water resources planning and management: An overview. *Water resource systems planning and management*, 1-49. https://doi.org/10.1007/978-3-319-44234-1_1

[29] U.S. Bureau of Labor Statistics. (2024, April 4). *Hydrologists: Occupational outlook handbook for hydrologists.* https://www.bls.gov/ooh/life-physical-and-social-science/hydrologists.htm#tab-6

[30] U.S. Bureau of Labor Statistics. (2024, April 4). *Hydrologists: Occupational outlook handbook for hydrologists.* https://www.bls.gov/ooh/life-physical-and-social-science/hydrologists.htm#tab-4

> "Heightened public interest in hazards facing the environment is projected to create demand for environmental scientists and specialists. These workers will continue to be needed to analyze environmental problems and develop solutions that ensure communities' health. Businesses are expected to continue consulting with environmental scientists and specialists to help reduce the impact of their operations on the environment. For example, environmental consultants help businesses to develop practices that minimize waste, prevent pollution, and conserve resources. Other environmental scientists and specialists will be needed to help planners develop and construct buildings, utilities, and transportation systems that protect natural resources and limit damage to the land."[31]

While the BLS notes that "environmental scientists and specialists need at least a bachelor's degree in a natural science," it also states that "a master's degree may be needed for advancement."[32]

Natural Sciences Managers
According to the U.S. Bureau of Labor Statistics (BLS), a 5% growth in employment demand is predicted for natural sciences managers from 2022-2032. The BLS states:

> "Employment growth should be affected by many of the same factors that affect employment growth for the scientists whom these managers supervise. For example, when organizations hire more hydrologists for water conservation, they also may need to hire more natural sciences managers to oversee them. However, managers often are flexible in the number of workers they supervise, which may reduce demand in organizations looking to cut costs."[33]

While the BLS notes that "natural science managers" need at least a bachelor's degree," it also states that "Some employers require or prefer to hire candidates who have a master's degree or Ph.D."[34]

The Virginia Employment Commission (VEC), Labor Market Information does not have data or a job category for hydrologists. The closest occupations to "hydrologists" on which data exist are environmental scientists and specialists and natural science managers.

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[31] U.S. Bureau of Labor Statistics. (2024, April 4). *Environmental scientists and specialists: Occupational outlook handbook for environmental scientists and specialists*. https://www.bls.gov/ooh/life-physical-and-social-science/environmental-scientists-and-specialists.htm#tab-6
[32] U.S. Bureau of Labor Statistics. (2024, April 4). *Environmental scientists and specialists: Occupational outlook handbook for environmental scientists and specialists*. https://www.bls.gov/ooh/life-physical-and-social-science/environmental-scientists-and-specialists.htm#tab-4
[33] U.S. Bureau of Labor Statistics. (2024, April 4). *Natural sciences managers: Occupational outlook handbook for natural sciences managers.* https://www.bls.gov/ooh/management/natural-sciences-managers.htm#tab-6
[34] U.S. Bureau of Labor Statistics. (2024, April 4). *Natural sciences managers: Occupational outlook handbook for natural sciences managers*. https://www.bls.gov/ooh/management/natural-sciences-managers.htm#tab-4

Virginia Employment Commission, Labor Market Information 2020-2030 (10-Yr)

Occupation[35]	Base Year Employment	Projected Employment	Total Projected Difference	Total Percent Change	Annual Change	Education
Environmental Scientists and Specialists, Including Health	3,484	3,687	203	5.82%	20	Bachelor's degree
Natural Sciences Managers	1,413	1,447	34	2.41%	3	Bachelor's degree

While the VEC does not have data or a job category for hydrologists listed in its long-term occupational projections (2020-2030), it does include short-term occupational projections (2022-2024) for hydrologists.[36] These projections note estimated employment at 145, projected employment at 150, a numeric change of 5, a percent change or 3.45%, and an annual change of 2. The VEC's short-term occupational projections for hydrologists list the education level as a master's degree.

