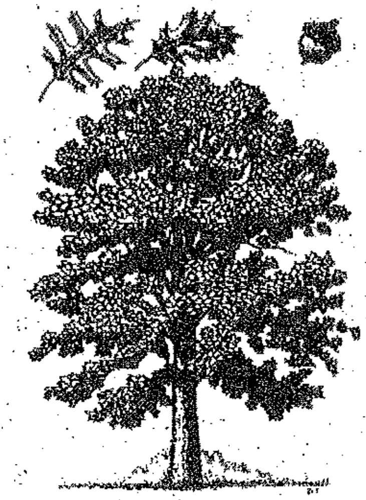


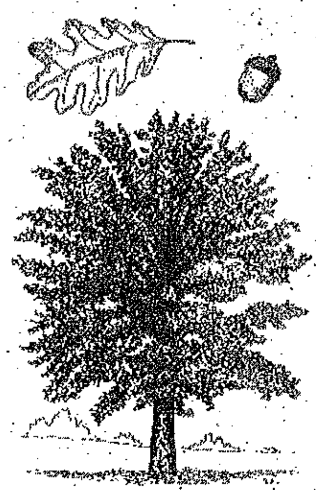
Black Oak
Quercus velutina

Northern Red Oak
Quercus rubra

A Teacher's Guide to Black Rock Forest

A Manual for Use in the Classroom and in the Field

Scarlet Oak
Quercus coccinea



White Oak
Quercus alba

FRIENDS SEMINARY

MISSION STATEMENT

Friends Seminary educates students from kindergarten through twelfth grade, under the care of the New York Quarterly Meeting of the Religious Society of Friends. Through instruction and example, students follow their curiosity and exercise their imaginations as they develop as scholars, artists and athletes. In a community that cultivates the intellect through keen observation, critical thinking and coherent expression, we strive to respond to one another, valuing the single voice as well as the effort to reach consensus. The disciplines of silence, study and service provide the matrix for growth: silence opens us to change; study helps us to know the world; service challenges us to put our values into practice. At Friends Seminary, education occurs within the context of the Quaker belief in the Inner Light--that of God in every person. Guided by the ideals of integrity, peace, equality and simplicity, we do more than prepare students for the world that is: we help them bring about the world that ought to be.*

*This last sentence is adapted *from Faith and Practice: The Book of Discipline of the New York Yearly Meeting of the Religious Society of Friends (1974).*

Approved by the Friends Seminary Committee and the Faculty, February 1997

Mission Statement for Community Services at Friends Seminary

Along with the disciplines of study and silence, service is integral to the Friends Seminary's educational mission. Our Community Service Program strives to instill a sense of stewardship of the school community and respect for and responsibility to our urban neighborhood and beyond. By providing opportunities within the curriculum and in other relevant activities for students to witness and understand the needs of others, we hope to prepare them for a life that includes service. Our goal is to integrate knowledge and understanding with compassion and social responsibility. Only through reflection and ~~taking seriously the need~~ commitment to put our values into practice will students be able to grasp the importance of the gift of caring for all humanity and the natural world.

(Adopted by the Educational Policies Committee December, 2003)

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Acknowledgements

"A Teacher's Guide to Black Rock Forest" came into being with the contributions and collaborations of several interested and helpful parties. I am most grateful to the *Friends Seminary Sabbatical Program* for providing me so generously and trustingly with the time to develop this manual. At the Forest, I was privileged to have the guidance and support of the visionary Director of Black Rock Forest, *Dr. William Schuster*, whose dedication to shaping the Forest's mission served as inspiration. *John Brady*, Forest Manager, was always ready with informative answers to questions about the forest that he knows and tends so caringly. *Matthew Munson*, Data Manager, who brings his knowledge and love of the Maine woods to the service of Black Rock, patiently helped me in innumerable ways from data interpretation and transfer, to removing fallen trees from the road. *Francie Schuster* introduced me to her work with GIS and GPS while we invoked the spirit of Edward Abby's environmental philosophy. I also owe many thanks to two valued and unexpected colleagues whom I met at the Forest: *Joyce Baron*, educator and kindred spirit, whose warmth, intelligence, experience, insight and humor I came to trust as a friend's; and *Rebecca Sussman*, a Dalton high school senior interning at the Forest, a future scientist in the making, and the perfect model for student participation. *Barbara Brady's* keen eye for scheduling kept us all on track.

At Friends, *Bernard Doctor's* infinite patience and graphic skill guided me through formatting labyrinths. *Darryl Chu* helped with scanning images. I thank *Ivy Baer* for introducing me to *Regis Scott*, designer of the beautiful cover with representative oak trees of Black Rock Forest.

With the support of this team and with the sanctuary of the Forest, this manual took shape.

Prologue: the Ecology of Education

If ever there were the ideal educational environment, it seems to me that every schoolteacher would be versed in broadly intersecting areas of academic endeavor, drawing from the wellsprings of universal knowledge and experience. For example, the science teacher would cite literary formulations, and the literature teacher would be aware of scientific principles; the teacher of mathematics would be informed by the patterns and cycles of nature as well as by the constructs of language and literature; the history teacher would relate environmental factors to the flow of world events and politics, and all educators would strive for the best possible integration of their subject field into the fabric of human experience. For each discipline has indeed been extracted from the whole, from which it really has no independent existence. Borrowing metaphors and symbols, seeing parallels and contrasts, and understanding interconnections would then becomes the model for a fluent educator and a well-educated student. We could call this perspective, "the ecology of education".

In a natural system, "ecology" refers to the interconnectedness and interdependence of the composite elements and cycles. Ecology teaches the essential principle that everything affects everything else, and that a change in one component reflects in the balance of the entire system. The metaphor of ecology, then, is an invitation to educators, scientists, humanists, artists and poets to present their subjects as facets of the whole.

Curriculum enriched by the Black Rock Forest experience has the potential to connect interdisciplinary and educational ecology ideals. "Real world' applications derived from the Forest offer authenticity and relationship to the study of arts and science. Teachers may discover that Black Rock Forest provides a context for applying lessons in science, nature, math, statistics, art, literature, history, human ecology and any other subject a creative teacher could imagine. And beyond intellectual content, contact with the natural world has the potential to relax and open the mind, to provide opportunities for inner reflection and pathways to personal development. May this handbook open new and unexplored paths.

Antonia Daly
Friends Seminary, NYC
August 2003

A TEACHER'S GUIDE TO BLACK ROCK FOREST

A Manual for Use in the Classroom and in the Field

"…from the Redwood Forests to the New York Island, this Land was made for you and me."
Woody Guthrie

Introduction

During my five years as the faculty representative from Friends Seminary to the Board of Black Rock Forest, I have witnessed the Forest's developing mission and growth. While teachers of Science or Environmental Studies may readily see the educational possibilities of the Forest and its resources as a natural field station, many others, including Science teachers, are just not sure what the Forest is about and how it can enrich their curriculum. For the duration of a spring term sabbatical, I immersed myself in the life of the Forest, guided by my own conviction that as educators, we must prepare students for their role in caring for the environment. This Guide was developed to inform teachers about the many opportunities at Black Rock Forest, to invite them to know and enjoy the forest resources, and to empower them in creative, independent use the facilities.

Why Black Rock (instead of Central Park)?

The two questions most frequently asked by New York City teachers and administrators about the Forest are: 1) Why go to Black Rock when Central Park is nearby? and, 2) How can we use Black Rock Forest? The following sections offer both philosophic perspectives and practical answers to these questions.

The first and basic distinction here is that Black Rock Forest is a native New York ecosystem, while Central Park is a manmade landscape. It is only in an ecosystem that the intricate networks of natural systems dynamically interact and support each other. A park, a welcome green landscaped oasis in a city, is different from an intact ecosystem with naturally occurring processes unimpeded by barriers. At Black Rock Forest, the geology, the soil, the hydrology, the plant life, the forested areas are all native components that continually interact with a minimum of human interference. It is truly remarkable that there exists an area so close to NYC that supports plants and wildlife as abundantly as does BRF. The health of this local forest implies ecosystem health, which contributes to biosphere health, a national and global concern.

Secondly, the urban students you and I teach, while versed in the culture of city life, are limited in their exposure to woods and streams, and in their appreciation of the interactive webs of nature. It seems that since these students are heirs to planet Earth and will serve as its future custodians and decision-makers, then we, as their teachers, have a responsibility to acquaint our students with their local ecosystem and its functions. Hopefully students will realize that they, too, are part of nature and dependent on nature's services, notably clean water, clean air, wood products and recreation. As educators, we can speculate that this awareness may enable some of our most noble pedagogical ideals: *the development of student citizenship through assuming stewardship of the natural world, and the enrichment of character through valuing the non-commercial processes and products of nature.*

Black Rock Forest (BRF) is located in the Hudson Valley in Orange Country of New York State at the intersection of two major New York ecosystems: the Hudson Highlands and the Hudson River. Proximate to New York City environs, BRF is a uniquely pristine preserve of approximately 4000 acres that represents a typical New York bioregion. In this setting, students can have a chance to develop regional identity by experiencing a "sense of place" in a natural, undeveloped forest. Experiences at the forest can foster ownership and connection to the land. Returning to the forest through the seasons can inspire reverence and responsibility in an environment of adventure, recreation, curiosity, creativity and freedom.

The Consortium

The Consortium is an alliance of currently 15 schools, universities and research institutions. Among the privileges of Consortium membership is the exchange of educational and scientific resources. Individually, each member institution gains access to the educational, research and recreational benefits simply by going to the forest and using the plentiful lessons and resources already developed. And, conversely Consortium membership supports the conservation of this land, keeping it free from encroaching development, available for research and recreation, and managed naturally to tell its story, past, present and future.

Consortium members currently include: the American Museum of Natural History, Barnard College, Brooklyn Botanical Garden, Browning School, The Calhoun School, Columbia University, including Lamont-Doherty Earth Observatory, Cornwall Central District, The Dalton School, Friends Seminary, Marine Biological Laboratory at Wood's Hole, New York-New Jersey Trail Conference, New York University, Newburgh Enlarged City School District, The School at Columbia University, and Storm King School.

A Brief History of the Forest

The original forests of the northeast were dominated by spruce, pine and fir, but as climate changed, the oak, chestnut and hickory forest we see today evolved. In modern times, the forest is currently in its third growth, having been logged during the settlement of the 18th century. From 1800 to 1928, the forest supported repeated timber cuttings as well as pasture and agricultural use. Charcoal produced during this time fueled the iron smelting and brick firing used in the building of New York City. From 1926 under the ownership and active forest management of Ernest G. Stillman, an average of one logging job per year allowed the forest to establish its third growth. Conservative forest practices continued after Stillman deeded the Forest to Harvard University in 1949. Then in 1989, Harvard transferred ownership to the Black Rock Forest Preserve. Through the efforts of William T. Golden, a national science advisor who envisioned the forest as a field station for the academic institutions of New York City, the Forest was leased to the Consortium. With a logging moratorium in effect since 1989, the maturing forest has had relatively little human disturbance. It now harbors more than fifty tree species, and has provided seven decades of data and inventories. The forest richly serves as a scientific research center and educational facility for both local and international institutions and universities.

Over the past few years, the Forest has expanded its mission and its facilities. In 1999, a Science and Education Center was erected, incorporating "smart and green" environmental principles and energy efficient design. A Lodge, also designed with sustainable, energy efficient features, will open in the spring of 2004. Lodging accommodations for 60 people will facilitate the planning of school group trips and maximize precious time traveling to and from the city.

Goal of this Guide: the Forest as Curriculum

The goal of this Guide is to empower teachers to make full and creative use of the forest for the benefit of the students, and not incidentally, for themselves. The BRF Staff is willing and able to introduce teachers and students to the many aspects of forest life, to lead them over trails and through demonstrations, and to point to the many print and electronic resources available. But ultimately it will be the informed and motivated teacher who will forge a connection to the forest with the students. This guided exposure can open pathways for students to informed career choices, to artistic expression or to a peaceful place in the heart. The forest delivers an experience of place, through continuity and change. In a word, the forest *is* the curriculum.

Section 1: Black Rock Forest and the Curriculum

1.1 How Can Teachers Use Black Rock Forest?

The second question asked by teachers *"How can we use BRF?"* is the subject of the following expanded sections of this Guide. We believe that if teachers become familiar with the resources at BRF, many will feel enthusiastic, comfortable and motivated in sharing these opportunities with their students.

Read the following sections in any order. Much of the information is repeated and cross-referenced for your convenience. The manual is designed to be both a practical and inspirational guide to creative use of the Forest for discovery, for subject enrichment and for personal renewal.

1.2 Curricula Suggestions: Subject-by-Subject

- ***Environmental Studies*** – sustainability studies; biodiversity of flora and fauna; climate change; air and water quality; ozone and acid rain effects; forest ecology; forest management; energy efficiency; animal populations; data interpretation
- ***Biology/Ecology*** – transect analysis, forest succession, dendrology; pond study; plant identification; ecological relationships: habitats, food chains; bird watching; data collection; hypothesizing; biodiversity and communities; ethno-botany
- ***Chemistry*** – water chemistry; ozone effect on chlorophyll in white pine needles; leaf photosynthesis, nitrogen/minerals in soils; air testing; atmospheric changes
- ***Physics*** – study of energy-efficiency features of the buildings, photovoltaic and solar panels, geothermal heat pump
- ***Earth Science/Geology*** – paleo-ecological development of the Hudson region and the northeastern United States; plenty of rocks and soil for sampling; contrasting landscapes; orienteering; reading topographic maps; compass skills; GPS skills; sky-watching, astronomy
- ***Mathematics*** – forest mensuration topics: carbon sequestration and allometric equations; board feet of lumber and market value; data collection; using data and statistical data analysis
- ***History*** – early native settlements of New York State; pioneer life; Hudson River and the Revolutionary Period; Storm King battle and birth of the modern environmental movement; development of Black Rock Forest as environmental history
- ***Economics*** – "Nature's services" (H. Daly, G. Daily, R. Costanza); discuss "true valuation" of resources: contribution to clean air, clean water, soil retention, carbon sequestration, habitat preservation; calculate board feet of marketable lumber, market valuation of timber
- ***Art*** – Storm King Sculpture Museum with works by Goldsworthy, Nguchi, Calder; Hudson River Schools of Painting and Landscape Design; nature photography; environmental design; green architecture; botanical illustration
- ***English/Language Arts*** – Creative writing; poetry writing; poetry readings; contemporary and classic nature literature: Henry David Thoreau and Ralph Waldo Emerson, John Muir, Aldo Leopold, Edward Abbey, Annie Dillard, Barry Lopez; nature-inspired poets, such as Emily Dickenson, to name but a few luminaries
- ***Foreign Language*** – Latin botanical names of biota; classes can be conducted in French or Spanish for general practice; nature literature in original languages
- ***Drama/Dance*** – space, space, space for rehearsals and improvisations; inspiration of nature

- *Music* – the hills, meadows, streams and animals are alive with the sound of music; (Debussy, impressionist composer); practice or compose using nature's acoustics
- *Human Relations* – Spark discussions by observation of interdependence of life; lessons from biodiversity and biological communities; value of diverse species in forming a healthy ecosystem; contribution of ecosystem resources to basic life needs; cycles of life in nature; dynamics of change.

