NAG5-6294

Progress Report on NASA MTPE Grant:

Summer Research Internships at Biosphere 2 Center

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I. Introduction

Through the support of NASA's Mission to Planet Earth, Biosphere 2 Center hosted 10 research interns for a 10 week period during the summer of 1998. In addition, we were able to offer scholarships to 10 students for Columbia University summer field courses. Students participating in these programs were involved in numerous earth systems activities, collecting data in the field and conducting analyses in the laboratory. Students enrolled in the field program were expected to design independent research projects as part of their coursework. In addition to laboratory and field research, students participated in weekly research seminars by resident and visiting scientists. Field school students were involved in field trips exposing them to the geology and ecology of the region including Arizona Sonora Desert Museum, Mount Lemmon, Aravaipa Canyon and the Gulf of California. Interns participated in laboratory-based research. All students were expected to complete oral and written presentations of their work during the summer.

II. Summer 1998 Student Profiles

Research Interns:

Interns spent 10 weeks on their projects, receiving a stipend, housing and support for field excursions from the NASA grant. Both individual and team research projects were assigned. Research interns were chosen by a number of criteria, including the following:

1. Demonstrated interest and ability in science (evaluated via letter of interest, letter or phone reference, and transcript)
2. Likelihood that research experience would advance their career goals (evaluated by letter of interest, resume and letter or phone reference)
3. Desire to provide research experience for students of high ability with little access to research at their home institutions
4. Desire to increase participation by underrepresented groups in Earth System Science education and research.

Of the ten research interns, 5 came from racial/ethnic groups underrepresented in science (African-, Hispanic-, and Native American) 2 were Asian American and 8 were women.

The following students were interns during the summer of 1998:

Angela Anderson was in her third year at Columbia University with a double major in Economics/Environmental Studies and a concentration in Political Science. She spent her spring semester attending Biosphere 2's interdisciplinary Earth Semester. Her Earth Semester independent research project focused on global warming through the eyes of an economist, a climatologist, a politician and a philosopher. Her intensive research during her NASA-sponsored internship focused on studying the effects of elevated CO2 concentration on photosynthesis, and respiration of cottonwoods (*Populus deltoides*).

Kate Barton was a sophomore at Cornell University, majoring in Science of Earth Systems. Her studies have been directed towards understanding the ecological interrelationships of organisms and how they respond to changes in their environment. As a result of her internship, Kate is currently enrolled in Biosphere 2's Spring Earth Semester. Kate's intern research consisted of studying carbon exchange and water use efficiency in the cottonwood plantation and the tropical rainforest mesocosm of Biosphere 2 using stable isotopic methods.

Jennifer German had just completed her sophomore year at Harvard-Radcliffe upon entering her internship. Jennifer is pursuing a degree in Engineering with an interest in closed ecological systems. Jennifer studied the light environment of the Intensive Agriculture Biome (IAB) of Biosphere 2 using data obtained from light sensors placed within each of the three bays of the IAB.

Nanel Francisco was in her senior year at New Mexico State University majoring in Animal Science/Range Science. She belongs to the American Indian Science and Engineering Society. Nanel teamed up with Kate Barton, splitting her research between studying the water use efficiency of cottonwood trees and performing ecosystem carbon exchange studies in the Biosphere 2 tropical rainforest mesocosm using stable isotopic methods.

Jolanka Fisher was a junior at Barnard College majoring in economics with a focus on environmental economics. She attend Biosphere 2's Fall 1997 Earth Semester and was interested in returning to take advantage of the opportunity the NASA-sponsored internship would provide. Jolanka worked on a 15-year data set of invertebrate populations in the intertidal zone of the Northern Gulf of California, following up on an Earth Semester project.

Alesha Herrera was a junior at Rice University majoring in Chemistry and Environmental Engineering. Alesha plans to use her communication skills to act as liaison between the scientific community and the general public. As a result of her internship, Alesha is co-author on two papers with her mentor. She conducted studies on the effect of the lack of UV light on plant growth inside and outside Biosphere 2.

Cockell, C.S. Herrera, A. 1998. Effects of high temperature and UV exclusion on two desert adapted plants, Sorghum bicolor and squash (Cucurbita). Physiologica Plantarum (in prep).

Herrera, A., Cockell, C.S. 1998. Seasonal response to ambient UVB radiation and temperature of two desert adapted crops. Tropical Agriculture (in prep).