See Appendix D for employment announcements.
See Appendix E for letters of support.

Duplication

Four (4) public institutions in Virginia offer a similar or related degree program. The following universities offer graduate programs in the field of environmental studies: Christopher Newport University, George Mason University, Virginia Commonwealth University, and University of Virginia.

Christopher Newport University

Christopher Newport University (CNU) offers a M.S. in Environmental Science that is related to the proposed degree program. The degree program focuses on "ecosystem ecology, the conservation of organisms and their environment, and environmental chemistry."[37] The program requires 30-33 credit hours, including 6 credit hours of core courses, 18-24 credit hours of concentration electives (these are restricted electives) and 3-6 credit hours of a capstone course or thesis research. The program offers a thesis option and a non-thesis option. The thesis option requires 30 credit hours, including 6 credit hours of core courses, 18 credit hours of concentration electives, and 6 credit hours of thesis research. The non-thesis option requires 33 credit hours, including 6 credit hours of core courses, 24 credit hours of concentration electives, and 3 credit hours of a capstone course.

[35] Virginia Employment Commission. (n.d.). *Labor market information*. https://virginiaworks.com/Occupational-Projections
[36] Ibid
[37] Christopher Newport University. (2023, July 31). *Master of Science in Environmental Science*. Graduate Catalog, 2023-2024. https://cnu.edu/admission/graduate/envs/

Similarities
Both CNU's program and Virginia Tech's proposed program offer a thesis option and a non-thesis option requiring a research project.

Differences
CNU's program requires core coursework focused on technical and scientific writing and biometry. Virginia Tech's proposed program's does not require these topics in its core coursework. Virginia Tech's proposed program's common core coursework requires topics in watershed hydrology, hydroinformatics, water quality, watershed assessment, management, and policy, interdisciplinary issues and ethics in water resources, and contemporary issues in water science and society.

George Mason University
George Mason University (GMU) offers a M.S. in Environmental Science and Policy that is related to the proposed degree program. The program focuses on "ecosystems, conservation, environmental biocomplexity, molecular ecology, sustainability science, environmental policy and management, and human/environmental interactions."[38] The program requires 33 credit hours. There is no designated common core. Students select one 3-credit-hour course from lists of courses in each of four categories: 1) science courses, 2) statistics courses, 3) policy courses, 4) science and policy courses (12 credits), and they take two seminar courses, one in environmental science and public policy (1 credit) and one in experimental design for environmental scientists (2 credits). Students take 12-15 credit hours of concentration coursework; seven concentrations are offered: Aquatic Ecology, Conservation Science and Policy, Environmental Science and Policy, Communication for Environmental Science, Policy, and Human Behavior, Environment and Management, Energy and Sustainability Policy and Science, and Conservation Medicine and Planetary Health. The program offers a thesis option and a non-thesis option. Students in the thesis option are required to take 3-6 credit hours of thesis research. Students in the non-thesis option are required to take 3 credit hours of research project.

Similarities
GMU's program requires students to select from lists of courses with content in the areas of statistics, science, and policy. Virginia Tech's proposed program will require core coursework with the same content. Both programs offer a thesis option and a non-thesis option requiring a research project.

Differences
GMU's program does not have a designated common core. Students are required to select one 3-credit-hour course from lists of courses in each of four categories: 1) science courses, 2) statistics courses, 3) policy courses, 4) science and policy courses. Virginia Tech's proposed program has a designated 15-credit core curriculum that requires specific coursework in watershed hydrology, hydroinformatics, water quality, assessment, management, and policy, interdisciplinary issues and ethics in water resources, and contemporary issues in water science and society.

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[38] George Mason University. (n.d.). *Environmental science and policy, MS*. University Catalog, 2024-2025. https://catalog.gmu.edu/colleges-schools/science/environmental-policy/environmental-science-policy-ms/#text

GMU's program requires students to select a concentration. Virginia Tech's proposed program does not offer concentrations.