1.3 What Are Other Ways Schools Can Make Use of the Forest?

- *Faculty or Student Retreats* – The Lodge will be able to sleep 60 people, and accommodate 100 in a lecture hall. Fully equipped and comfortable, built into the natural surroundings, it is an ideal secluded setting in which to relax and refocus.
- *Training Workshops* – Teacher training workshops are being planned for the near future. Professional groups can conduct their own earth curriculum workshops, or request an orientation to the resources from the Black Rock Forest staff.
- *Pairing with Member Organizations* – Opportunities abound for transfer of knowledge between and among schools and the scientific institutions. Teachers can connect with other teachers, with scientists and graduate researchers to develop curriculum.
- *World-class Consortium members*, the American Museum of Natural History, (www.amnh.org), and Lamont Doherty Earth Observatory, (www.ldeo.org), each offer educational curriculum, classes in natural history and environmental topics for teachers, and opportunities for research. Columbia University's CERC program (www.columbia.edu) offers STEEP, Science Teachers Environmental Education Program, a summer program for educators that uses Black Rock Forest for some of its field investigations. The Brooklyn Botanical Gardens (www.bbg.org) has an extensive description of the vegetation of Black Rock Forest.
- *Student Internship* – Ideal for the scientifically or environmentally aspiring student planning May projects or second semester senior projects. The AMNH High School Research Program, and the Institute for Climate and Planets Summer Institute (ICP, through Goddard Institute for Space Studies and NASA at Columbia University) each conduct student internship programs at BRF.
- *Community Service* – Students can fulfill this essential component of their curriculum by assisting with the ongoing tasks of the forest, such as tree planting, tree clearing, trail repair, or stone removal. Arrangements can be flexibly scheduled.
- *Student-to-Student Mentorship* – Upper School students can pair with Middle or Lower School students for hikes, explorations or investigations at the Forest. Teachers can arrange for undergraduate students from member institutions to pair with high school students and share their research.

Section 2: Resources Available at Black Rock Forest

A teacher's imagination may be ignited simply by reading this list. Activities can be programmed or improvised, can have one or more components to a visit, and can always include recreational pastimes and reflective musings in the Forest. To start you thinking, here is an overview of resources.

- ***Black Rock Forest website*** – The website contains curricula, research, and geographic information, photos, links to Consortium sites, and data information. It is updated periodically, and will contain "real time data" some time in the future. www.blackrockforest.org

- ***3800 acres*** - Extensive areas of forest, open meadows, ponds and streams are networked with hiking trails and nature observatory stations. Trails are mapped and marked and come in all variation of length, difficulty and terrain. There is a genuine Teepee to visit, and an original Stone House, built in 1834, with historical artifacts and information. Forest staff can suggest the right trail for your group. Camping areas are also available for overnight stays.

- **35 *Master Lessons*** - This collection is the centerpiece treasure of teacher resources. It is a huge catalogue of 35 ready-to-use curricula of activities and lessons developed over many years by the Forest staff and Consortium teachers on topics including water study, forest ecology, tree identification, mensuration (measurement), habitats and more. There are lessons for all age groups and interests. Call for copies of individual lessons to be sent to you for review. See Appendix A for list of lesson titles.

- ***Science and Education Center w/ Lab*** - This building is a unique example of an energy-efficient structure fully equipped with "green and smart" features, such as sensor-regulated lights, locally harvested wood, and a model geo-thermally powered heating and cooling unit, and odorless composting toilets. *The Laboratory* is equipped with microscopes, computers, lecture or classroom, tables and some computers.

- ***The Lodge*** – Opening in the spring of 2004, with overnight accommodations for up to 60 people, and gathering space for 100, this structure also features "green" and energy efficient design. See Section 7 for information on reservations and pricing.

- ***Library*** - Located in the Science Center, the Library has a wealth of forestry literature, nature and ecology journals and books useful to the educator or researcher. There is a drawer of historic and new *topographic maps* of forest areas ideal for learning terrain cartology.

- ***Research Archives*** - The Forest keeps on file all research done at the forest, and will make copies upon request for teachers wishing to gain background information on a topic of interest. Research is conducted by scientists from local universities such as Columbia University, and by research centers such as Lamont Doherty Earth Observatory and The American Museum of Natural History, as well as by guest universities worldwide. Topics include forest research, animal population studies and water ecology. See 6.2 for list of current research. Additional archived titles are available.

- ***Data Sensors and Data Harvester*** – Sets of archival data from the 25 environmental sensors around the Forest are recorded by the software tool, Data Harvester. The sensors are of two main groups: field monitors and building monitors. Hourly data from both types are recorded in Data Harvester which is available at the BRF website. In the future, real time data will be available online for school and research use. See **Data Section** for full description and applications of BRF data.

- ***Equipment*** – The Forest maintains a full complement of field and lab equipment.

    - Field supplies include sampling and measuring equipment for streams, ponds, soil and trees; dip nets and traps for insects, fish, turtles and small mammals; plant presses; spotting scopes and hand lenses; maps, compasses, waders, first aid kits, some camping supplies.

    - Lab supplies include a tree ring analysis station; soil sieves; water chemistry meters; dissecting kits; tanks and terrariums; basic lab equipment such as microscopes, glassware, ovens, refrigerators, freezers, a hood, distilled water and ice.

    - Classroom supplies include computers, printers, scanners, overhead and digital slide projectors, VCR's and videotape, and access to the Internet and to the Forest database. Also lecture rooms.

- ***On-going Projects*** - These may change with the seasons, but past marvels have been displays of trout breeding tanks, tree "cookies" (rings), animal pelts, bones and skulls. A forest staff person can explain and demonstrate these collections to your group. Some projects have activities and worksheets prepared for student use. See Trout Brookies for an example.

- ***GIS and GPS*** - Global Positioning Systems (GPS) are hand held electronic tools that collect digitalized field data, which is then transferred to a computerized mapping system, Geographic Informational Systems (GIS). Physical elements of the environment, such as forest cover, waterways or elevations can be isolated and presented in visual or map format. Currently there is no curriculum for these powerful mapping tools, but for the teacher who is already knowledgeable BRF is a diverse setting to use the three Trimble Explorer 3 GPS units plus Pathfinder software. Excellent for the accelerated high school class.

- ***Herbarium*** - This compilation of about 700 dried local plant specimens is a botanist's treasure trove. A teacher can demonstrate the biological components of New York State flora from this collection, as well as the art of pressing, drying and mounting plants.

- "***Student Investigations using Data***" by Dr. Kim Kasten, scientist and educator at LDEO. An excellent collection of lessons using BRF "real data" to answer questions from everyday life. Describes educational value of "real data" and characteristics of a good "first" data set. Contains five "Harvester Puzzles" that introduce teacher and student to an "Earth Curriculum" through use of the environmental sensors and their applications. Available in hard copy upon request, and at the Black Rock Forest Home page: http://www.blackrockforest.org

Section 3: The Sensors and the Data

3.1 What are the Sensors? And What Do They Measure?

A battery of sensors has been installed to record data of patterns of climate change, forest regeneration and animal population dynamics. These 25 environmental monitoring sensors are at four field stations at BRF, and the data they generate can be grouped into these categories:

- ***Weather Data*:** Sensors record wind speed and direction, barometric pressure, relative humidity
- ***Water Resources Data*:** Sensors measure stream flow, pH, temperature, conductivity, dissolved oxygen, (DO); precipitation, pH and conductivity of precipitation
- ***Soil Data*:** Sensors measure temperature at depths of 10cm, at 100 cm; soil moisture
- ***Solar Radiation*:** Sensors measure two types: 1) total radiation, and 2) part and amount of the spectrum available to plants
- ***Building Data*:** Sensors record air temperature, relative humidity, energy use, heat/cool energy use, water in, effluent discharge, geothermal temperature in/out of building

The four **Field Stations** are locations in BRF that represent a variety of natural environments:

1. ***Open Lowland*** – at low elevations, such as Aleck Meadow, in the central part of the forest, near the Old Headquarters
2. ***Ridge-top*** **-** the rocky upper regions of mountains and ridges where soil is shallow and conditions are severe. Mixed conifer and deciduous trees grow. Black Rock Mountain top at 1410 feet above sea level is a ridge-top environment.
3. ***Cascade Stream*** – on the eastern side of the forest, flows through Glycerine Hollow and empties into the Hudson River.
4. ***The Building*** – This is the Science and Education Center with energy efficient features. By spring 2004, *the Lodge* building will be the second structure to house sensors.

3.2 What are the Data? How Are They Recorded?

The data are ongoing records of information about building, forest, air and water functions. At BRF, data recorded by the sensors are cached as archival data from the past decade or earlier, depending on the item being measured. For example, each sensor records an average of hourly data for each hour of a 24-hours day, followed by a daily average, marked "24". This is "raw" data, which is then converted at BRF into "clean" data, by removing the anomalies and organizing it into columns in an Excel spreadsheet. At present, only cached data is available from the BRF website through *Data Harvester*. This software tool was developed by a scientist from LDEO, and provides means to display the data and to create and compare data graphs. In the future, a *real-time* data system will be accessible on the web.

3.3 What Other Data are Available at BRF?

- ***Precipitation:*** collected in two buckets and measured in mm and mL after each precipitation event (rain or snow). One, a metal bucket, records precipitation events (in inches, then converted into millimeters; inches times 24.5 = mm). This system has been in operation since 1960. The other bucket collects precipitation and is collected every week.

- ***Annual Tree Growth:*** data collected manually each year from 4 plots of two-1/4 acre sections each, one tended and the other control plot left to natural influences for the sake of comparison.
- ***Deer Population Data:*** number of males/females, fawns/yearlings, size of antlers, etc
- ***Other Biological and Animal Data:*** coyote and raccoon data from research projects; turtle population and species information from mark-and-recapture projects.

3.4 How Can a Teacher Use the Data? General Ideas

The data can be used in many ways in Chemistry, Earth Science, Ecology, Geology, and Environmental classes, or in historic or cultural presentations pertaining to logging or the history of New York State. These are some suggestions that are adaptable to any grade level.

Examine either the Building Data or the Weather Data. A sample of each is listed in the Appendix. Guide students in any of the following:

- Read and understand the data entries for a particular item, i.e., stream flow, weather elements, building data. A list of headings and explanations can be found in Section 4
- Use the Excel functions to make graphs over time, i.e., air temperature or rainfall through the year.
- Compare data sets from various years or seasons, i.e., stream flow in August for the past 10 years, noting changes over time leads to discussions of causes for changes.
- Compare sets of different data, i.e., air temperature versus soil temperature at different depths; precipitation versus barometric pressure; density vs. temperature.
- Make conjectures about data regarding climate and weather, possible climate change, global warming, carbon storage, etc.
- Observe relationships between weather and water characteristics, animal data, forest growth, etc. to find overall trends.
- Manipulate or adjust the data to simulate hypothetical situations, i.e., what would happen to the soil temperature if the air temperature were increased? What are the implications of temperature variation for the forest as a whole?
- Compare samples of data *through the seasons*, i.e., comparing air temperature (with a high amplitude of variation) to soil temperature at 10 cm and at 100 cm. shows varying and interesting patterns in summer and in winter.

Data is available for classroom use upon request from the Forest,
either on a CD disk or in hard copy. Call Matt Munson at 845 -534-4517
Or by email: **blackroc@ldeo.columbia.edu**

Section 4: Examples of Data Used In High School Classroom Lessons

Water Data - Weather Data - the Building Data

4.1 Using Water Data in the Classroom

Water data provides a most adaptable study at the Forest. Existing data can serve as a basis for classroom study before a visit to the Forest. On request, the Forest can provide actual source samples of recent precipitation, stream water from nearby urbanized areas, Hudson River water, or BRF stream water for comparative analysis. Water samples can be tested at the home or school site and compared with samples from various forest sites. Following are three sample applications.

4.1.1 Elements of Water Chemistry

Any Chemistry class can obtain insight into the variations in water characteristics by comparing the tap water at the school site with water from BRF sources, as listed above. BRF water sources include springs, streams, ponds and wetlands. There are lab kits at the Science Center for measuring dissolved oxygen (DO), pH or acidity, conductivity, hardness or the presence of minerals, and turbidity using the secci disks. Students can analyze water along a gradient and hypothesize about the effects of variables such as altitude, source, flow, or surrounding soil. They can compare BRF water with water at their home site, or elsewhere. Keeping seasonal or annual records of data can be studied for atmospheric or climate changes.