Jayne Joo was a sophomore at Harvard-Radcliffe, majoring in Environmental Science and Public Policy. While Jayne had prior research experience in a paleomagnetics lab, she was interested in gaining expertise in environmental studies. Jayne studied the effect of calcium carbonate saturation state on the rate of coral calcification. The experiment explored the possibility of threats to coral growth through anthropogenic CO_2 emissions.

Chad Mealey was a senior at San Francisco State studying media arts. Chad also attended Earth Semester in Spring of 1998. He spent his internship developing a website for use by future Earth Semester students, as well as other college and high school students. The website takes students step by step through construction of and experimentation with a carbon-cycle model for the Biosphere 2 rainforest. He was able to show how the material closure of Biosphere 2 allows for the easy testing of models against real data.

Courtney Pegus attended Morehouse College as a senior majoring in biology and ecological research. Courtney also attended Earth Semester in Spring of 1998. Courtney used his internship to study the methane cycle in the Biosphere 2 rainforest. His work provided preliminary evidence for methane transport by the umbrella sedge, *Cyperus alternifolius*.

Jenee Rowe was also a spring 1998 Earth Semester student. Prior to coming to Biosphere 2 she was a sophomore at Lawrence University studying Geology and Fine Arts. Jenee designed an undergraduate exhibit outlining the goals of the Biosphere 2 Earth Semester. She also designed a miniature model of a children's exhibit now under consideration in the overall Biosphere 2 Master Plan. Jenee successfully used her creative talents to provide interpretative education to the visiting public of Biosphere 2.

Field Scholars:

Field scholars attended one of the two field courses described below. They received need-based scholarships of up to $2000 from the NASA MTPE grant, which allowed them to supplement their classroom work with practical and perspective-changing field experience. As a whole, they did very well in the courses. Of 5 field scholars, 4 were African American and 1 was female.

Name	College	Major	Grade in course
Marques L. Bradshaw	Morehouse College	Biology	A
Marcus J. Brooks	Columbia College	Bioscience	A
Frederick L. Durden	Morehouse College	Biology	B
William E. Humphries	Morehouse College	Biology	B+
Ashley B. Tipton	Texas Christian Univ.	TBD	B

III. Program enhancement in summer 1998

We made several changes to our 1998 program based on evaluations of our first intern summer of 1997.

We improved the diversity and equity of opportunity for interns and field school students: We were able to recruit students with enough lead time and were able to improve our outreach to community college and minority students for both the intern program and field school.

...increased length of internships: We increased the internship to 10 weeks, which gave both students and mentors adequate time for a more satisfactory research experience.

...hired a Resident Assistant:: We hired two of our prior Earth Semester students as resident assistants. In addition, due to the 10-week length of the internship, the interns were easily integrated into the student life programs already in place for the existing field programs. The resident advisors reported to the Assistant Director of Student Affairs. This gave interns adequate access to shopping, libraries, cultural events and field trips.

...provided more opportunity for student-intern interaction: We were able to provide joint orientation activities for students and interns. Interns were encouraged to attend selected field school lectures on topics of general interest, we housed interns and students in close proximity, and included interns in all student-life activities.

...revised format of weekly mentor-intern lunches:: Intern led discussions of a paper from the scientific literature related to research activities at Biosphere 2 were held weekly.

...increased number of research seminars: We increased our research seminars by inviting outside speakers each week by re-directing some of the NASA funding toward honoraria for outside lecturers, and by inviting interns to specific field school lectures. Speakers included:

Diana Liverman, Director of Latin American Studies, University of Arizona
W. James Shuttleworth, Professor of Hydrology and Water Resources, University of Arizona
Thomas Day, Dept. of Plant Biology, Arizona State University
George Koch, Dept. of Biological Sciences, Northern Arizona University
Stanley Smith, Dept.of Biological Sciences, University of Nevada, Las Vegas
James Elser, Dept. of Zoology, Arizona State University
Wallace Broecker, Lamont-Doherty Earth Obs. of Columbia University (via videolink)

...improved housing facilities: Interns were housed in new dormitories installed in the fall of '97. Ten interns lived with a RA in a large 6-bedroom house with living, cooking and dining areas. This house is located adjacent to field student housing.

IV. Summer 1999 Research Projects:

Studies on the effects of UV radiation exclusion on plants: Charles Cockell
Artificial ecosystems like Biosphere 2 cut out natural UV radiation causing changes in plants and ecosystem balance. Understanding the role of UV radiation on plant function is important for the design of such systems and also for understanding the role of natural levels of UV radiation on plants. This project will involve the study of some desert adapted plants under UV exclusion. Questions to be answered include : 1) How does exclusion of UV radiation affect plant growth and what does this tell us about artificial ecosystems? 2) How do natural levels of UV radiation affect desert plants in their natural setting, such as in Arizona.