University of Virginia
The University of Virginia (UVA) offers an M.A./M.S. in Environmental Sciences degree program that is related to the proposed degree program. The program is focused on the areas of "ecology, geosciences, hydrology, and atmospheric sciences."[39] The program requires 30 credit hours, including 24 hours of graded coursework. There is no designated common core. Students are required to take at least one 3-4 credit hour course in each of the following four areas: 1) ecology, 2) geosciences, 2) hydrology, 4) atmospheric sciences. Students must also complete 3 credit hours of seminar coursework and 6 credit hours of research. Students in the M.A. degree designation only are required to take at least one 3-4 credit hour application-related course (e.g., geographical information systems (GIS), remote sensing, environmental statistics). All students are required to complete a thesis.

Similarities
There are no similarities between UVA's M.A./M.S. in Environmental Sciences degree program and Virginia Tech's proposed program.

Differences
UVA's program does not have a designated common core. Students are required to select at least one 3-4-credit-hour course from each of the four areas: 1) ecology, 2) geosciences, 3) hydrology, 4) atmospheric sciences. Virginia Tech's proposed program has a 15-credit core curriculum that requires specific coursework in watershed hydrology, hydroinformatics, water quality, assessment, management, and policy, interdisciplinary issues and ethics in water resources, and contemporary issues in water science and society.

UVA's program requires students to complete a thesis. Virginia Tech's proposed program offers a thesis option and a non-thesis option.

Virginia Commonwealth University
Virginia Commonwealth University (VCU) offers a M.S./M.Envs. in Environmental Studies degree that is related to the proposed degree program. The program focuses on environmental science, environmental technology, and environmental policy, emphasizing the links between environmental life sciences and public policy.[40] The program requires 33 credit hours. The M.S degree designation requires 13 credit hours of core coursework, 7 credit hours of electives, and 13 credit hours of research/thesis. The M.Envs. degree designation requires 12 credit hours of core coursework, 18 credit hours of electives, and 3 credit hours of practical experience, such as an internship or independent study.

Similarities

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[39] University of Virginia. (n.d.). *Graduate program in environmental sciences*. Department of Environmental Sciences. https://evsc.as.virginia.edu/graduate

[40] Virginia Commonwealth University. (n.d.). *Environmental Studies, Master of Science (M.S.).* VCU Bulletin, 2024-25 Edition.
https://bulletin.vcu.edu/graduate/vcu-life-sciences/center-environmental-studies/environmental-studies-ms/

The VCU program requires core coursework in statistical and research methods in environmental science. Virginia Tech's proposed program will require core coursework with the same content specifically focused on water. Both programs offer a thesis option and a non-thesis option.

Differences
VCU's program requires core coursework in environmental studies and Geographic Information Systems (GIS). Virginia Tech's proposed program's core coursework does not require these topics.

Virginia Tech's proposed program's core coursework requires topics in watershed hydrology, water quality watershed assessment, management, and policy, interdisciplinary issues and ethics in water resources, and contemporary issues in water science and society. VCU's program does not require these topics in its core curriculum.

VCU's non-thesis option requires 3 credits of practical experience, such as an internship or independent study. Virginia Tech's proposed program's non-thesis option requires a project and report.

Enrollment and Degrees Awarded of Comparable Programs in Virginia

Enrollments[41]	**Fall 2019**	**Fall 2020**	**Fall 2021**	**Fall 2022**	**Fall 2023**
Christopher Newport University	17	22	28	26	21
George Mason University	61	55	56	51	38
University of Virginia (MA/MS)	15	18	30	21	21
Virginia Commonwealth University	28	25	23	14	17
Degrees Awarded[42]	**2020**	**2021**	**2022**	**2023**	**2024**
Christopher Newport University	1	8	14	13	9
George Mason University	22	14	9	13	13
University of Virginia (MA/MS)	3	7	7	11	9
Virginia Commonwealth University	12	13	10	10	5

Student Demand

Evidence for student demand comes from one source: a survey of demand among Virginia Tech undergraduate students.