4.1.2 Stream Flow at Cascade Stream and at Tamarack Pond

At a certain location in Cascade Stream (see map) water flow is measured by a sensor as it passes through a V-notch, its height measured in mm. Examine the data for daily, monthly, and seasonal variations in stream flow. Students can conjecture about the predictability of the patterns, about natural anomalies, and about influences on other natural phenomena. The table also contains data for other water characteristics such as dissolved oxygen, temperature. Conductivity and pH, while possibly influenced by extraneous factors, can also be measured. These can be compared to the stream flow, or to each other. The overall profile of a stream can be understood by studying these features in tandem.

The _Earth Curriculum Project_ has developed a series of investigations that introduces students to the principles of systems dynamics. The exercises use Stella II software to model the behavior of natural systems, in this case, the stream flow of Tamarack Pond in Black Rock Forest, and its capability to support the water demands of the town of Cornwall, NY. The _Earth Curriculum_ is available from Black Rock upon request.

4.1.3 Conductivity of Water

Though possibly influenced by the measurement methods themselves, conductivity is an interesting characteristic of water that gives insight into the effects of the Acid Rain phenomenon. For example, the data table, *(* fig.1) shows the "conductivity" of the water, which is the measure of the amount of dissolved minerals, such *as iron, copper, sodium, nitrate, and sulfur* present in the water at a given time. The student will recognize some of these as the pollutants that both cause and stem from Acid Rain. The conductivity value is always changing due to the influences of precipitation in combination with pollutants present in the atmosphere. The lower the conductivity number, the less concentrated are the minerals. It is interesting to note that a first rain will wash down more pollutants from the air, while a while a second, even heavier rain will bring down lower amounts of pollutants. The range of conductivity numbers can be from as low as 2 to a high of 160-190, which indicates a high concentration of solid minerals from industrial and other sources that have run off or fallen from the air into the stream. Students can compare the conductivity from season to season or over several years. Implications regarding "Acid Rain" can be inferred from the data. The path of the Jet Stream for a period of time can help explain variations. (Data for mega-weather patterns from the Midwest to the Eastern United States can be found at www.NASA.giss.gov.)

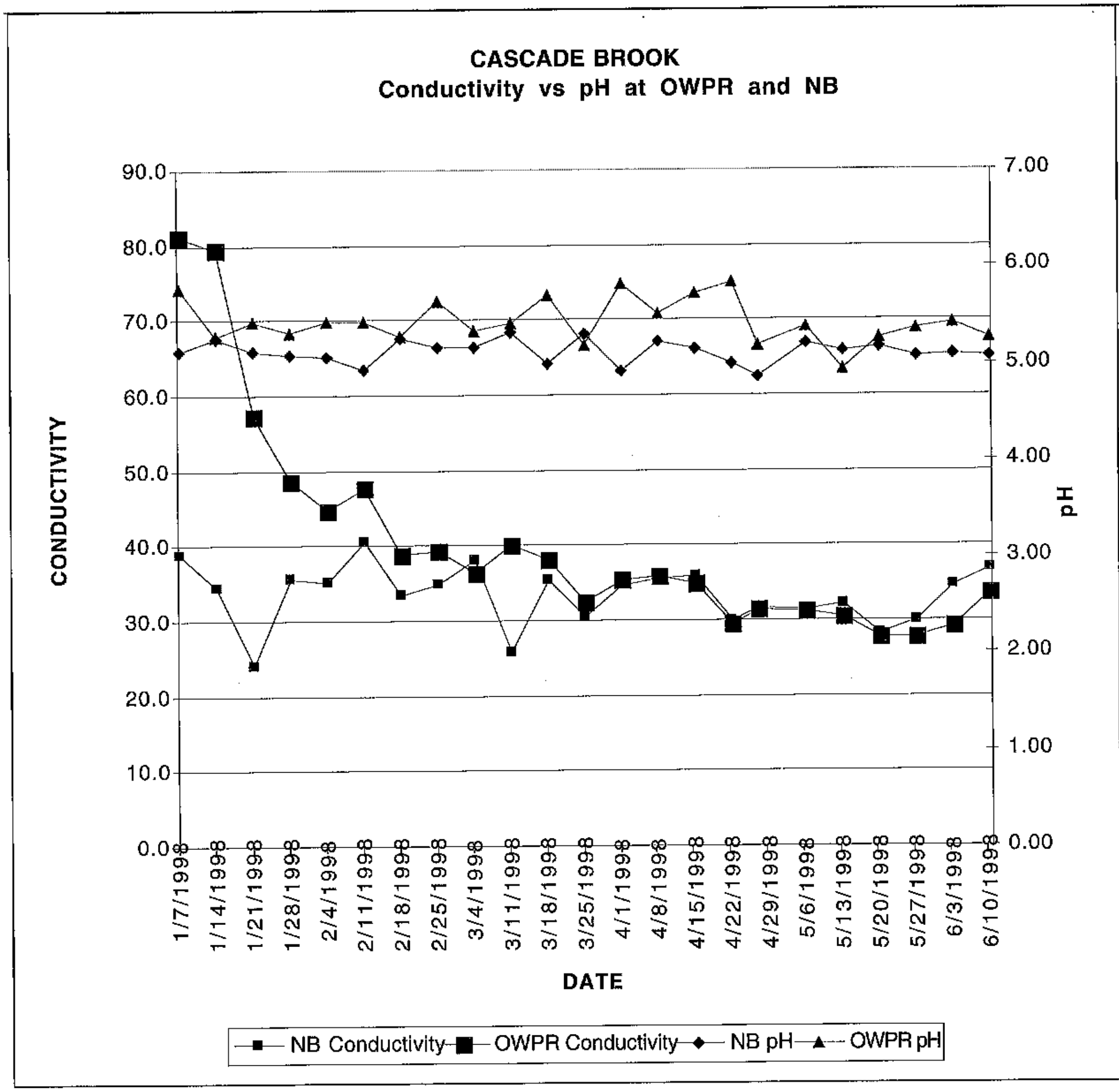
Conductivity data can be compared to pH of the water sample, measured with a hand-held devise. Dissolved oxygen (DO) is on the data table, as mg/V and as ppm. Temperature is given in Centigrade (C) and students can be given the formulas for conversion to Fahrenheit ($F = 9/5\ C + 32$). Students can compare the pH of the stream to the pH of a lower-lying lake.

Figure 1 shows a six-month weekly sample of pH and conductivity data from two locations on Cascade Brook. ***Figure 2,*** showing the graph of the data, can be studied for relationships between pH, conductivity and season.

Figure 1 – pH and Conductivity Data for a 6–Month Period

	North Bridge		Old West Point Road	
Date	pH	Conductivity	pH	Conductivity
1/7	5.13	38.9	5.77	81.1
1/14	5.26	34.4	5.27	79.5
1/21	5.13	24.2	5.43	57.2
1/28	5.09	35.7	5.31	48.6
2/4	5.06	35.1	5.43	44.7
2/11	4.94	40.5	5.44	47.8
2/18	5.26	33.5	5.28	38.8
2/25	5.17	34.9	5.65	39.3
3/4	5.16	38.2	5.34	36.5
3/11	5.31	25.9	5.42	40.2
3/18	5.00	35.5	5.69	38.0
3/25	5.29	30.6	5.18	32.5
4/1	4.92	34.6	5.81	35.4
4/8	5.23	35.6	5.51	35.8
4/15	5.15	36.0	5.72	34.8
4/22	5.00	30.1	5.84	29.5
4/27	4.86	31.7	5.18	31.4
5/6	5.21	31.4	5.38	31.3
5/13	5.12	32.3	4.93	30.6
5/20	5.16	28.3	5.26	27.7
5/27	5.06	30.0	5.35	27.8
6/3	5.09	34.7	5.42	29.2
6/10	5.06	36.8	5.26	33.6

Figure 2. Graph of conductivity and pH at two locations on Cascade Brook: near the source (North Bridge) and at the end of flow (Old West Point Road)



4.2 Using Weather Station Data

Weather data are recorded at two locations at BRF: Ridge-top (RT), Open Lowland (OL). Data from past years are available on Data Harvester and at the Forest, right up to the present day and hour. The data are obtained by sensors in the field and include measurements for air temperature, soil temperature at different depths, relative humidity, barometric pressure, wind direction and wind speed, and solar light and available solar energy for plants. The student can explore the changes hourly, daily, monthly, or yearly by using the "Sort" function of Excel. We will show you some examples, sorted by day, comparing the air temperature to the soil temperature at RT and at OL. Further explorations are left to the curiosity and creativity of teachers and students alike.

For the following exercise, request the complete weather data set for any station (Ridge-Top or Open Lowland) from BRF. The information is too extensive to reproduce here, but will be sent on a disk. The following *Table 1* summarizes and explains the RT data headings. A sample of a complete 24-hour day of data is included in the Appendix.

Table 1 – Weather at Ridge Top - Data Headings

Heading	Units	Explanation
Array ID	60/24	(60) - Hourly Average; (24) - Daily Average
Year		Yearly Date
Jul_Day		Days (1 through 365)
Hour		Military Time (0100 through 2400)
TEMP_C_AVG	C^0	Average Temperature
TEMP_C_MAX	C^0	Maximum Hourly Temperature
TEMP_C_MIN	C^0	Minimum Hourly Temperature
RH___AVG		Average Relative Humidity
RH___MAX		Maximum Hourly Relative Humidity
RH___MIN		Minimum Hourly Relative Humidity
VP_kPa_AVG		Vapor Pressure
DewPt_C_AVG		Dew Point
PAR_PPFD_TOT		Solar Radiation
GSR_W_m2_AVG	$W\ m^{-2}$	Average Solar Radiation
Wspd_m_s_S_WVT		Wind Speed
Wdir_deg_D1_WVT		Wind Direction
Wdir_deg_SD1_WVT		Wind Direction
Wspd_m_s_MAX		Wind Speed - Maximum
Rain_mm_TOT	mm	Rain Total
BP_mbar_AVG		Barimetric Pressure Average
BP_mbar_MAX		Barimetric Pressure Maximum Value
Ref_temp		
BP_mbar_MIN		Barimetric Pressure Minimum Value
STEMP_10_AVG	cm	Soil Temperature at 10 cm
STEMP_20_AVG	cm	Soil Temperature at 20 cm
BattVolt	Volts	Datalogger Battery Volts

4.2.1 Air Temperature and Soil Temperature - Procedure for Using Excel Data

1. Look at an Excel sheet with data for one of the stations at BRF. *Appendix B* shows a one-day example of data from Ridge-top. Read and interpret each heading of the data. Note the maximums and minimums and the average. Note the hourly readings and the daily averages at the line marked "24".

2. Use the "Sort" command to group the "24" rows which represent the daily averages. Tell the "Sort" to list in ascending order, which will list the "24's" first.

3. Use the Excel "Chart" to graph. Start by selecting the columns, "julian day" for the x-axis, and one other column, such as "air temp avg" for the y-axis. Chose appropriate domain and range for each graph.

4. Now chart and compare the Air Temp and the Soil Temp at various depths (10 cm and 20 cm at RT; 10 cm and 100 cm at OL). Why are the depths different at the two sites? How do the relationships change from season to season?

5. Variations can include comparisons between RT and OL, using air temperature or soil temperature.

4.2.2 Wind Direction Data - Observations and Questions

1. Look at data in columns headed, "wind speed" and "wind direction". The wind direction reading is given in degrees starting from 0° at North, and rotating counterclockwise through 180° at South, back to 360°. Make observations and deductions from these numbers. How can the wind switch direction hourly?

2. Look at the "wind speed". During which months is the wind direction and speed the most variable? The least variable? How fast is x m/sec.in mph? (how many meters in a mile?) What speed do you think represents a gusty wind?

3. Compare RT and OL in regard to wind characteristics. Make observations and deductions. How might plant life and animal habitat be affected by these differences?

4.2.3 Solar Energy Data

Two very interesting data columns record solar energy. The column headed, *"GSR W"* stands for the total amount of solar light reaching an area (Global Solar radiation in Watts), while the column marked *"PAR PPF"* represents the amount of solar light available for plant growth (Photosynthetic Active Radiation measured in # of photons).

Observe these numerical values and create a column in Excel to find the percentage of solar light available each day for plant growth. Is there any consistency to these numbers? Why do you think this percentage is the size it is? What happens to the rest of the solar light coming in? What is the seasonal change? What amount of solar light coincides with the season of spring, as you know it? What is the difference in solar light at RT and OL?

4.3 The Building Data

A tour of the Science and Education Center is reason enough for a visit to the Forest. This "smart" and green" building exemplifies unique lessons in architecture, design, physics, and the economics of energy efficiency.

Completed in 1999, the Center was designed by Fox & Fowle Architects and is an elegant model of functional environmental sustainability and energy efficiency. Building design and construction carry visible and quantifiable environmental awareness messages to all who visit and use the space. Some of its outstanding features include:

- Geothermal Heat Pump for heat and cooling
- Water and light sensors
- Use of locally-harvested wood from BRF, including four columns of hand-hewn oak tree trunks (red, white, scarlet and chestnut varieties) as non weight-bearing decorative interior beams
- Waterless composting toilets that produce natural fertilizer
- "Smart" technology includes a network of sensors to monitor the environment of the building, and the development of a network/data center to distribute data through the Internet

A selection of data for the building can be found in the Appendix. Data includes temperatures at three locations: one in the lobby and one each on the first and second floors. These sensors read the ambient temperatures when the thermostat kicks on and inform the GHP to start running to maintain even ambient temperature.

Power usage is recorded two ways: power used by the building as a whole, and power used by the Geothermal Heat Pump (GHP) alone.

Currently, the water readings are inoperative, though headings for them are included.

Figure 3 shows each category for building data. Use with data sheet in the Appendix.