Environmental Controls On Tree Growth: Kevin Griffin
This project will follow the development of morphological, physiological and biochemical properties of trees as they grow from cuttings to a full canopy in our controlled environment facility. The project will involve scaling gas-exchange characteristics from the leaf to the system level and correlating this activity with environmental factors such as light, temperature and atmospheric CO2 concentrations.

Response of Nitrogen Fixing Trees to Elevated CO2: Kevin Griffin
This experiment will involve growing tree seedlings in open top chambers under different ambient CO2 concentrations to study the effects of carbon availability on the biological process of nitrogen fixation.

Leaf Fine Structure and Correlated Physiological and Isotopic Characteristics: Kevin Griffin

Based on physiological theory, the photosynthetic apparatus (chloroplasts) and respiratory organelles (mitochondria) of plant tissue should be most responsive to changes in atmospheric CO2 concentrations since these organelles are directly involved respectively in CO2 fixation into organic compounds and their utilization for respiratory-based energy production yielding CO2 as a byproduct. To document these fine structural correlates with physiological parameters, we will sample leaf tissue of plants grown in Biosphere 2 under different CO2 concentrations. These microanatomical measurements will provide evidence of leaf adaptations that may help to explain the physiological responses and yield a more complete theoretical explanation of how plants adapt to changes in atmospheric concentrations of CO2. This project will require travel to Lamont-Doherty Earth Observatory in NY for the electron microscope analysis.

Environmental controls on trace gas concentrations in Biosphere 2: Debra Colodner, Joost van Haren
Trace gases in our atmosphere (H_2O, CO_2, CH_4, N_2O) are largely responsible for the greenhouse effect, and recent increases in these gas concentrations have raised concern about global warming. Biosphere 2 offers the unique opportunity to study the terrestrial cycling of these gases, and the potential for interactions and feedback among the different cycles. In particular, we plan to study the effects of higher CO_2 on the fluxes of CH_4 and N_2O to the atmosphere in the tropical rainforest biome of Biosphere 2. In preparation for this work, we are completing baseline studies at ambient CO_2 to determine the functioning of the system in its "natural" state. Students will make a suite of environmental measurements (water quality, soil moisture, nutrients, etc) along with measurements of CH_4 and N_2O in order to determine the controls on temporal and spatial variability of trace gas fluxes in the Biosphere Rainforest. They will also investigate the role of specific wetland plants in the transport of methane to the atmosphere.

Calcification in hermatypic corals: Francesca Marubini
Skeletal accretion in hermatypic corals is known to be influenced by a variety of factors such as light, pH, saturation state, dissolved inorganic carbon and calcium concentrations, nutrients, water velocity. Commonly, each parameter has been studied on its own. We wish to look at calcification using a novel multivariable approach and will test the short-term growth rate of nubbins of Porites compressa in a variety of chemical/physical conditions. This project will suit best students with an interest/background in zoology, psychology, physiology, biochemistry and chemistry.

Experimental Study of Response of Ecosystem Carbon Exchange to Elevated CO2: Drs. Guanghui Lin and Joe Berry
Recent field studies indicate that undisturbed tropical rainforests under current climate conditions can sequestrate significant amounts of carbon from the earth atmosphere, probably due to the increase in CO2 concentration. Our previous study with the tropical rainforest of Biosphere 2 suggests that the capacity of tropical rainforests to stabilize global atmospheric CO2 concentration may reduce as CO2 continues to rise. This summer, we will further test this hypothesis by conducting a series of CO2 response experiments using this rainforest mesocosm with the new curtains and CO2 control systems.

V. Field course descriptions

NASA-funded Field Scholars participated in one or both field courses (three in session 1, one in session 2, and one in both sessions). Descriptions of these courses are listed below.

Earth Systems Field School, Session 1: Field Course in Earth Systems

This six-week summer field course is designed to equip students with practical and state-of-the-art experience in the use of field techniques that address a broad range of Earth system, environmental, and research problems. The course was designed especially for students of Earth System Science, and stresses the connections between the various Earth "spheres" (geo-, bio-, atmo- and hydro-). Students learn to assess various sites in an integrated fashion, including biological, geological, geochemical and geophysical techniques. The unique Biosphere 2 global change research facility, together with the incomparable environmental resources within a day's drive of campus (the Grand Canyon, Meteor Crater, Gulf of California, archaeological sites, the Sonoran Desert), give students a view of methods used to understand past, present, and future Earth system problems.