Student Survey
In November-December 2023, an electronic, anonymous online survey of undergraduate students at Virginia Tech was conducted. The survey was sent to undergraduate students in 22 courses within AAEC, BIOL, BSE, CEE, ENGL, ENSC, FREC, GEOG, and GEOS. They were enrolled in the following degree programs: B.S. in Animal and Poultry Science, B.S. in Applied

[41] State Council of Higher Education for Virginia (SCHEV). *Enrollment summary by program level*. https://research.schev.edu//enrollment/E01_Report.asp
[42] State Council of Higher Education for Virginia (SCHEV). *Completions, Program Detail*. https://research.schev.edu//Completions/C1Level2_Report.asp

Economic Management, B.S. in Biological Systems Engineering, B.S. in Civil Engineering, B.S. in Environmental Science, B.S. in Fish and Wildlife Conservation, B.S. in Forest Resources and Environmental Conservation, , B.S. in Geosciences, B.A. in International Studies, B.S. in Meteorology, B.S. in Mining Engineering, B.S. in Statistics, and B.S. in Water: Resources, Policy, and Management. The online survey remained open for approximately two weeks. A total of 77 undergraduate students completed the survey. Of those, 55 were seniors and 22 were juniors.

Of the 55 seniors, 4 (7 %) responded “definitely,” 6 (11%) responded “very likely,” and 11 (20%) responded “likely” when asked, if Virginia Tech offered the proposed M.S. in Water Resources degree program, how likely is it you would enroll. Of the 22 juniors, 0 (0%) responded “definitely,” 2 (9%) responded “very likely,” and 4 (18%) responded “likely" when asked, if Virginia Tech offered the proposed M.S. in Water Resources degree program, would you enroll.

See Appendix F for the original survey. A summary of responses is included after the survey.

State Council of Higher Education for Virginia
Summary of Projected Enrollments in Proposed Program

Year 1		Year 2		Year 3		Year 4 **Target Year (2-year institutions)**			Year 5 **Target Year (4-year institutions)**		
2025 - 2026		2026 - 2027		2027 - 2028		2028 - 2029			2029 - 2030		
HDCT 10	FTES 10	HDCT 25	FTES 25	HDCT 30	FTES 30	HDCT 30	FTES 30	GRAD _____	HDCT 30	FTES 30	GRAD 30

Assumptions:
Retention percentage: 95%
Full-time students: 100% Part-time students: 0%
Full-time students credit hours per semester: 12
Full-time students graduate in 3 semesters

Projected Resources for the Proposed Program

Resource Needs

Virginia Tech, the Departments of Forest Resources and Environmental Conservation, Geography, and Geosciences as well as the School of Plant and Environmental Sciences have all of the faculty, classified support, equipment, space, library, and other resources necessary to initiate the proposed M.S. in Water Resources degree program. The proposed program allocates 1.0 FTE of instructional effort for every 8.0 FTE of student enrollment. The proposed program will require a total of 1.25 FTE faculty instructional effort in the initial year rising to 3.75 FTE faculty instructional effort by the fifth year.

Full-time Faculty
In year one, two (2) existing faculty members from the Department of Forest Resources and Environmental Conservation will be reallocated to dedicate 0.50 FTE of instructional effort each to the proposed program.

A total of 1.0 FTE full-time instructional effort will be dedicated to the proposed program in year one.

In year two, two (2) existing faculty members from the Department of Forest Resources and Environmental Conservation will increase instructional effort to dedicate 1.0 FTE of instructional effort each to the proposed program. One (1) existing faculty member from the School of Plant and Environmental Sciences will be reallocated to dedicate 0.75 FTE of instructional effort each to the proposed program.

A total of 2.75 FTE full-time faculty instructional effort will be dedicated to the proposed program in year two.

