

W.G. Jackson and D.J. Angus Scientific Cruises
February 2011

The list below shows the High School Earth Science content expectations that are highlighted on the water quality sampling trips. Strong elements of the program are in the inquiry, reflection and social implications category. The experience integrates earth science, chemistry and biology. Some Earth Science Content Expectations that are not specifically addressed are not on this list. For more information or to add more to this list contact GVSU Annis Water Resources Institute at 616-331-3048.

HSCE Code	Expectation	Current Instructional Materials and Activities
Standard E1	INQUIRY, REFLECTION, AND SOCIAL IMPLICATIONS	
Statement E1.1	Scientific Inquiry Science is a way of understanding nature. Scientific research may begin by generating new scientific questions that can be answered through replicable scientific investigations that are logically developed and conducted systematically. Scientific conclusions and explanations result from careful analysis of empirical evidence and the use of logical reasoning. Some questions in science are addressed through indirect rather than direct observation, evaluating the consistency of new evidence with results predicted by models of natural processes. Results from investigations are communicated in reports that are scrutinized through a peer review process.	Key to the cruises on the <i>W.G. Jackson</i> and the <i>D.J. Angus</i> is hands-on, inquiry science. The students practice the scientific method to make observations that allow them to evaluate water quality.
E1.1A	Generate new questions that can be investigated in the laboratory or field.	Students practice methods that can be applied to answer questions in their own projects.
E1.1B	Evaluate the uncertainties or validity of scientific conclusions using an understanding of sources of measurement error, the challenges of controlling variables, accuracy of data analysis, logic of argument, logic of experimental design, and/or the dependence on underlying assumptions.	Protocols are followed for sampling and analysis. The importance of replicates and careful measurement is stressed.
E1.1C	Conduct scientific investigations using appropriate tools and techniques (e.g., selecting an instrument that measures the desired quantity—length, volume, weight, time interval, temperature—with the appropriate level of precision).	Students use a wide variety of tools and techniques including pH meters, dissolved oxygen kits, Secchi disks, grab samplers, turbidity meters, alkalinity kits, plankton nets, thermometers, etc.
E1.1D	Identify patterns in data and relate them to theoretical models.	Data generated are analyzed for patterns of the quality of a water body – eutrophic, mesotrophic, and oligotrophic.
E1.1E	Describe a reason for a given conclusion using evidence from an investigation.	During a summary on the vessel, students use evidence from their investigations to rate a water body.
E1.1f	Predict what would happen if the variables, methods, or timing of an investigation were changed.	In the context of analysis and sampling, students can predict what would affect results. The summary emphasizes that variation in environmental conditions such as weather and time of year influence results.
E1.1g	Based on empirical evidence, explain and critique the reasoning used to draw a scientific conclusion or explanation.	In the summary, conclusions are drawn based upon the information collected by the students.
E1.1h	Design and conduct a systematic scientific investigation that tests a hypothesis. Draw conclusions from data presented in charts or tables.	As a follow-up to cruises, students are encouraged to design their own experiments. A data chart is used in our summary.