Week 1: Introduction and Orientation
The first week of the course is devoted to field methods, as well as developing basic computer and statistical skills. During this week, students get an introduction to various field and computer techniques, organism and rock identification, arid ecosystems and the special issues of sky islands, map-reading and orienteering skills, Biosphere 2, including a tour and safety walk and to the geology of Arizona. In addition, they review basic Earth System concepts.

Week 2: Northern Arizona trip: Deep time processes
The second week is devoted to a trip around Northern Arizona to focus on Earth History as revealed in the landscape. Students visit the Salt River Canyon to study and sketch the stratigraphic section, as well as get an introduction to water management issues in Arizona. They stop at Meteor Crater to discuss evolution and mass extinctions. A trip to Sunset Crater focuses them on the important roles of volcanoes in the Earth System, over various time scales. Along the way, stops at archaeological sites are used to illustrate the changing relationship between humans and the environment through time. Students finally visit the Grand Canyon and describe the stratigraphic section as well as the biological gradients they find on a walk part-way down and up.

Weeks 3, 4: Systems analysis in the field
Students are introduced to mapping using Electronic Total Stations and Geographic Information Systems by producing a base map for one of the biomes of Biosphere 2. They create a layered geological and vegetation map of the field site in the Catalina mountains. Geophysical techniques are introduced so that students can include features of the sub-surface as well. During week 3, student teams design a research project for the site to be carried out during the following week. In addition to collecting data during week 4, students receive additional instruction in class and on field trips about ecological, climatological and hydrological gradients, biogeochemical cycles, and soil characterisitics and processes. They use the information they collect in the field as well as historical data to formulate and test their research hypotheses. Areas for student investigation include the relationships among soil moisture, texture, mineralogy, chemistry, microfauna and vegetation; the relationships among bedrock, soils and vegetation; the partitioning of carbon or other nutrients in different parts of the field area, etc. Because the field area is likely to be very dry, we also bring students to a canyon stream to complete mini-projects on the physical, chemical and biological gradients associated with these features.

Week 5: Biome management

During this week students are introduced to the challenges of managing an ecosystem using examples primarily from Biosphere 2. Student teams collect data for projects such as relating water quality and quantity to vegetation and microfauna, comparing the morphology of plants grown inside and outside Biosphere 2, designing solutions for some of the technological or design problems of Biosphere 2, examining the role of human management in determining changes in the biotic communities in Biosphere 2, modeling nutrient cycles inside Biosphere 2, etc. Students compare their results to those from their field exercises, where appropriate.

Week 6: Coastal environments and marine ecosystems
During this week students travel to Rocky Point, at the northern edge of the Gulf of California. There, they help to collect data on the distribution and abundance of intertidal organisms, adding to a 15-year data set for this ecologically sensitive region. Students analyze pieces of this data set in an attempt to relate trends in commercial, residential and industrial development in the area and fresh water availability (tremendously depleted because of upstream use and diversion of the Colorado River) to changes in intertidal populations. Students also compare and contrast the limiting factors in marine and terrestrial ecosystems, and organism adaptations to these different environments.

Earth Systems Field School Session 2: Ecological Stewardship

Humans are changing the environment on a planetary scale. In a sense, we are planetary managers, whether consciously or unconsciously. This course is designed to teach basic skills in ecosystem management using the high-desert terrain outside, and the varied ecosystems inside Biosphere 2. The course stresses systems thinking and modeling skills that can be applied to management challenges at the global, as well as local scales.

This four-week course introduces students to field and computer-based techniques for observing, measuring, monitoring, modeling and managing ecosystems. The focus of Session 2 is management for the future, and complements Field School session 1 (six weeks) in that the first session focuses on understanding how the Earth and living systems arrived at their present state.

Biosphere 2 Center is set in a high desert-savanna landscape just north of the Santa Catalina mountains. Within a two-hour drive students can access pine forest (9000 feet), desert, grasslands, agricultural areas, cattle ranches, urban areas, and the varied ecosystems within Biosphere 2 (rainforest, mangroves, ocean, savanna and desert). This broad range allows students to learn about a number of different challenges to the sustainability of these ecosystems, such as changes in temperature, moisture, nutrient availability, acidity, salinity, light and toxic chemicals.