Figure 3 – Building Data Headings

CATEGORY		UNITS
Array		HOUR(60) / DAY (24)
Year		YEAR
Day of Year		Julian Day
Hour		HOUR
Second		
Average Temp		deg C
Max Temp		deg C
Min Temp		deg C
Average RH		RELATIVE HUMIDITY
Max RH		RELATIVE HUMIDITY
Min RH		RELATIVE HUMIDITY
Power kwh		KILOWATS PER HOUR
Total_Effluent_gal/hr		GALLONS PER HOUR
GeoTemp_In		deg C
GeoTemp_Out		deg C
Total_WaterIN		GALLONS PER HOUR
GeoPower_Kwh		KILOWATS PER HOUR
Avg. Water		GALLONS PERCENT
Total_GeoFlow		GALLONS PER HOUR
Batt Volt		VOLTS

4.3.1 The Geothermal Heat Pump

The Geo Heat Pump is the most innovative and interesting feature of the building because it both heats the building in winter and cools it in summer, using only the temperature of the ground. The building is always just the "right" temperature, evenly and comfortably warm or cool. It utilizes heat exchange principles and the fact that the temperature of the ground below about six feet is a constant temperature of approximately 40° F. Huge amounts of energy are saved by not utilizing conventional AC for cooling nor fossil fuel for heating. The GHP is a wonderful concrete example for high school physics, with many environmental and engineering applications.

How does the GHP work?

The Geothermal Heat Pump uses underground water that is circulated through six pipes sunk 500 ft. vertically into the ground. At this depth, the temperature of the ground is always about 40° to 45° Fahrenheit (diagram 1). For each of the six pipes, there is an entry pipe and a return pipe.

In winter, water is passed down into the ground through an entry pipe. Since the temperature below ground is warmer than the water in the pipes, heat from the ground is transferred to the water. The warmed water is then passed up through a return route pipe and through an anti-freeze liquid* which takes up the heat. This warmed liquid is then run through coils and compressed, raising the temperature even further. Fans then blow the heated air around the coils into the building.

In summer, water continues to be passed down through the ground, which still maintains a constant temperature of 40° F. Now the water loses its heat to the below-ground temperature. This cooled water now comes up through the return pipe and cools the refrigerant liquid. The system uses a Freon substitute anti-freeze, an alternative to an ozone-damaging refrigerant. The compressor is in "air conditioning" mode, convexing (not compressing) the liquid, so the liquid remains cold. The liquid passes through coils, the coils cool the air, and the cooled air is then circulated by fan through the building to produce an air-conditioned effect.

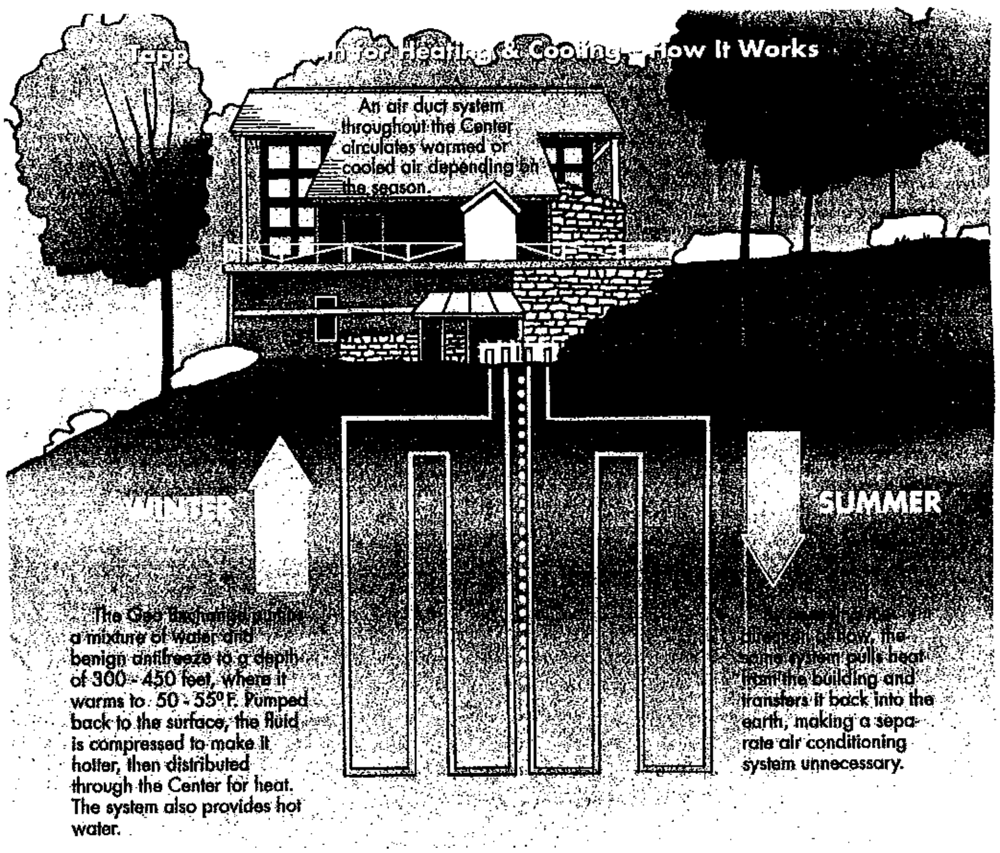


Diagram 1 – Geothermal Heating and Cooling

4.3.2 The Data for Power Use in the Science Center

Remember, power usage for the building is recorded two ways. One column (K) shows the power used for all appliances and lighting in the building. The other column (T) records the power used solely for the Geothermal Heat Pump, compressor and fan. Possible uses of this information include comparisons with each other, with a student's home or school use, seasonal comparisons, comparisons with outside air temperature data, and variations with human usage such as visitors (high) or holidays (low).

The Science and Education Center is prepared to have solar roof panels installed in the near future, which should optimally supply 100% of the energy needs of that building. When the Lodge is built and operational, both structures will be linked to the solar power source. At that point, about 50% of total power needs for both buildings will be provided by solar. There will also be solar panels mounted on the ground, which will serve for educational purposes as well as energy needs. The data generated will be raw material for further research.

As of July 2003, the New York State Energy Research and Development Authority (NYSERDA) has granted an award to the Black Rock Forest Consortium to cover 61% of the cost of installing a 25-kilowatt photovoltaic system (solar panels). The PV system will harness solar power to supply the energy needs of both the Science Center and the newly built Lodge. The panels will be linked to the Forest's existing data monitoring system.

4.3.3 Toilets & Waste

The waterless composting toilets in the building are an example of a clean, efficient system that saves water and energy. The toilets empty into three large bins in the basement, to which have been added shavings of soft wood and red worms. Bacteria and other scavengers and decomposers have naturally colonized themselves in the collection bins. When natural waste combines with these elements, it decomposes without odor to produce natural fertilizer. Ninety-nine percent of the waste is converted to CO_2 and water, plus a small amount of methane and other gases. A fan circulates the methane and other gases produced in the process of decomposition out of a pipe at the top of the building, preventing any build up of odor. If water waste becomes too high, a pump removes the excess liquid to a septic field. Maintenance is minimal because once the waste is composted into fertilizer; it condenses into a very small space, requiring only the removal of one-third every few years.

Students can calculate the water saved by using these toilets by multiplying the number of times they flush each day by 3-5 gallons of water for each flush. Further, if they have access to a water usage bill from a homeowner, they can calculate the money saved by reducing or eliminating water used for toilets.

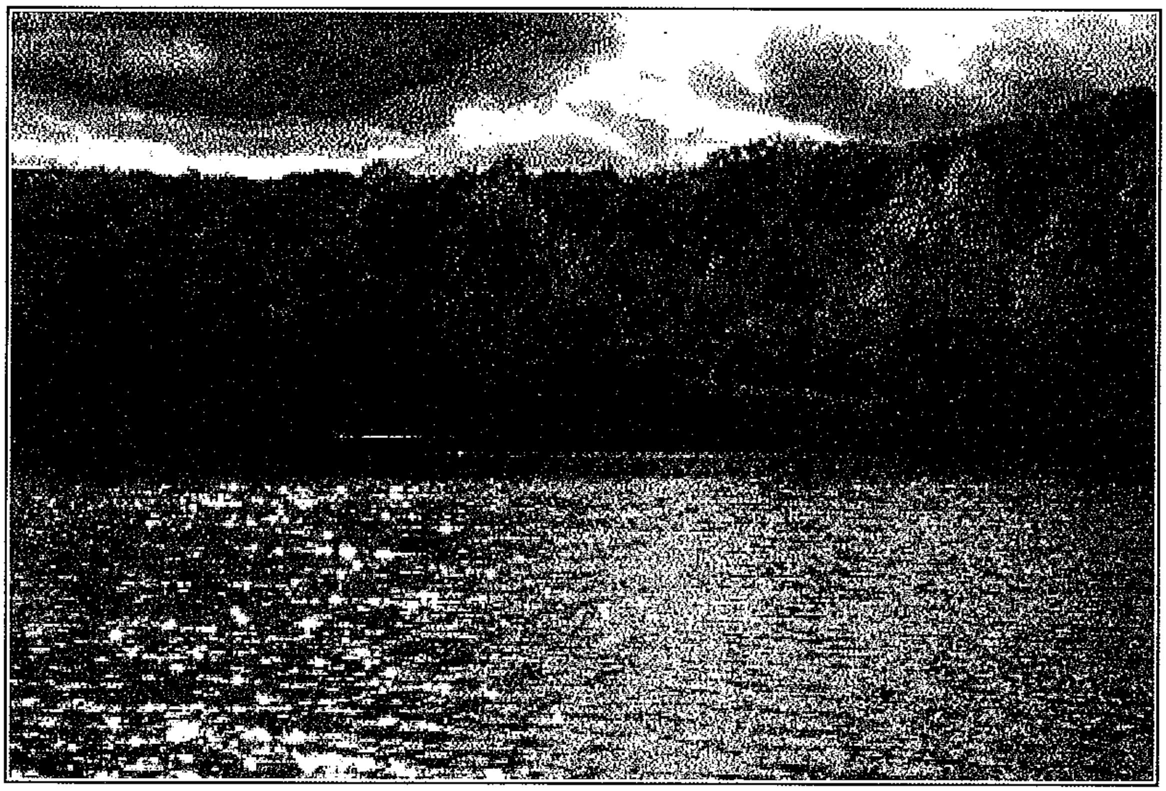
4.3.4 Additional Suggestions for Using the Building Data

- Graph the relationship between temperature and relative humidity in the building. What are your observations?

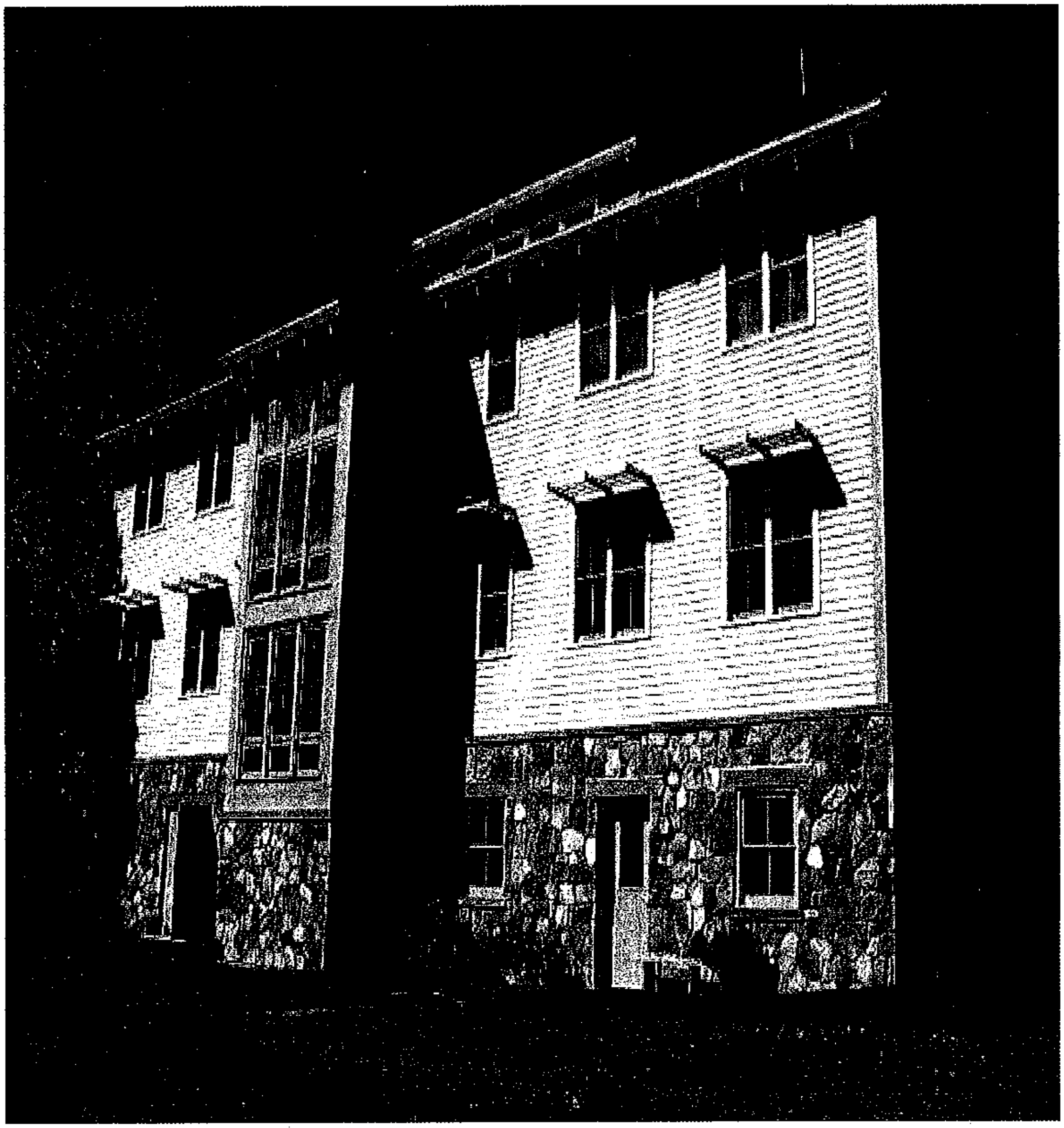
- Look at the sensor readings for the "first floor" the "second floor", and the "middle of the building" average. Why do you think these reading are all needed? What do they tell about the efficiency of the insulation and temperature control of the building?