E1.1i	Distinguish between scientific explanations that are regarded as current scientific consensus and the emerging questions that active researchers investigate.	How climate change may affect the Great Lakes and what will be the impacts of shoreline restoration are mentioned.
Statement E1.2	Scientific Reflection and Social Implications The integrity of the scientific process depends on scientists and citizens understanding and respecting the “Nature of Science.” Openness to new ideas, skepticism, and honesty are attributes required for good scientific practice. Scientists must use logical reasoning during investigation design, analysis, conclusion, and communication. Science can produce critical insights on societal problems from a personal and local scale to a global scale. Science both aids in the development of technology and provides tools for assessing the costs, risks, and benefits of technological systems. Scientific conclusions and arguments play a role in personal choice and public policy decisions. New technology and scientific discoveries have had a major influence in shaping human history. Science and technology continue to offer diverse and significant career opportunities.	Stakeholders in fashioning solutions to the problems in the Muskegon Lake Area of Concern involve not only AWRI scientists but social scientists and the general public as well. On the <i>W. G. Jackson</i> , students evaluate water quality in Lake Michigan and Muskegon Lake from a scientific perspective. On the <i>D. J. Angus</i> , the focus is Spring Lake and the Grand River Watershed. They learn about how government agencies and the scientific community work together. Elements of E1.2A through E1.2K are all addressed on cruises.
Standard E2	EARTH SYSTEMS	
Statement E2.1	Earth Systems Overview The Earth is a system consisting of four major interacting components: geosphere (crust, mantle, and core), atmosphere (air), hydrosphere (water), and biosphere (the living part of Earth). Physical, chemical, and biological processes act within and among the four components on a wide range of time scales to continuously change Earth’s crust, oceans, atmosphere, and living organisms. Earth elements move within and between the lithosphere, atmosphere, hydrosphere, and biosphere as part of geochemical cycles.	The interplay between Muskegon Lake, Spring Lake, the Grand River, and Lake Michigan serve as examples of earth as a system.
E2.1A	Explain why the Earth is essentially a closed system in terms of matter.	Historical contamination of Muskegon Lake and phosphorus loading in Spring Lake illustrate this concept.
E2.1B	Analyze the interactions between the major systems (geosphere, atmosphere, hydrosphere, biosphere) that make up the Earth.	Students take environmental measurements in these four areas with the intent of analyzing the interactions.
E2.1C	Explain, using specific examples, how a change in one system affects other Earth systems.	Specific examples of change are explored such as the impact of zebra and quagga mussels on water clarity.
Statement E2.2	Energy in Earth Systems Energy in Earth systems can exist in a number of forms (e.g., thermal energy as heat in the Earth, chemical energy stored as fossil fuels, mechanical energy as delivered by tides) and can be transformed from one state to another and move from one reservoir to another. Movement of matter and its component elements, through and between Earth’s systems, is driven by Earth’s internal (radioactive decay and gravity)	The “on the water” experience helps students to understand the difference in energy storage in land and water.

	<p>and external (Sun as primary) sources of energy. Thermal energy is transferred by radiation, convection, and conduction. Fossil fuels are derived from plants and animals of the past, are nonrenewable and, therefore, are limited in availability. All sources of energy for human consumption (e.g., solar, wind, nuclear, ethanol, hydrogen, geothermal, hydroelectric) have advantages and disadvantages.</p>	
E2.2A	Describe the Earth's principal sources of internal and external energy (e.g., radioactive decay, gravity, solar energy).	Solar energy and its effect on bodies of water is explored.
E2.2B	Identify differences in the origin and use of renewable (e.g., solar, wind, water, biomass) and nonrenewable (e.g., fossil fuels, nuclear [U-235]) sources of energy.	Students view a power plant and often see delivery of coal via freighters.
E2.2C	Describe natural processes in which heat transfer in the Earth occurs by conduction, convection, and radiation.	Stratification of lakes is used as an example of heat transfer.
E2.2D	Identify the main sources of energy to the climate system.	Students take temperature readings for the water column and the air. They connect temperature differences to solar energy and heat storage capacity.
E2.2e	Explain how energy changes form through Earth systems.	Photosynthesis in algae converts solar to chemical energy; solar energy heats the water.
E2.2f	Explain how elements exist in different compounds and states as they move from one reservoir to another.	Dissolved oxygen vs. atmospheric oxygen and location of phosphorus in lake systems illustrate movements to different reservoirs.
Statement E2.3	<p>Biogeochemical Cycles</p> <p>The Earth is a system containing essentially a fixed amount of each stable chemical atom or element. Most elements can exist in several different states and chemical forms; they move within and between the geosphere, atmosphere, hydrosphere, and biosphere as part of the Earth system. The movements can be slow or rapid. Elements and compounds have significant impacts on the biosphere and have important impacts on human health.</p>	Case studies from the work of AWRI scientists address this concept.
E2.3A	Explain how carbon exists in different forms such as limestone (rock), carbon dioxide (gas), carbonic acid (water), and animals (life) within Earth systems and how those forms can be beneficial or harmful to humans.	Students measure alkalinity and study the carbonate-bicarbonate buffering system.
E2.3b	Explain why small amounts of some chemical forms may be beneficial for life but are poisonous in large quantities (e.g., dead zone in the Gulf of Mexico, Lake Nyos in Africa, fluoride in drinking water).	Especially in Muskegon Lake, attention is given to the historical sources of contamination, which include mercury and various organic compounds.
E2.3c	Explain how the nitrogen cycle is part of the Earth system.	On advanced trips, students measure nitrate levels using a spectrophotometer.
E2.3d	Explain how carbon moves through the Earth system (including the geosphere) and how it may benefit (e.g., improve soils for agriculture) or harm (e.g., act as a pollutant) society.	On advanced trips, students measure carbon dioxide in water and relate it to the carbon cycle.
Statement E2.4	<p>Resources and Human Impacts on Earth Systems</p> <p>The Earth provides resources (including minerals) that are used to sustain human affairs. The supply of non-renewable natural resources is</p>	Human activities and their effects on Spring Lake, Muskegon Lake, Grand River and Lake Michigan are part of the cruise narrative.