In year three, two (2) of the existing faculty members from the Department of Forest Resources and Environmental Conservation will continue to dedicate 1.0 FTE of instructional effort each to the proposed program. One (1) existing faculty member from the School of Plant and Environmental Sciences will increase instructional effort, to dedicate 1.0 FTE of instructional effort each to the proposed program. A total of 3.0 FTE full-time faculty instructional effort will be dedicated to the proposed program in year three. This level of full-time faculty instructional effort will remain constant through the target year.

A total of 3.0 FTE full-time faculty instructional effort will be dedicated to the proposed program in year three and will remain constant through year five.

Part-time Faculty
In year one, one (1) existing faculty member from the School of Plant and Environmental Sciences will be reallocated to dedicate 0.25 FTE of instructional effort to the proposed program.

A total of 0.25 FTE part-time faculty instructional effort will be dedicated to the proposed program in year one.

In year two, one (1) existing faculty members from the School of Plant and Environmental Sciences will continue to dedicate 0.25 FTE of instructional effort each to the proposed program. One (1) existing faculty member from the Department of Geography will be reallocated to dedicate 0.25 FTE of instructional effort to the proposed program. One (1) existing faculty member from the Department of Geosciences will be reallocated to dedicate 0.25 FTE of instructional effort to the proposed program.

A total of 0.75 FTE part-time faculty instructional effort will be dedicated to the proposed program in year two. This level of part-time faculty instructional effort will remain constant through the target year.

Adjunct Faculty
No adjunct faculty are required to initiate or sustain the proposed degree program.

Graduate Assistants
No graduate assistants are required to initiate or sustain the proposed degree program.

Classified Positions
In year one, a Program Coordinator will be hired to support the proposed program. The Program Coordinator position will require 0.50 FTE of classified support to initiate, and this level of effort will remain constant through the target year. Salary proportion paid for by the program for the program coordinator will be $30,000 with fringe benefits of $14,316 for a total of $44,316.

Equipment (including computers)
No new equipment, including computers, is required to initiate or sustain the proposed degree program. Adequate equipment currently exists for the new Program Coordinator to be hired.

Library
No additional library resources are required to initiate or sustain the proposed degree program. The library has an adequate collection to support the proposed program. Resources include journals and publications for water quality, watershed management, and water resources. As a member of the Virtual Library of Virginia (VIVA), on-line access to journals is also available for the proposed degree program.

Telecommunications
No additional telecommunications costs are needed to initiate or sustain the proposed degree program. Adequate telecommunications equipment currently exists for the new Program Coordinator to be hired.

Space
No additional space is required to initiate or sustain the proposed degree program. Adequate office space currently exists for the new Program Coordinator to be hired.

Targeted Financial Aid
No targeted financial aid is required to initiate or sustain the proposed degree program.

Special Tuition or Fee Charges
No special tuition or fee charges will be utilized or instituted to initiate and sustain the proposed degree program.

Other resources (specify)
No other resources are needed to launch or sustain the proposed program.

Funds to Initiate and Operate the Degree Program

Figures provided in the table below will be compared to SCHEV funding estimates using the current base adequacy model. This comparison will serve as a reference for the estimated costs. If there are large discrepancies, SCHEV may request additional clarification to ensure the institution's assumptions are correct, or require modifications as a condition of approval.

Note: Institutions must use the recommended student-faculty ratio when estimating FTES enrollments and required faculty FTEs.