- Read the Geothermal temperature as it enters the building and as it exits the building. After studying the way the Geothermal Heat Pump works to heat and cool, what can you observe about these readings?
- Compare an equivalent square footage of conventional energy usage with the energy used at the Science Center.
- Calculate how much solar radiation falls on an area the size of the footprint of the Science Center and compare to the amount of solar power needed to power the building.
- Visit the Science Center for a subjective experience of the comfort levels of temperature and light.

Mount Rascal represents a typical cliff and outcrop formation found at Black Rock. The gneiss or granite bedrock is steeply sloped with a series of ledges, thin layers of soil, sparse plant cover and stunted trees. (Photo credit: K. Barringer, BBG)



Alec Meadow is one of the forest's six reservoirs that supply the town of Cornwall. Alec Meadow is the deepest of these reservoirs at 20 feet, and is the site of several educational programs. (Photo: courtesy BRF)



The Science and Education Center at Black Rock Forest features "green" and "smart" energy-saving building design. A geothermal ground pump system provides heating and cooling, reducing energy consumption. The facility was constructed using local wood and stone materials in a sustainable manner. The roof is prepared to receive photovoltaic panels that will harness solar energy for power needs. (Photo: courtesy BRF)

Section 5. Applications for Middle and Lower School Students

5.1 Curricular Concepts and Themes for Younger Students

- Cycles of Nature: water, rocks and soil, CO_2, nitrogen, sulfur, decay
- Systems, ecosystems; ecologic relationships, biodiversity, food chains (webs); biomes, plant and animal communities;
- Water ecology, ponds, acid rain
- Forests: assessment of forest health as nationally significant; tree identification, succession, vertical structure of forest (canopy, under story, ground story), acorn hunt
- Leaf identification; leaf and plant pressing; litter and ground observation;
- Living things: mammals; amphibians, salamanders, turtles, insects (spiders), plants; birds
- Geography, topography, orienteering, compass and maps
- Geology, glacial history, soils, rock composition, terrains, bogs
- Acorn and oak tree study

5.2 *Oak Trees and Acorns: Seeds,Trees and Food*

Young students can experience satisfaction and enjoyment in an acorn hunt. They can note the tree under which certain acorns are found, the condition of the acorn, full or cap, healthy or decayed, and the abundance. A unit on acorns provides a good start to dendrology study. Students can sketch the acorn, the leaf and the parent tree. Here is some background information to start a unit on the acorns found in Black Rock Forest.

Acorns Facts - There are seven species of oaks found in Black Rock Forest. Pollen studies show that oaks have been characteristic of the region for the past 10,000 years. Regeneration due to acorn viability has undergone change, with implications about climate change. Currently, in order of abundance the oak species in Black Rock Forest with their Latin botanical names are:

1. Northern Red Oak – *Quercus rubra*
2. Chestnut Oak – *Quercus Montana*
3. White Oak – *Quercus alba*
4. Black Oak – *Quercus velutina*
5. Scarlet Oak – *Quercus coccinea*
6. Scrub Oak – *Quercus illicifolia*
7. Swamp White Oak – *Quercus bicolor*

Acorns, the fruit of the oak, are an extremely valuable source of food for mammals, birds and insects. They provide protein, calcium, crude fiber and fat for deer, turkey, bear, squirrel, grouse, raccoon, mice and insects. The whitetail deer population depends for its food on the quantity and quality of the annual acorn crop. Animals of the forest compete for the acorns, so a scarcity of acorns affects animal viability, while high acorn consumption affects tree propagation. Acorns are very adaptable, some taking root on stumps rather than soil.

Research counting acorns using several "hoops" placed near parent trees in early fall has provided data about acorns from each oak species. Acorn count per acre ranges from a high of 250,000, a bumper crop, to a low of 20,000 an acre, a poor crop.

Questions for Students to Research

What is an acorn?

What is a parent tree?

How many acorns does a tree produce? And how many do you think become trees?

Who eats acorns? What is the nutritional value?

How long have Oak trees been growing in Black Rock Forest?

Do you think oak trees will change in number? In species?

What factors do you think affect the growth of oaks?

What methods can we use to "count" acorns in a forest?

5.3 *The Trout Breeding Project or "Brookies at Black Rock"*

Borrowing from the protocol of www.**troutintheclassroom.org**, which is sponsored by the conservation organization, Trout Unlimited, Black Rock has started a project of breeding trout from the fertilized eggs of a mated pair of trout.

The Trout breeding program is an engaging project for fourth graders and up. Ideally, the students visit the forest four times through the year, twice in fall and twice in spring, to see the process evolve from eggs to fish. Students collect and graph data about temperature, nutrient cycles, dissolved oxygen and fish mortality. Math and science lessons are complemented by the experience of care-taking the growing fish, referred to as "fish parenthood".

Background

Brook Trout (*Salvelinus fontinalis*) is the New York State fish. It is the top predator in streams and a prized catch of anglers. Trout come in many varieties, each spawning at a specific time. Rainbow trout originally from Asia spawn in spring. Brown trout, from Europe, spawn in Fall and hatch in Spring. The Black Rock project uses the Heritage strain of Brook trout from the Adirondacks that spawn in February, and produce eggs that take about 37 days to incubate at about 52° F. The developing alevin are attached to nutrient yolk sacs for a stage that feed them for about a month and a half while developing into juvenile fry, and eventually into adult trout.

The Tanks

At the Black Rock Science and Education Center, there are two-180 gallon tanks, one with ground water and one with stream water. Trout require cold temperatures, so an aqua-chiller introduces water at 36-38° F, to create and maintain an ideal 55° F. The water is passed through layers of filters to remove sediments. A pump in the tank shoots water in, creating the needed agitation and introducing oxygen to activate the fish. Two circulation filters in the tanks keep the water flowing.

Procedure

An adult male and female pair of Heritage Brook trout obtained from a hatchery farm is acclimatized to the tanks. The male is milked of his sperm, and the eggs of the female are removed to a bowl, where they are gently mixed with the sperm liquid. The fertilized eggs are then placed in an egg tray, which is a mesh screen suspended at the top of the tank. After experiencing 97% mortality when about 7000 eggs were generated, the staff found 300-400 eggs to be a more viable amount.

Life Cycle of the Brookies

After four weeks, the backbone and the eye are visible through the sac, dubbing this the "eyeing up" stage. At 37 days, the alevin or fry are in their last sack. When they are longer than one inch, the fry are called fingerlings.

The young trout, about six months old and four to six inches long, and raised during the winter of 2003 were ceremoniously released into surrounding streams on June 8, 2003, Consortium Day.

Student Activities for the Trout Project

The Forest can provide Lab Sheets and Activity Sheets for the project. Students observe lab protocol and can be directed to do the following tasks:

1. Students observe behavior and anatomy of the trout, feeding habits (invertebrates & black-nosed dace). Classroom preparation for a visit is best. Visit the website, www.troutintheclassroom.org for more information.

2. Students make periodic mortality counts and graph results over time.

3. Students measure length of 10 fish and get an average of those measurements. These measurements are graphed over a 3-month period.

4. Students can measure water temperature, water chemistry and water characteristics such as pH, and dissolved oxygen (DO).

5. Class can discuss the relationships of water characteristics, especially temperature, to fish health. They can compare the characteristics of the ground water tank and the stream water tank.

Resources for the Trout Project

- Website: www.troutintheclassroom.com

- The Browning School has been given a small grant by BRF to recreate this project at their school in Manhattan. Contact Sam Keany, Science Chair (email: skeany@browning.edu) for further information on their project in NYC.

- Materials, publications, worksheets about limnology, anatomy, etc. are available through BRF.

- *Worksheet on Dissolved Oxygen* (developed by Rebecca Sussman for grades 4 and up) explains the concept of DO by comparing it to sugar dissolved in water, and includes a graphing activity of dissolved oxygen at different temperatures. Available from the Forest.

5.4 School in the Forest

"School in the Forest" is a pilot project initiated in the winter of 2003 to create an experiential curriculum for fourth and fifth graders from PS 176, a public school in upper Manhattan. Funded by a grant from New York Community Trust, and implemented under the direction of Joyce Baron, the program met its goals of providing public school students the same opportunities to participate in the science education at the Forest as the independent school students enjoy. In May 2003, the BRF Board was pleased to invite PS 176 to become a member of the Consortium. The Principal of PS 176 accepted with enthusiastic appreciation. A second public school, PS 220, is currently invited to participate in the School in the Forest program in the spring of 2004.

Example of a Recent Fourth and Fifth Grade Field Trip

Three teachers of the 4th-5th grades groups were first prepared by visiting the forest in March and April and collaborating on possible activities. Three student groups each about 15 fourth and fifth graders visited the Forest on a day trip in May. Each group followed a different forest itinerary, accompanied by their teacher and one or two BRF staff members. In the classroom, students had prepared by generating a list of questions about the Forest. They were instructed to keep a field journal of observations (science, art drawings), and a record of impressions (language arts) while at the Forest.

The day of the visit, one group hiked to a pond with nets and wading boots. They examined life at the edges of the water, observing newts, salamanders, snakes and turtles. The children learned that that swimming is permitted in only one of the seven ponds, since the ponds at Black Rock are water sources for the nearby town of Cornwall.

The group spiritedly hiked a steep mile to Black Rock summit where they sighted landmarks such as the Hudson River and the fire tower from a map, observed the terrain with the help of contour maps, and worked with compasses and directions. After lunch on the summit, they hiked down the mountain, and followed a forest trail, observing plants, more salamanders and listening for birdcalls. At the historic "Stone House" students heard the history of the structure, while some conducted a planned archeological dig outside the kitchen window. At the site the children explored the well water and hand pump, the cider press, an old barn foundation, two spruce trees and porta-potty.

The other group proceeded directly to the Stone House area, heard the history of the structure (owned by the Babcock family in the 18th century), and gathered in a genuine tee-pee where they saw a demonstration about the original Native American inhabitants, sample animal hides and other artifacts of the land. There was a picnic spot at nearby Arthur's Pond where a pond study was conducted.

Both groups completed their day with verbal sharing of experiences, silent contemplation and written journal entries. In writing and in drawings, they evaluated what they had wanted to learn originally and what they had actually learned, in addition to recording their subjective impressions. The inspired quality of these products and the children's positive responses deemed the day and the entire project supremely successful.

The Hike up to Black Rock (1420 ft): from Twin Gates, follow trail with blue and yellow markers (to the right of the entrance road); walk up takes about 20-30 minutes with a steep rock climb at the end and a great view of Newburg and the Hudson River at the top; the walk down takes about 15 minutes. Sturdy hiking boots or sneakers are a must.

5.5 Lesson Ideas Using Research from BRF or AMNH

Teachers can design lessons and discussions for students at any grade level using on-line information from the Forest or from the American Museum of Natural History, which conducts research at BRF. For example, animals and amphibians are of great interest to young children, and there are studies of populations of deer, raccoons, foxes, coyotes, spiders, turtles, salamanders, and stream critters. Teachers can also find research on the many types of acorns in the Forest, which children can then collect and identify when they visit. For the older student, numerous research projects on forestry issues, including tree growth and leaf biomass, can stimulate interest in forest ecology and perhaps in forestry careers not usually familiar to urban students.

For Middle or Lower School classes, many topics can be used to launch interdisciplinary units in literature, art, social studies, science or math. For example, a fascinating study is the ***Biodiversity of Spiders*** (Ovtsharenko), a collection of realistic photos and drawings that would engage child and scientist alike. This particular project is available in full color glory at the Museum of Natural History website, www.amnh.org. Preparatory study can be done in the classroom, followed by a visit to the Forest to observe actual specimens. ***Turtle Trapping*** (Karrmann, AMNH) is an ongoing project to establish a complete census of the turtles in Black Rock's seven ponds. Students as young as seventh grade collect data on species, age, sex, and growth by a mark and recapture method.

Stimulating subject matter is found in research on pond breeding of amphibians and predator-prey co-existence (Walls), seasonal social den use by raccoons (Wright), white-tail deer management (Brady), or social studies about the history of land use from the pre-colonial period to 1927 (Mahar). See *Section 6* for a complete list of 2003 research presentations.

A teacher can request a copy of a research paper from the Forest for review. Classroom applications are limited only by the imagination, and can be integrated into any chapter of high school science, history or art.

Phone 845 -534-4517
Or email: **blackroc@ldeo.columbia.edu**

Section 6: Research at Black Rock Forest

Black Rock Forest serves as a field station for many scientific research projects conducted by graduate students and by professional researchers. About 300 research papers published since 1931 are on file at BRF, with the preponderance dating over the past 15 years. Scientists from BRF, from Lamont Doherty Earth Observatory, Palisades, NJ, and from Columbia University's Earth Institute as well as from various other world-class universities worldwide have contributed to a library of research at the Forest.

Topics include forest health, environmental changes and population studies. A partial list of recent (2002-03) research projects carried out by both graduate and undergraduate students and by professional scientists at BRF follows in 6.2.

6.1 Using Research in the Classroom

Incorporating research into the classroom can yield several instructional benefits.

- First, for college-bound students, the papers serve as examples of "the scientific method" of hypothesis, observation and deductions used in actual research. Students can note the hypothesis, the experimental design, the parameters and the conclusions of a research subject.
- Second, connect mathematical and analytical skills to science for the high school student by observing how a researcher uses statistical methods and graphs.
- Finally, the subjects of these studies complement curricula by providing motivating and inspiring material in chemistry or biology classroom lessons, used in combination with, say, water or soil chemistry, or biology dendrology.
- Teachers can read authentic scholarly research on a wide range of topics: forest ecology, the role of fire, biodiversity of species, water ecology, animal populations, and insect entomology to name a few.
- Other benefits include: teaching scientific practice in scientific education; using students' work as sources of data; communicating and collaborating; asking meaningful questions of real scientists; learning where to find scientific information

6.2 Proceedings: Third Black Rock Forest Research Symposium June 23, 2003

Session I: Long-term Studies

William Schuster, Black Rock Forest, "Past and potential future change in tree species dominance in the Black Rock Forest".