Week 1: Students are oriented to the area, learn basic rock and desert/savanna plant identification, tour inside Biosphere 2, explore ecological gradients in the Santa Catalina Mountains and inside Biosphere 2, and take a number of conditioning hikes to learn and practice map-reading, observational and record-keeping skills. They also get an introduction to systems and system modeling using Stella software.

Week 2: Students are introduced to scientific field methods by making and testing hypotheses about the distribution of life in the desert outside and the desert inside Biosphere 2. They look at the effects of cattle grazing, enhanced moisture and near-by development (i.e., buildings, lawns, roads) on species distribution and soil properties.

Week 3: Students learn to make ecological comparisons by studying the various biomes inside Biosphere 2, as well as the gradients outside. From these exercises they gain insight into the limiting and critical factors that structure organisms as well as ecosystems. They concurrently build simple computer models of the carbon cycle inside Biosphere 2 and on the Earth. They then develop management strategies for maintaining carbon dioxide at specified levels and test these strategies with their models.

Week 4: Students travel to several regional sites to study current environmental management issues: management of groundwater supply, biodiversity in riparian ecosystems, biodiversity of sky islands, the impacts of copper mining, range management and fire management.

Budget Detail Sheet

TITLE: Undergraduate Internships in Earth Systems Research at Bios 2 Center

PRINCIPAL INVESTIGATOR(S): W.S. Broecker/D. Colodner/K. Griffin

PERIOD: 8/15/99 - 8/14/00

AMT. REQUESTED: $75,000

		Mos.	Yr. II
A. Salaries and Wages			
Senior Personnel			
W. S. Broecker	Newberry Professor		N/C
D. Colodner	Associate Research Sci.		N/C
K. Griffin	Assistant Professor	1	5,846
Other Personnel			
Resident advisor	TBD		2,500
(10) Student Interns (10wks@2500)			25,000
TOTAL SALARIES & WAGES			33,346
Fringe @ 26.1%			1,526
Total Salaries, Wages and Fringe			34,872
D. Permanent Equipment			0
E. Travel: Domestic			
10 (RT)coach airfares to Tucson @ $400/ea			4,000
Travel to/from Tucson (collaborating sci.)			4,000
Housing 10@ $5/day x 70 days			3,500
RA Housing 1 @ $5/dayx70 days			350
RA travel @ $400			400
Intern field trips (van rentals, gas, fees, etc.)			1,000
Total Travel			13,250
G. OTHER DIRECT COSTS:			
1. Materials/Supplies:			
Misc. lab supplies			500
office supplies			0
2. Publication costs/page charges			500
3. Computer charges			0
6. Other			0
Communications, phone (to include videolink), Fax			950
Shipping			0
Scholarships @ $1000/student			10,000
Total Other Costs: (G1-G6)			11,950
H. Total Direct Costs (A-G)			60,072
I. Indirect Costs @ 24.85%			14,928
J. Total Requested			75,000

Appendix A

CERTIFICATION REGARDING LOBBYING

Certification for Contracts, Grants, Loans, and Cooperative Agreements.

The undersigned certifies, to the best of his or her knowledge and belief, that:

(1) No Federal appropriated funds have been paid or will be paid, by or on behalf of the undersigned, to any person for influencing or attempting to influence an officer or employee of any agency, a Member of Congress, an officer or employee of Congress, or an employee of a Member of Congress in connection with the awarding of any Federal contract, the making of any Federal grant, the making of any Federal loan, the entering into of any cooperative agreement, and the extension, continuation, renewal, amendment, or modification of any Federal contract, grant, loan, or cooperative agreement.

(2) If any funds other than Federal appropriated funds have been paid or will be paid to any person for influencing or attempting to influence an officer or employee of any agency, a Member of Congress, an officer or employee of Congress, or an employee of a Member of Congress in connection with this Federal contract, grant, loan, or cooperative agreement, the undersigned shall complete and submit Standard Form-LLL, "Disclosure Form to Report Lobbying," in accordance with its instructions.

(3) The undersigned shall require that the language of this certification be included in the award documents for all subawards at all tiers (including subcontracts, subgrants, and contracts under grants, loans, and cooperative agreements) and that all subrecipients shall certify and disclose accordingly.

This certification is a material representation of fact upon which reliance was placed when this transaction was made or entered into. Submission of this certification is a prerequisite for making or entering into this transaction imposed by section 1352, title 31, U.S. Code. Any person who fails to file the required certification shall be subject to a civil penalty of not less than $10,000, and not more than $100,000 for each such failure.