Cost and Funding Sources to Initiate and Operate the Program			
Informational Category		Program Initiation Year	Program Target Year
		20 25 - 20 26	20 27 - 20 28
1.	Projected Enrollment (Headcount)	10	30
2.	Projected Enrollment (FTES)	10	30
3.	Projected Enrollment Headcount of In-State Students	9	27
4.	Projected Enrollment Headcount of Out-of-State Students	1	3
5.	Estimated Annual Tuition and E&G Fees for In-State Students in the Proposed Program	$15,881	$15,881
6.	**Revenue** from Tuition and E&G Fees for In-State Students Due to the Proposed Program	$142,929	$428,787
7.	Estimated Annual Tuition and E&G Fees for Out-of-State Students in the Proposed Program	$32,407	$32,407
8.	**Revenue** from Tuition and E&G Fees for Out-of-State Students Due to the Proposed Program	$32,407	$97,221
9.	**Projected Revenue Total from Tuition and E&G Fees Due to the Proposed Program**	**$175,336**	**$526,008**
10.	Other Funding Sources Dedicated to the Proposed Program (e.g., grant, business, private sources, university funds)	$0	$0
11.	**Total Funding**	**$175,336**	**$526,008**

Part V: Certification Statements

1. A request of any kind will be submitted to the General Assembly for funds to initiate and/or maintain the proposed degree program.

   Yes ☐
   No ☒

   If "Yes" is checked, include narrative text to describe: when the request will be made, how much will be requested, what the funds will be used for, and what will be done if the request is not fulfilled.

2. The proposed degree program is included in the institution's most recent six-year plan.

   Yes ☐
   No ☒

   If "No" is checked, include narrative text to explain why the program is being advanced at the present time despite not being included in the six-year plan.

The proposed Master of Science (M.S.) in Water Resources degree program has been under development for approximately 3 years and had been previously included on the Virginia Tech 6-year plan. The degree program has been fully vetted through the institution's internal process.

Subtle updates in the 2024-2030 six-year plan submission template led to less specificity in the institution's response and as a result, a formal list of planned new degree programs was not included by the institution. A comprehensive process for communicating and validating that new degree programs are appropriately identified within the six-year plan is being implemented for future submissions.

3. The institution's governing board has been provided information regarding duplication (if applicable) and labor market projections as part of its approval action.

   Yes ☒
   No ☐

   If "No" is checked, include narrative text to explain why the governing board has not been provided the information.

The institution's Chief Academic Officer attests to the accuracy of the above statements

Cyril R. Clarke, Executive Vice President and Provost
Name (Printed)

	Month Day, Year
Signature	Date

Appendices

Appendix A – Sample Plan of Study

Thesis Option

All new courses are denoted with an asterisk.

Year 1 Fall	**Credits**	**Year 1 Spring**	**Credits**
CSES 5314: Water Quality for Professionals	3	FREC/WATR 5244G: Advanced Hydroinformatics	3
FREC/CSES 5144: Watershed Hydrology	3	WATR 5004: Seminar in Water Science and Policy *	1
GEOG 5134/GEOS 5844: Advanced Interdisciplinary Issues and Ethics in Water Resources *	3	WATR 5614G: Advanced Watershed Assessment, Management and Policy	2
Elective	3	Elective	3
Total	**12**	**Total**	**9**
Year 2 Fall	**Credits**		
GRAD 5994: Research and Thesis	6		
Elective	3		
Total	**9**		

Full-Time Students

Credit Hours – Year 1 – Fall Term	12
Credit Hours – Year 1 – Spring Term	9
Credit Hours – Year 2 – Fall Term	9

Total Credit Hours **30**

Sample Plan of Study

Non-Thesis Option

All new courses are denoted with an asterisk.

Year 1 Fall	**Credits**	**Year 1 Spring**	**Credits**
CSES 5314: Water Quality for Professionals	3	FREC/WATR 5244G: Advanced Hydroinformatics	3
FREC/CSES 5144: Watershed Hydrology	3	WATR 5004: Seminar in Water Science and Policy *	1
GEOG 5134/GEOS 5844: Advanced Interdisciplinary Issues and Ethics in Water Resources *	3	WATR 5614G: Advanced Watershed Assessment, Management and Policy	2
Elective	3	Elective	3
Total	**12**	**Total**	**9**
Year 2 Fall	**Credits**		
GRAD 5904: Project and Report	3		
Elective	3		
Elective	3		
Total	**9**		

Full-Time Students
Credit Hours – Year 1 – Fall Term 12
Credit Hours – Year 1 – Spring Term 9
Credit Hours – Year 2 – Fall Term 9

Total Credit Hours 30

Appendix B – Course Descriptions

Core Courses

New courses are denoted with an asterisk.