William E. Wright, Columbia University/Tree Ring Laboratory, "Stable oxygen isotopes and needle maturation of *Pinus strobus*".

Joseph Liddicoat, Barnard College, "Paleomagnetic dating of Sutherland Pond sediments in Black Rock Forest and early Holocene paleoclimate in the Hudson Highlands".

Dorothy Peteet, Columbia University/Lamont-Doherty Earth Observatory (LDEO), *Dee Pederson* Columbia University/LDEO, *T. Maenza-Gmelch*, New York University, *D. Kurdyla*, *P. Higginson*, and NASA/GISS ICP teachers and students, "Soil carbon storage – uplands vs. lowlands".

Session II: Forest Processes

Will Bowman, Columbia University/Center for Environmental Research and Conservation (CERC), "Quantifying stem respiration in the forest carbon cycle".

Kevin Griffin, Columbia University/LDEO, *J.D. Lewis*, Fordham University/Calder Center, *David Tissue*, Texas Tech University, *Matthew Turnbull*, University of Canterbury, New Zealand and *William Schuster*, Black Rock Forest, "Age-related impacts on tree growth".

Matthew Turnbull, University of Canterbury, New Zealand, *Kevin L. Griffin,* Columbia Unviersity/LDEO, *David T. Tissue,* Texas Tech University, *S. J. Richardson,* Landcare Research, New Zealand, *D.A. Peltzer,* Landcare Research, New Zealand, *William S.F. Schuster,* Black Rock Forest, *and David Whitehead,* Landcare Research, New Zealand, "Environmental factors influencing canopy respiration – implications for predicting forest carbon exchange".

David Whitehead, Landcare Research, New Zealand, *Kevin L. Griffin* Columbia University/LDEO, *Matthew Turnbull,* University of Canterbury, New Zealand, *David Tissue**, Texas Tech University, *Victor C. Engel,* Duke University, *Kim J. Brown,* Ohio University, *William Schuster,* Black Rock Forest, *and A.S. Walcroft,* Landcare Research, New Zealand, "Response of total night-time respiration to differences in total daily photosynthesis in a canopy of *Quercus rubra* L." *presenter

Session III: Animal Population Studies

Dave Karrmann, American Museum of Natural History, "Structure and dynamics of a *Chrysemys picta* metapopulation (integrating research & education)".

Elizabeth Nichols, James Danoff-Burg, Columbia University/CERC, and *Fred Koontz,* Wildlife Trust, "Diversity and abundance of dung beetles in fragmented forest along an urban to rural gradient in the New York Bioscape".

Fred Koontz, Wildlife Trust, *Andres Gomez,* Columbia University/CERC *William Schuster, John Brady,* Black Rock Forest, *William Lynn,* Center for Humans and Nature, and *Scott Newman,* Wildlife Trust, "Coyotes of the Hudson River Highlands and the New York Bioscape initiative".

John Brady, Black Rock Forest, "A 19-year study of the whitetail deer in Black Rock Forest".

Session IV: Community Studies

J.D. Lewis, Fordham University/Calder Center, "Tree and stand level responses to eastern hemlock decline".

Jerome Rozen and Valerie Giles, American Museum of Natural History, "The how, when, and whys of the bee survey of Black Rock Forest".

John Mickelson, Columbia University/Center for International Earth Science Information Network (CIESIN), *Fred Koontz,* Wildlife Trust, and *William Schuster,* Black Rock Forest, "Delineating ecological land units using multi-temporal Landsat imagery".

James Danoff-Burg, Columbia University/CERC, *Ed Goodell,* New York-New Jersey Trail Conference, *Jean Rothe,* Columbia University/CERC, and *Edwin McGowan,* New York-New Jersey Trail Conference, "Trail impacts on the birds and the bee(tle)s".

Aaron Kimple, Bard College/Black Rock Forest, and *William Schuster*, Black Rock Forest, "Impact of hemlock wooly adelgid on eastern hemlock stands in the Black Rock Forest".

Section 7: Visiting Black Rock Forest

7.1 Preparation for a Visit to Black Rock

A visit to Black Rock represents an experience away from city life into a natural environment. When teachers help students prepare their inner environment before the visit, they establish a quiet and receptive frame of mind. It is best to travel without electronics, videos or headphones, and to structure the bus trip to include preparation of queries about the forest. Successful trips occurred when teachers set expectations for journals and drawings, experiments and reports. These activities require observation and attention to the sights, sounds, smells and textures of the forest. Quiet contemplation with a minimum of distractions establishes a smooth transition from city energy to forest environment.

7.2 Staff and Functions

Dr. William Schuster, Forest Director - Call Bill Schuster for matters pertaining to education or research at the Forest and for grant information.

John Brady, Forest Manager - Call John Brady to request his guidance through special activities, such as forest mensuration (measurement) activities or animal hide demonstrations. John can instruct and orient teachers as well as student groups.

Matthew Munson, Data Manager - Call Matt Munson for data sets to be sent via CD or by email in Excel. Matt also instructs student groups in the Trout Project and in forest activities.

Barbara Brady, Administrative Assistant – Call Barbara Brady to schedule class visits, or to request materials, such as specific curriculum activities or copies of research papers.

7.3 Directions to Black Rock

By Car: From Manhattan: cross the George Washington Bridge; take the Palisades Parkway (north) to the very end (about 40 miles). Go 3/4 around circle then north on 9W for 10 miles. Take a left across 9W at Reservoir Road. At the T in Reservoir Rd., take a right for 1/2 mile to Science Center parking lot.

Buses are not allowed on the Palisades Parkway. From New York City, take the NYS Thruway to exit 16. Continue to 32 N for 10 miles; take right at light (rt. 107) to 9W S for about 1.5 miles. Take right onto Reservoir Rd. Continue as above.

7.4 Accommodations and Reservations

The Lodge can sleep 60 people in several multi-occupancy rooms. An equitable rate per head will be determined by the BRF Board, and may include bedding. Food is not provided but a number of caterers, delivery services and restaurants are readily available. Please make reservations as far in advance as possible.

The Old Headquarters can sleep up to 16 people, four to a bunk bed room, with some living room and couch space. There is currently a $5 per person charge per night. Overnighters can use the linen supplied or bring their own sleeping bags.

The Stone House is a rustic alternative that can sleep up to 18 people (bunks for 8) who provide their own sleeping bags and camping gear as needed. There is also a defined outdoor space for tent camping in the pines between the Stone House and Tamarack Pond, available to groups of 40 who leave no trace. Near the Stone House there is a hand pump for well water and two portable toilets maintained on the site

7.5 Suggestions for a Safe and Comfortable Visit

Students and teachers should wear clothing appropriate to the weather and the activity. For hikes, bring sturdy walking shoes, layers of shirts and jacket, long pants, boots when necessary, extra socks, rain gear, sun hat, sunscreen, insect repellant.

Tick precautions should be taken. This means long pant legs tucked inside socks, and repellant on cuffs. Do a skin check after an outing.

Poison ivy may be present in Black Rock Forest. Hikers should learn to identify the plant and avoid it. Wearing protective clothing and washing with a caustic soap after an outing are worthwhile precautions.

A knapsack with a non-perishable supply of food and enough water for a few hours is suggested.

Don't forget your camera, notebook, sketch pad, paints and brushes to record the vivid impressions of the Forest.

Enjoy the Forest. Let it teach you its harmonious lessons.

For information and reservations
845 -534-4517
Or by email: **blackroc@ldeo.columbia.edu**

Mailing Address:
Black Rock Forest
129 Continental Road
Cornwall, NY 12518

APPENDIX

A. Outline of Black Rock Forest Curricula

B. Weather Station Data Sample

C. Building Data Sample

D. Carbon Sequestration Lesson

E. Map of Black Rock Forest

Outline of Black Rock Forest Curricula

	Title	Field Exercises	Digital Exercises
1	Teacher & Staff Orientation		
2	Watershed Exploration (1A)	x	
3	Invertebrate Survey (1B)	x	
4	Surface Water Testing (1C)	x	
5	Wetland Study (1D)	x	
6	Dendrology (2A)	x	
7	Tree Measurement (2B)	x	
8	Forest Mensuration (2C)	x	
9	Forest Ecosystems: Wildlife	x	
10	Forest Ecosystems: Plants	x	
11	Forest Ecosystems: Geology & Soils	x	
12	Forest Ecosys: Env. Measurements	x	x
13	Forest Ecosystems: Human Impact	x	
14	Forest Ecosystems: All 5 in one	x	x
15	Black Rock Forest History	x	
16	Map Reading and Orienteering	x	
17	Eagle Cliff Hike	x	
18	Split Rock Hike	x	
19	Mammal Hike	x	
20	Tree Ring	x	x
21	Biodiversity	x	
22	Forest Species Diversity	x	
23	Dalton: Environmental Science	x	
24	Dalton: Earth Science	x	
25	Dalton: Plant Ecology	x	
26	Dalton: Aquatic Biology	x	
27	Cold Air is Dense		x
28	Solstice vs. Season		x
29	Sensors / Senses I		x
30	When Does it Rain?		x
31	Harvester Puzzles		x
32	Earth Curriculum: Investigations		x
33	What's the Flow?	x	x
34	Global Warming		x
35	What Influences Climate?		x

Obtain a copy of any of these lessons by calling Black Rock Forest: 845-534-4517

Appendix B1 – Weather Station Data, Col. A to N

	A	B	C	D	E	F	G	H	I	J	K	L	M	N
1	Array ID	Year	Jul_Day	Hour	TEMP_C	TEMP_C	TEMP_C	RH	RH	RH	VP_kPa	DewPt_C	PAR_PPFD	GSR_W_m2
2					AVG	MAX	MIN	AVG	MAX	MIN	AVG	AVG	TOTAL	AVG
3	60	2003	231	100	17.99	18.12	17.8	97.5	98.4	96.4	2.009	17.57	0	0
4	60	2003	231	200	17.76	18.1	17.59	98.5	99.8	96.8	2.002	17.52	0	0
5	60	2003	231	300	18.2	18.61	17.81	94.6	98.2	91.8	1.976	17.31	0	0
6	60	2003	231	400	18.49	18.65	18.37	92.2	93.6	91.2	1.962	17.2	0	0
7	60	2003	231	500	18.22	18.45	18.07	92.1	93.6	89.8	1.926	16.9	1.684	0.337
8	60	2003	231	600	18.39	18.47	18.29	92.7	94.8	90.3	1.959	17.17	144.3	18.72
9	60	2003	231	700	18.84	19.43	18.31	91.6	94.6	87.4	1.99	17.42	435.6	55.65
10	60	2003	231	800	19.9	20.72	19.32	84.6	88.8	79.8	1.964	17.22	1233	296.5
11	60	2003	231	900	21.73	22.41	20.72	79.7	83.2	76.6	2.073	18.06	2931	521.8
12	60	2003	231	1000	23.01	23.99	22.39	77.6	82.3	72	2.182	18.88	3767	664.6
13	60	2003	231	1100	24.62	25.08	23.98	72.6	78.4	66.82	2.247	19.36	4406	771
14	60	2003	231	1200	25.82	26.45	25.06	66.31	75.5	58.2	2.204	19.04	4665	810
15	60	2003	231	1300	26.91	27.72	26.17	57.9	67.28	51.53	2.052	17.9	4889	842
16	60	2003	231	1400	27.88	28.32	27.27	57.15	64.74	51.46	2.145	18.6	4525	770
17	60	2003	231	1500	28.32	28.69	27.91	57.69	64.27	51.39	2.222	19.16	3964	671.7
18	60	2003	231	1600	28.61	29	28.09	56.76	61.4	50.13	2.222	19.17	2994	504.1
19	60	2003	231	1700	27.76	28.33	27.36	58.25	62.87	53.6	2.172	18.8	1828	310.6
20	60	2003	231	1800	26.47	27.39	25.45	60.27	65.28	55.93	2.081	18.13	862	157.5
21	60	2003	231	1900	24.27	25.47	23.55	66.84	69.35	62.61	2.025	17.7	113.3	20.38
22	60	2003	231	2000	23.26	23.6	23.03	68.38	69.5	67.36	1.951	17.11	0.27	0.034
23	60	2003	231	2100	22.95	23.15	22.77	67.57	69.57	65.36	1.891	16.62	0	0
24	60	2003	231	2200	22.65	22.78	22.52	66.95	67.84	66.03	1.841	16.19	0	0
25	60	2003	231	2300	22.53	22.77	22.3	65.64	67.23	63.96	1.791	15.76	0	0
26	60	2003	231	2400	22.37	22.66	21.94	66.92	68.97	64.56	1.808	15.92	0	0
27	24	2003	231	2400	22.789	29.003	17.595	74.6	99.783	50.125	2.029	17.697	36759	267.24