	<p>limited and their extraction and use can release elements and compounds into Earth systems. They affect air and water quality, ecosystems, landscapes, and may have effects on long-term climate. Plans for land use and long-term development must include an understanding of the interactions between Earth systems and human activities.</p>	
E2.4A	<p>Describe renewable and nonrenewable sources of energy for human consumption (electricity, fuels), compare their effects on the environment, and include overall costs and benefits.</p>	<p>Energy sources are illustrated as students view a coal-burning power plant from the water</p>
E2.4B	<p>Explain how the impact of human activities on the environment (e.g., deforestation, air pollution, coral reef destruction) can be understood through the analysis of interactions between the four Earth systems.</p>	<p>Students look for evidence of past and present human activities on the environment (lumbering, water pollution) using an earth systems perspective.</p>
Standard E3	THE SOLID EARTH	
Statement E3.p1	<p>Landforms and Soils (prerequisite) Landforms are the result of a combination of constructive and destructive forces. Constructive forces include crustal deformation, volcanic eruptions, and deposition of sediments transported in rivers, streams, and lakes through watersheds. Destructive forces include weathering and erosion. The weathering of rocks and decomposed organic matter result in the formation of soils. <i>(prerequisite)</i></p>	<p>The pathways of rivers as they flow into Lake Michigan as well as coastal features are highlighted.</p>
E3.p1A	<p>Explain the origin of Michigan landforms. Describe and identify surface features using maps and satellite images. <i>(prerequisite)</i></p>	<p>From the on the water vantage point, students relate surface features to maps and satellite images.</p>
E3.p1B	<p>Explain how physical and chemical weathering leads to erosion and the formation of soils and sediments. <i>(prerequisite)</i></p>	<p>Lake sediments are collected and compared/contrasted.</p>
E3.p1C	<p>Describe how coastal features are formed by wave erosion and deposition. <i>(prerequisite)</i></p>	<p>Students observe shorelines, sand dunes, and experience wave action.</p>
Standard E4	THE FLUID EARTH	
Statement E4.p1	<p>Water Cycle (prerequisite) Water circulates through the crust and atmosphere and in oceans, rivers, glaciers, and ice caps and connects all of the Earth systems. Groundwater is a significant reservoir and source of freshwater on Earth. The recharge and movement of groundwater depends on porosity, permeability, and the shape of the water table. The movement of groundwater occurs over a long period time. Groundwater and surface water are often interconnected. <i>(prerequisite)</i></p>	<p>The <i>W. G. Jackson</i> and <i>D. J. Angus</i> trips are primarily focused on the fluid earth.</p>
E4.p1A	<p>Describe that the water cycle includes evaporation, transpiration, condensation, precipitation, infiltration, surface runoff, groundwater, and absorption. <i>(prerequisite)</i></p>	<p>Students observe the water cycle in action on their trips.</p>