CSES 5314: Water Quality for Professionals (3 credits)
Global water resource sustainability and management. Current water quality policies. Physical, chemical, biological, and anthropogenic factors affecting water quality, fate and transport of contaminants in water. Approaches of water quality risk assessment. Water treatment and management technologies. Pre: Graduate Standing.

FREC 5144/CSES 5144: Watershed Hydrology (3 credits)
Physical concepts of hydrological processes that affect age, origin, cycling, and flowpaths of water within watersheds. Analysis of current and historical research methods. Hydrological science as an interdisciplinary topic. Pre: Graduate standing.

FREC/WATR 5244G: Advanced Hydroinformatics (3 credits)
Analysis and examination of hydrologic data using basic statistics in computer programming. Calculation and interpretation of flow frequency and duration, hydrologic analysis of geospatial digital terrain data, and implementation and analysis of simple hydrologic models. Advanced methods of temporal and spatial hydrologic data visualization using computer programming. Pre: Graduate standing.

GEOG 5134/GEOS 5844: Advanced Interdisciplinary Issues and Ethics in Water Resources (3 credits) *
Issues and ethics related to water resources, water as a hazard upon human (infrastructure, economy) and ecological (rivers, groundwater) systems, water- and vector-borne disease, climate change, dams, and eutrophication. Multidimensionality of water resources. Pre: Graduate standing.

WATR 5004: Seminar in Water Science and Society (1 credit) *
Interdisciplinary seminar on contemporary issues in water science and society. Critical evaluation, comparison, and discussion of effective science communication, current research issues, findings, and interdisciplinary approaches in water science, policy, and management. May be repeated three times with different content for a maximum of four credit hours. Pre: Graduate standing.

WATR 5614G: Advanced Watershed Assessment Management and Policy (2 credits)
Multidisciplinary perspectives of assessment, management, and policy issues for protecting and improving watersheds ecosystems. Topics include: monitoring and modeling approaches for assessment, risk-based watershed assessment, geographic information systems for watershed analysis, decision support systems and computerized decision tools for watershed management, policy alternatives for watershed protection, urban watersheds, and current issues in watershed management. Pre: Graduate standing.

Appendix C – Faculty Curriculum Vitae (abbreviated)

College of Agriculture and Life Sciences

School of Plant and Environmental Sciences

Stewart, Ryan, Ph.D. in Water Resource Engineering, 2013, Oregon State University, Associate Professor, Specialization: Soil hydrology, water resources management.

Xia, Kang, Ph.D. in Soil Chemistry, 1997, University of Wisconsin-Madison, Professor, Specialization: Environmental occurrence, fate, and impact of contaminants in water and soil, wastewater treatment.

College of Natural Resources and Environment

Department of Forest Resources and Environmental Conservation

Gannon, John, Ph.D. in Forest Resources and Environmental Conservation, 2014, Virginia Polytechnic Institute and State University, Collegiate Associate Professor, Specialization: streamflow generation in rivers and streams across scales, college teaching.

McGuire, Kevin, Ph.D. in Hydrology, 2004, Oregon State University, Professor, Specialization: Hydrology, watershed management, watershed processes and water quality.

Department of Geography

Juran, Luke, Ph.D. in Geography, 2012, University of Iowa, Associate Professor, Specialization: Household water quality, water sanitation and hygiene, community water management, hazards and disasters.

College of Science

Department of Geosciences

Schreiber, Madeline, Ph.D. in Geology, 1999, University of Wisconsin-Madison, Professor, Specialization: Chemical hydrogeology, hydrogeosciences.

Appendix D – Employment Demand
Job Announcements

Appendix E – Letters of Support
(Employment Demand)

Appendix F – Student Demand Survey