Appendix B2 - Weather Station Data, Col. O to Z

	O	P	Q	R	S	T	U	V	W	X	Y	Z
1	Wspd_m_s_S_WVT	Wdir_deg_D1_WVT	Wdir_deg_SD1_WVT	Wspd_m_s	Rain_mm	BP_mbar	BP_mbar	Ref_temp	BP_mbar	STEMP_10	STEMP_20	BattVolt
2				MAX	TOTAL	AVG	MAX		MIN	AVG	AVG	
3	0.949	206.6	60.14	3.626	0	989	989	53.25	989	20.5	20.42	12.74
4	1.074	250.7	50.38	3.587	0	989	989	13.25	989	20.43	20.4	12.73
5	2.005	273.2	24.92	4.136	0	989	989	33.38	989	20.35	20.37	12.73
6	1.945	275.6	24.37	3.538	0	989	989	33.38	989	20.27	20.33	12.69
7	1.781	284.6	19.74	3.107	0	989	989	33.38	989	20.19	20.29	12.68
8	1.707	285.4	19.5	3.087	0	990	990	33.38	989	20.13	20.25	12.65
9	1.87	285	24.73	3.744	0	990	991	53.38	990	20.07	20.23	12.7
10	1.647	288.1	20.92	3.881	0	991	991	53.38	990	20.02	20.2	12.72
11	1.01	298.6	33.52	2.626	0	991	991	33.38	990	20.02	20.23	13.04
12	0.887	321.2	30.63	2.215	0	991	991	13.38	991	19.94	20.15	13.2
13	0.867	318.9	30.28	1.94	0	990	1008	23.38	927	19.97	20.07	12.53
14	1.004	311.2	35.9	2.372	0	990	991	33.38	913	20.17	20.03	12.37
15	1.064	308	31.66	2.607	0	990	1004	3.375	963	20.43	20.03	12.54
16	1.011	309.6	36.45	2.185	0	990	1010	53.38	906	20.66	20.03	13.11
17	1.191	298	32.74	2.264	0	990	990	3.375	917	20.9	20.06	12.6
18	1.089	296.3	24.88	2.832	0	989	990	23.38	989	21.12	20.11	13.04
19	1.239	288.5	25.38	2.93	0	990	990	13.38	989	21.24	20.15	13.02
20	1.515	272.7	23.61	3.557	0	989	989	13.38	989	21.28	20.22	12.9
21	2.178	272.5	22.4	4.008	0	989	989	43.38	989	21.2	20.26	12.85
22	2.532	274.3	23.21	4.234	0	989	990	23.38	989	21.17	20.36	12.82
23	2.889	273.9	24.44	4.439	0	989	990	3.375	989	21.11	20.44	12.79
24	3.224	272.1	23.15	5.076	0	989	990	43.38	989	21.02	20.47	12.78
25	3.17	272.1	24.56	4.714	0	990	990	3.375	989	20.91	20.48	12.76
26	2.542	271	23.12	4.312	0	990	990	3.375	990	20.8	20.47	12.74
27	1.6829	285.26	36.203	5.0764	0	989.68	1009.6	53.375	905.66	20.579	20.252	12.366

Appendix C1 – Building Data, Col. A to N

	A	B	C	D	E	F	G	H	I	J	K	L	M	N
1	Array	Year	Jul_Day	Hour	Temp_C	Temp_C	Temp_C	RH	RH	RH	Power	Total_Effluen	tGeoTemp_IN	GeoTemp_IN
2					AVG	MAX	MIN	AVG	MAX	MIN	kwh	gal/hr	AVG	MAX
3	60	2003	252	100	23.81	24.03	23.63	49.91	50.31	49.71	5	0	12.9	13
4	60	2003	252	200	23.78	23.96	23.63	49.97	50.24	49.77	4	0	12.84	12.94
5	60	2003	252	300	23.64	23.83	23.29	50.11	50.51	49.5	8	0	12.79	13.1
6	60	2003	252	400	23.51	23.7	23.29	50.04	50.38	49.23	5	0	12.84	13.09
7	60	2003	252	500	23.43	23.56	23.23	49.91	50.18	49.57	4	0	12.85	13.09
8	60	2003	252	600	23.29	23.56	23.02	49.1	49.97	48.7	7	0	12.86	13.22
9	60	2003	252	700	23.24	23.43	23.09	48.63	49.37	48.56	6	0	12.76	12.9
10	60	2003	252	800	23.1	23.36	22.82	48.56	49.1	48.3	6	0	12.78	13.04
11	60	2003	252	900	23.19	23.43	22.96	48.5	48.7	48.29	8	0	12.72	12.81
12	60	2003	252	1000	23.43	23.7	23.16	48.5	48.97	48.16	7	0	12.73	13.02
13	60	2003	252	1100	23.62	23.9	23.29	47.76	48.7	47.42	10	0	12.98	13.43
14	60	2003	252	1200	23.82	24.1	23.49	45.4	48.02	45.4	10	0	13.22	13.62
15	60	2003	252	1300	23.93	24.23	23.63	43.38	45.94	42.85	8	0	13.44	13.98
16	60	2003	252	1400	23.74	24.03	23.43	42.71	43.65	42.17	9	0	13.89	14.29
17	60	2003	252	1500	23.83	24.17	23.49	43.45	43.52	42.04	9	0	13.97	14.33
18	60	2003	252	1600	24	24.3	23.63	43.18	44.32	42.98	7	0	13.67	14.06
19	60	2003	252	1700	23.83	24.3	23.49	43.25	43.38	41.77	10	0	13.79	14.14
20	60	2003	252	1800	23.83	24.17	23.56	43.85	44.05	42.64	10	0	13.95	14.44
21	60	2003	252	1900	23.8	24.03	23.49	44.26	44.39	43.25	7	0	13.8	14.19
22	60	2003	252	2000	23.97	24.17	23.76	45.2	45.27	44.12	5	0	13.4	13.71
23	60	2003	252	2100	23.81	24.1	23.56	45.54	45.67	44.32	7	0	13.26	13.64
24	60	2003	252	2200	23.72	23.96	23.43	45.94	46.28	45	5	0	13.12	13.37
25	60	2003	252	2300	23.69	23.96	23.43	46.88	47.02	45.87	5	0	13.01	13.24
26	60	2003	252	2400	23.58	23.76	23.43	47.28	47.42	46.75	6	0	12.9	13.02
27	24	2003	252	2400	23.65	24.3	22.82	47.28	50.51	41.77	168	0	13.19	14.44

Appendix C2 – Building Data, Col. O to X

	O	P	Q	R	S	T	U	V	W	X
1	GeoTemp_IN	GeoTemp_Out	GeoTemp_Out	GeoTemp_Out	Water IN	GeoPower	Avg. Water	GeoFlow	Air_Temp	Air_Temp
2	MIN	AVG	MAX	MIN	TOTAL	Kwh		TOTAL		
3	12.77	13.54	13.62	13.44	0	2	0	0	25.41	23
4	12.73	13.47	13.56	13.37	0	3	0.002	1.6	23.62	22.99
5	12.66	13.47	14.25	13.33	0	3	0	0	23.54	22.95
6	12.7	13.52	14.09	13.36	0	3	0	0	25.09	22.89
7	12.73	13.48	13.69	13.33	0	2	0	0	23.65	22.82
8	12.69	13.52	14.21	13.29	0	3	0	0	22.8	22.54
9	12.62	13.32	13.46	13.22	0	3	0	0	24.75	22.54
10	12.62	13.43	14.03	13.23	0	3	0	0	23.86	22.48
11	12.62	13.34	13.44	13.25	0	2	0.001	0.8	22.52	22.47
12	12.62	13.43	14.04	13.28	0	3	0	0	23.68	22.54
13	12.69	13.85	14.64	13.4	0	4	0	0	25.36	22.63
14	12.94	14.16	14.88	13.76	0	5	0	0	23.33	22.78
15	13.07	14.55	15.6	13.86	0	6	0	0	23.55	22.73
16	13.47	14.99	15.58	14.35	0	5	0	0	24.99	22.87
17	13.67	14.9	15.67	14.29	0	5	0	0	23.48	23.12
18	13.44	14.52	15.27	14.15	0	4	0	0	23.05	23.08
19	13.45	14.9	16.16	14.35	0	7	0	0.2	23.96	23.05
20	13.55	14.93	16.17	14.46	0	4	0	0.2	24.78	23.04
21	13.56	14.62	15.35	14.21	0	4	0	0	24.11	23.04
22	13.15	14.08	14.74	13.85	0	3	0	0	23	23
23	13.06	13.97	14.87	13.73	0	3	0.001	0.6	24.28	22.99
24	12.98	13.84	14.42	13.66	0	3	0	0	24.74	23.01
25	12.88	13.69	14.29	13.55	0	3	0.001	1	22.98	22.97
26	12.78	13.55	13.68	13.43	0	3	0	0	23.5	22.9
27	12.62	13.96	16.17	13.22	0	86	0	4.4	23.92	22.85

Introduction to Carbon - Why Study Carbon?

Carbon is the fourth most abundant element in the universe and is an essential component of everything called "organic". Carbon is part of every living thing, animal or vegetable. It is concentrated in fossil fuels, which are the result of plant and animal decay under pressure and over time. It is also found in soil, rocks and sediments.

The carbon cycle is a major cycle of earth science, having an atmospheric budget with sources and sinks. Carbon sources include natural ones such as volcanoes, oceans, rock weathering, and anthropogenic sources, such as burning of fossil fuels and deforestation. Carbon is also released into the atmosphere through the processes of respiration and decay. Oceans, forests, and plant life serve as carbon sinks.

The process by which plants take in carbon and put out oxygen is called photosynthesis, and has the following chemical equation showing carbon dioxide absorbed from the air and oxygen released.

:

Photosynthesis: $\mathbf{6\ CO_2} + 6\ H_2O$ ----sunlight----> $C_6H_{12}O_6 + 6\ O_2$
carbon dioxide + water (in sun) ----> carbohydrate sugar + oxygen

The reverse process whereby plants and trees release oxygen into the atmosphere is called respiration.

The chemical equation for decay of wood shows the release of carbon dioxide and water when oxygen combines with cellulose:

Decay of wood: $4\ C_5H_9O_4 + 25\ O_2$ ---> $\mathbf{24\ CO_2} + 18\ H_2O$
oxygen is absorbed in decay - carbon dioxide is released into atmosphere

Over the past hundred years the amount of CO_2 in the atmosphere has risen from a pre-industrial 280 ppm to an exponentially increasing 360 ppm. It is estimated that CO_2 comprises about 60% of greenhouse gasses, and is mostly generated by human activities.

While the carbon cycle is complex and has many feedback loops, forests contribute their "ecosystem services" by regulating the amount of CO_2 in the atmosphere through absorption. The stored carbon is "sequestered" in the form of cellulose or wood fiber. In addition, forest soils contain 20 to 100 times more carbon than do croplands or pastures. The following set of exercises is intended to quantify some of the carbon storage in the forest and measure it against personal carbon-producing activities.

Finally, the students should make the distinction between the carbon dioxide molecule, which has a weight of 44 (C=12, O = 16), and the element, Carbon. Carbon is 12/44, or .27 of the weight of the molecule CO_2.
Conversely, amount of C stored multiplied by 3.67 = CO_2 taken in.

Field Lesson: Determine Biomass and Carbon Content of Trees in a One-tenth Acre Plot

Objectives:

1. Students will use a dendrology key to identify tree species in a forest plot.
2. Students will gain data collection and measurement skill in the field.
3. Students will use algebraic allometric equations to find tree biomass in a forestry application.
4. Students will gain skill obtaining regression equation by using data for DBH vs. Biomass
5. Students will graph DBH against Biomass to see a power equation.
6. Students will compare various carbon-producing activities to carbon capacity of an acre of trees.

Materials needed:

String at least 25 meters for each group
Biltmore Sticks
Graphing calculators or Excel sheets
Data Sheet for Trees & DBH
Allometric Equations & Worksheet
Carbon Calculator

Field Procedure:

1. In teams of 3 to 6 students, instruct students to cordon off 1/10 acre of forest with string. An acre is about 62 x 62 meters, or 69 yards on a side.
2. Supply dendrology keys for tree identification. Start by each student identifying trees. Students can then make a code or signs for each tree, i.e., colored ribbon, colored stick pin, tags...
3. After a sufficient number of trees are identified, measurement of Diameter at Breast Height (DBH = 4.5 ft. high) can be done using Biltmore sticks. Using centimeter scale is best for allometric equation. Instruct students in using the Biltmore Sticks, if necessary. Directions available at BRF.
4. Data is kept carefully on a data sheet (tree species and DBH)

Calculations

1. Use Allometric Equation Worksheet to calculate dry biomass and carbon content of each tree. Find total for one acre.
2. Convert carbon stored to CO^2. Compare with amounts used by each person in the US. Calculate how many trees are needed to store one person's CO^2 emissions for a year.

Conclusions Students can work in the field or indoors to calculate the biomass and the carbon content of trees. Observe which tree species has the greatest mass and contains the most carbon (Compare same DBH). Teams can compare their totals for an acre, and make conjectures about the differences. Then use the Carbon Calculator Sheet to find how much forest is needed to balance a person's carbon output.

Carbon Dioxide and Carbon Emissions: Global and US
Carbon Calculator Fact Sheet

Students should note that in a molecule of CO_2, the carbon atom has a weight of 12, and the oxygen atom has a weight of 16, totaling 44 for the molecule.
Thus, carbon is 12 /44, or .27 of CO_2, and, carbon dioxide is 3.67 times the weight of carbon.

Global	Emissions	Per Capita (6 Billion Pop.)
Total CO2	23.6 Billion Metric Tons	3.93 tons CO2/cap/yr
Carbon equivalent = .27 * CO2	6.37 Billion Metric Tons	1.06 tons Carbon/cap/yr

United States	Emissions	Per Capita (pop: 291 M)
Total CO2	5.67 BMT CO2	20 tons CO2/cap/yr
Carbon equivalent = CO2 *.27	1.6 BMT Carbon	5.4 tons Carbon/cap/yr

Questions: Find the percentage of US emissions to world emissions. __________ %

Discuss "per capita". Whom does that include?

What are the sources of the CO2 emissions?

Students can compare their individual Carbon Calculator amounts to the national average.