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E4.p1B	Analyze the flow of water between the elements of a watershed, including surface features (lakes, streams, rivers, wetlands) and groundwater. <i>(prerequisite)</i>	A typical cruise follows the water flow through a watershed into Lake Michigan.
E4.p1C	Describe the river and stream types, features, and process including cycles of flooding, erosion, and deposition as they occur naturally and as they are impacted by land use decisions. <i>(prerequisite)</i>	The Grand River (<i>D.J. Angus</i>) and Muskegon Lake (<i>W. G. Jackson</i>) are used as examples for this concept.
E4.p1D	Explain the types, process, and beneficial functions of wetlands.	Wetlands in Spring Lake and Muskegon Lake are noted.
Statement E4.p2	Weather and the Atmosphere <i>(prerequisite)</i> The atmosphere is divided into layers defined by temperature. Clouds are indicators of weather. <i>(prerequisite)</i>	Students make weather measurements including temperature and cloud cover.
E4.p2A	Describe the composition and layers of the atmosphere. <i>(prerequisite)</i>	
E4.p2B	Describe the difference between weather and climate. <i>(prerequisite)</i>	In a discussion of climate change, weather is contrasted with climate.
E4.p2C	Explain the differences between fog and dew formation and cloud formation. <i>(prerequisite)</i>	Under certain conditions, students may experience fog on their trip,
E4.p2D	Describe relative humidity in terms of the moisture content of the air and the moisture capacity of the air and how these depend on the temperature. <i>(prerequisite)</i>	On some trips, relative humidity measurements are taken.
E4.p2E	Describe conditions associated with frontal boundaries (cold, warm, stationary, and occluded). <i>(prerequisite)</i>	The trips go out in all kinds of weather, which is related to frontal boundaries.
Statement E4.p3	Glaciers <i>(prerequisite)</i> Glaciers are large bodies of ice that move under the influence of gravity. They form part of both the rock and water cycles. Glaciers and ice sheets have shaped the landscape of the Great Lakes region. Areas that have been occupied by ice sheets are depressed. When the ice sheet is removed, the region rebounds (see also climate change). <i>(prerequisite)</i>	This Great Lakes experience can be put in the context of geologic history.
E4.p3A	Describe how glaciers have affected the Michigan landscape and how the resulting landforms impact our state economy. <i>(prerequisite)</i>	Students observe the results of glacial activity in the landscape. Sand mining is mentioned.
E4.p3B	Explain what happens to the lithosphere when an ice sheet is removed. <i>(prerequisite)</i>	
E4.p3C	Explain the formation of the Great Lakes. <i>(prerequisite)</i>	The formation of the Great Lakes, specifically Lake Michigan, is discussed.
Statement E4.1	Hydrogeology Fresh water moves over time between the atmosphere, hydrosphere (surface water, wetlands, rivers, and glaciers), and geosphere (groundwater). Water resources are both critical to and greatly impacted by humans. Changes in water systems will impact quality, quantity, and movement of water. Natural surface water processes shape the landscape everywhere and are affected by human land use decisions.	The overarching theme of the experience on the <i>W. G. Jackson</i> or the <i>D. J. Angus</i> is water.
E4.1A	Compare and contrast surface water systems (lakes, rivers, streams, wetlands) and groundwater in regard to their relative sizes as	“Compare” and “contrast” are two important elements of the exploration of water systems on cruises. Water quality is related to reservoir size and water movement.

	Earth's freshwater reservoirs and the dynamics of water movement (inputs and outputs, residence times, sustainability).	
E4.1B	Explain the features and processes of groundwater systems and how the sustainability of North American aquifers has changed in recent history (e.g., the past 100 years) qualitatively using the concepts of recharge, residence time, inputs, and outputs.	Although not addressed directly, groundwater can influence surface water quality.
E4.1C	Explain how water quality in both groundwater and surface systems is impacted by land use decisions.	Students observe and explore how shoreline development relates to water quality.
Statement E4.2	Oceans and Climate Energy from the Sun and the rotation of the Earth control global atmospheric circulation. Oceans redistribute matter and energy around the Earth through currents, waves, and interaction with other Earth systems. Ocean currents are controlled by prevailing winds, changes in water density, ocean topography, and the shape and location of landmasses. Oceans and large lakes (e.g., Great Lakes) have a major effect on climate and weather because they are a source of moisture and a large reservoir of heat. Interactions between oceanic circulation and the atmosphere can affect regional climates throughout the world.	The specific content expectations for this section relate to the ocean. By analogy, Lake Michigan can be used to illustrate currents, waves, and moderating effect of large water bodies on climate.,
Standard E5	THE EARTH IN SPACE AND TIME	
Statement E5.4	Climate Change Atmospheric gases trap solar energy that has been reradiated from the Earth's surface (the greenhouse effect). The Earth's climate has changed both gradually and catastrophically over geological and historical time frames due to complex interactions between many natural variables and events. The concentration of greenhouse gases (especially carbon dioxide) has increased due to human industrialization which has contributed to a rise in average global atmospheric temperatures and changes in the biosphere, atmosphere, and hydrosphere. Climates of the past are researched, usually using indirect indicators, to better understand and predict climate change.	Climate change in the Great Lakes is a topic of interest by AWRI researchers as well as those seeking to restore the Great Lakes. Examples of possible climate change effects and mitigation strategies can be explored on cruises.