Next, use the following table to calculate how many trees it would take to offset the CO2 emissions:

a) for one average US citizen's CO2 ________________ b) for the student's CO2 use _______________

*Remember, one ton = 2000 pounds

Carbon Uptake of 1 tree	How many trees needed to store 1 person's CO2?	
One Tree: 25 to 48 lbs CO2/yr.	?	Trees
One Tree: 6 to 13 lbs. C/yr.	?	Trees
One Acre: sequesters an average of 2.6 tons Carbon/year	?	Acres

Math Challenge: Use Allometric Equations to Find Biomass and Carbon Content of a Tree

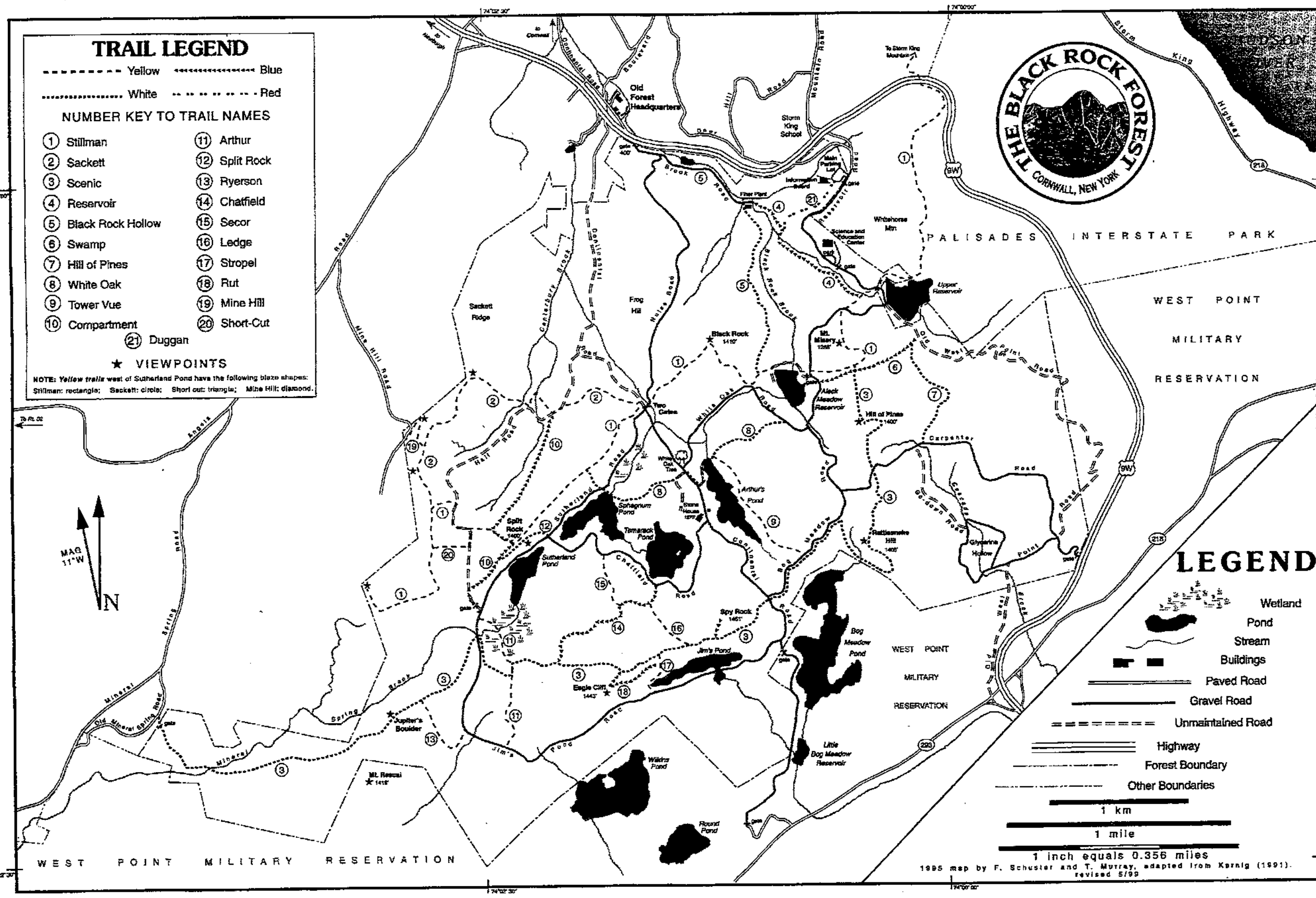
Because various species of trees have different wood densities, there are specific equations for finding the biomass of each tree. All allometric equations use "diameter at breast height" or DBH for the common measurement. The following equations have been developed by various researchers to use for trees in certain states. The equations use familiar algebraic mathematical functions, such as logs, natural logs, and sometimes the square of DBH, for more accuracy. The math student is encouraged to decipher these equations and to use them with a graphing calculator or with an Excel spreadsheet. Use the **Allometric Equation Worksheet** to organize your results.

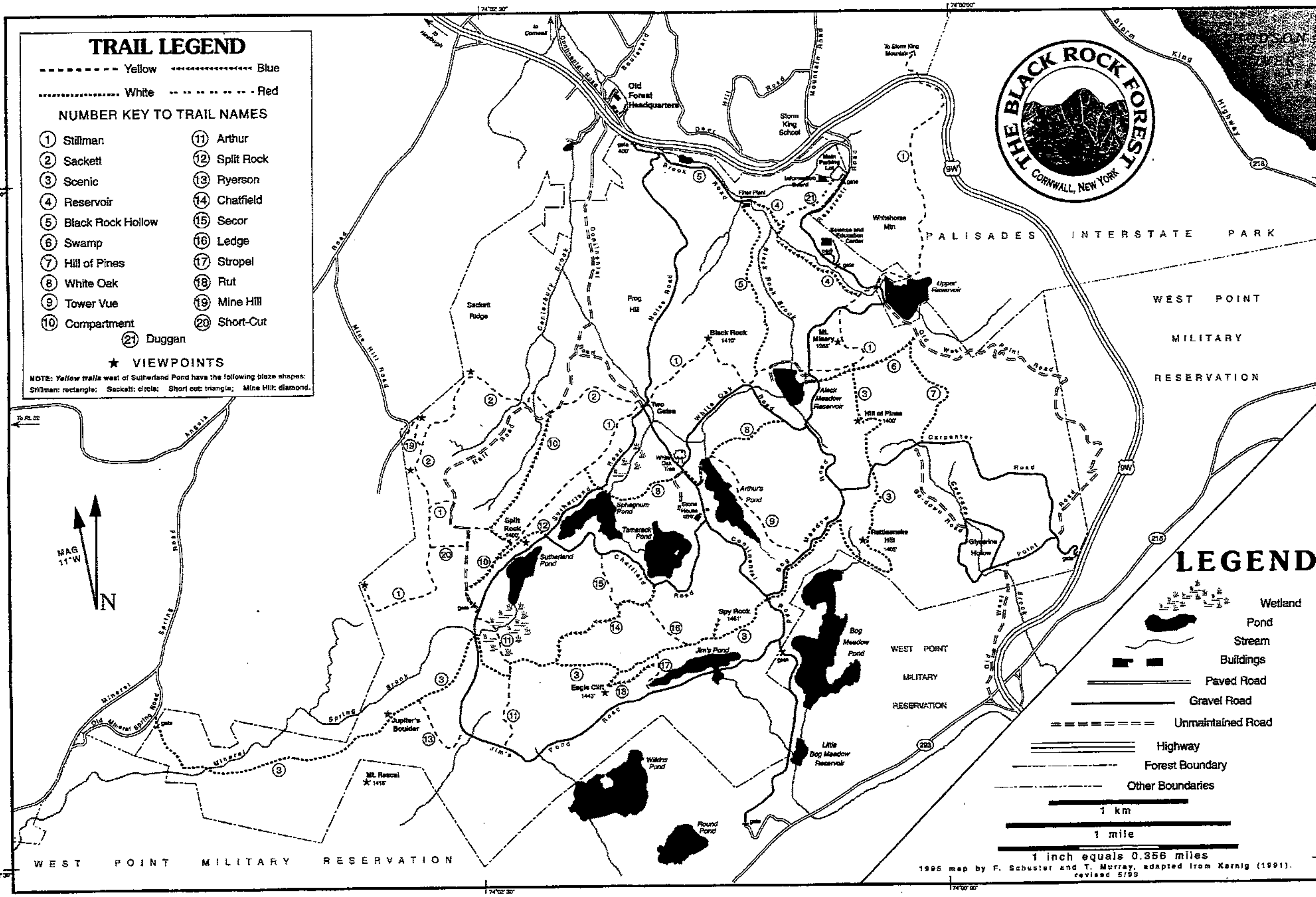
SPECIES	ALLOMETRIC EQUATIONS (biomass)	STATE/notes
White Oak (Quercus Alba)	$wt = -4{,}763 + 0.082(DBH^2 * ht)$	PA (uses height)
	$\ln wt = -0.82061 + 2.84694 \ln DBH$	RI (uses natural logs)
	$\log wt = 2.3058 + 2.166 \log DBH$	NY (stem & branches; logs base 10)
	$\log wt = 1.5849 + 1.7380 \log DBH$	NY (leaf & twigs; logs base 10)
Hemlock (Tsuga Canadensis)	$wt = 1.3449 * DBH^{2.450}$	WV
Red Oak (Quercus Rubra)	$wt = 11.0417 - (0.5258*DBH) + (0.007678*D^2)$	NY
Red Maple (Acer Rubrum)	$wt = 6.1147 - (0.3598 * D) + (0.006344 * DBH^2)$	NY
Sugar Maple (Acer Saccharum)	$\ln wt = 5.33 + 2.33 \ln DBH$	...whole tree weight,
	$wt = 5.2480 - (0.3661 * DBH) + (0.007605 * D^2)$	...above & below ground (WT)
Black Birch (Betula Lenta)	$wt = 1.6542\ DBH^{2.6606}$	... perfect form of $y = a D^b$
Chestnut Oak (Quercus Prinus)	$wt = 1.5509\ DBH^{2.7276}$	$y = a D^b$
Spruce (Picea spp.)	$wt = 6.0177 - (0.2822 * D) + (0.004654 * D^2)$	
Yellow Poplar (Tulipfera)	$wt = 1.0259\ DBH^{2.7324}$	$y = a D^b$
General Eq. for Softwoods	$Biomass = a * DBH^b$	where $a = 0.006$, $b = 2.172$
Gen Eq. for Hardwoods	$Biomass = a * DBH^b$	where $a = 0.133$, $b = 1.164$

Allometric Equation Worksheet to Find Biomass and Carbon

Procedure: You and your team have identified each tree in a .1-acre plot and then measured the DBH of each tree. Enter the data from your .1-acre plot survey in columns A and B. Group the trees by species, and use the allometric equation (C) to find Biomass (D). Carbon content is approximately 50% of biomass by weight (E). The last column (F) converts the stored carbon back to carbon dioxide, CO^2, by multiplying by a factor of 3.67 (the weight of the molecule CO^2)

A **Tree Species**	B **DBH** (in. * 2.54 = cm)	C **Allometric Equation (from list)**	D **Biomass units**	E **Carbon (C)**	F **Carbon Dioxide CO^2**


TRAIL LEGEND
Yellow
Blue
White
Red
NUMBER KEY TO TRAIL NAMES
1 Stillman
2 Sackett
3 Scenic
4 Reservoir
5 Black Rock Hollow
6 Swamp
7 Hill of Pines
8 White Oak
9 Tower Vue
10 Compartment
11 Arthur
12 Split Rock
13 Ryerson
14 Chatfield
15 Secor
16 Ledge
17 Stropel
18 Rut
19 Mine Hill
20 Short-Cut
21 Duggan
★ VIEWPOINTS
NOTE: Yellow trails west of Sutherland Pond have the following blaze shapes: Stillman: rectangle; Sackett: circle; Short cut: triangle; Mine Hill: diamond.
THE BLACK ROCK FOREST
CORNWALL, NEW YORK
PALISADES INTERSTATE PARK
WEST POINT MILITARY RESERVATION
LEGEND
Wetland
Pond
Stream
Buildings
Paved Road
Gravel Road
Unmaintained Road
Highway
Forest Boundary
Other Boundaries
1 km
1 mile
1 inch equals 0.356 miles
1995 map by F. Schuster and T. Murray, adapted from Karnig (1991). revised 5/99
Old Forest Headquarters
Storm King School
Sackett Ridge
Frog Hill
Black Rock
Whitehorse Mtn
Upper Reservoir
Aleck Meadow Reservoir
Hill of Pines
Sutherland Pond
Tamarack Pond
Arthur's Pond
Spy Rock
Jim's Pond
Eagle Cliff
Bog Meadow Pond
Little Bog Meadow Reservoir
Wilkins Pond
Round Pond
Jupiter's Boulder
Mt. Rascal
Rattlesnake Hill
Glycerine Hollow
Split Rock



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1 km
1 mile
1 inch equals 0.356 miles
1995 map by F. Schuster and T. Murray, adapted from Karnig (1991). revised 5/99

Name ________________

Luck

Sometimes a crumb fall
From the tables of joy,
Sometimes a bone is flung.

To some people
Love is given
To others
Only heaven.

DIRECTIONS:
Read the six poems on this page and decide which adjectives best describe each one. Some adjectives you might choose include the following -

sweet, serious, shocking, sad, hopeful, pleasant, comical

Write the title of each poem on the lined yellow paper followed by the adjective(s)

Dream Deferred

What happens to a dream deffered?
Does it dry up like a raisin in the sun?
Or fester like a sore - and then run?
Does it stink like rotten meat?
Or crust and sugar over - like a syrupy sweet?

Maybe it just sags like a heavy load.

Or does it explode?

The Dream Keeper

Bring me all of your dreams,
You dreamers,
Bring me all of your
heart melodies
That I may wrap them
In a blue cloud-cloth
Away from the too-rough
fingers
Of the world.

To Make Words Sing

To make words sing
Is a wonderful thing-
Because in a song
Words last so long.

Homework, O Homework

Homework O Homework I hate you, you stink!
I wish I could wash you away in the sink.
If only a bomb would blow you to bits,
Homework O homework, you're giving me fits.
I'd rather take baths with a man-eating shark
Or wrestle a lion alone in the dark,
Eat spinach and liver, pet ten porcupines,
Than tackle the homework my teacher assigns.
Homework O homework you're last on my list;
I simply don't know why you even exist!
If you just disappear it would tickle me pink.
Homework O homework, I hate you, you stink!

I Loved My Friend

I loved my friend
He went away from me.
There's nothing more to say,
The poem ends,
Soft as it began -
I loved my friend

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