____
Signature and Date

Barbara Lucas, Sr. Projects Officer
Name and Title of Authorized Representative

____
Organization Name

Appendix A

Certification Regarding
Debarment, Suspension, and Other Responsibility Matters
Primary Covered Transactions

This certification is required by the regulations implementing Executive Order 12549, Debarment and Suspension, 34 CFR Part 85, Section 85.510, Participant's responsibilities. The regulations were published as Part VII of the May 26, 1988 Federal Register (pages 19160-19211). Copies of the regulation may be obtained by contracting the U.S. Department of Education, Grants and Contracts Service, 400 Maryland Avenue, S.W. (Room 3633 GSA Regional Office Building No. 3), Washington, DC. 20202-4725, telephone (202) 732-2505.

(1) The prospective primary participant certifies to the best of its knowledge and belief, that it and its principals:

(a) Are not presently debarred, suspended, proposed for debarment, declared ineligible, or voluntarily excluded from covered transactions by any Federal department or agency;

(b) Have not within a three-year period preceding this proposal been convicted of or had a civil judgment rendered against them for commission of fraud or a criminal offense in connection with obtaining, attempting to obtain, or performing a public (Federal, State, or local) transaction or contract under a public transaction; violation of Federal or State antitrust statues or commission of embezzlement theft, forgery, bribery, falsification or destruction of records, making false statements, or receiving stolen property;

(c) Are not presently indicted for or otherwise criminally or civilly charged by a governmental entity (Federal, State or local) with commission of any of the offenses enumerated in paragraph (1)(b) of this certification; and

(d) Have not within three-year period preceding this application/proposal had one or more public transactions (Federal, State, or local) terminated for cause or default.

(2) Where the prospective primary participant is unable to certify to any of the statements in this certification, such prospective participant shall attach an explanation to this proposal.

Trustees of Columbia University

Organization Name PR/Award Number or Project Name

Barbara Lucas, Sr. Projects Officer

Name and Title of Authorized Representative

Signature Date

ED Form GCS-008 (REV.12/88)

Appendix A

Certification Regarding Drug-Free Workplace Requirements
Grantees Other Than Individuals

This certification is required by the regulations implementing the Drug-Free Workplace Act of 1988, 34 CFR Part 85, Subpart F. The regulations, published in the January 31, 1989 Federal Register, require certification by grantees, prior to award, that they will maintain a drug-free workplace. The certification set out below is a material representation of fact upon which reliance will be placed when the agency determines to award the grant. False certification or violation of the certification shall be grounds for suspension of payments, suspension or termination of grants, or governmentwide suspension or debarment (see 34 CFR Part 85, Sections 85.615 and 85.620).

This grantee certifies that it will provide a drug-free workplace by:

(a) Publishing a statement notifying employees that the unlawful manufacture, distribution, dispensing, possession or use of a controlled substance is prohibited in the grantee's workplace and specifying the actions that will be taken against employees for violation of such prohibition;

(b) Establishing a drug-free awareness program to inform employees about -

(1) The dangers of drug abuse in the workplace;
(2) The grantee's policy of maintaining a drug-free workplace;
(3) Any available drug counseling, rehabilitation, and employee assistance programs, and
(4) The penalties that may be imposed upon employees for drug abuse violations in the workplace;

(c) Making it a requirement that each employee to be engaged in the performance of the grant be given a copy of the statement required by paragraph (a);

(d) Notifying the employee in the statement required by paragraph (a) that, as a condition of employment under the grant, the employee will -

(1) Abide by the terms of the statement; and
(2) Notify the employer of any criminal drug statute conviction for a violation occurring in the workplace no later than five days after such conviction;

(e) Notifying the agency within ten days after receiving notice under subparagraph (d)(2) from an employee or otherwise receiving actual notice of such conviction;

(f) Taking one of the following actions, within 30 days of receiving notice under subparagraph (d)(2), with respect to any employee who is so convicted -

(1) Taking appropriate personnel action against such an employee, up to and including termination; or
(2) Requiring such employee to participate satisfactorily in a drug abuse assistance or rehabilitation program approved for such purposes by a Federal, State, or local health, law enforcement, or other appropriate agency;

(g) Making a good faith effort to continue to maintain a drug-free workplace through implementation of paragraph (a), (b), (c), (e), and (f).

Trustees of Columbia University

Organization Name PR/Award Number or Project Name

Barbara Lucas, Sr. Projects Officer

Name and Title of Authorized Representative

Signature Date

ED 80-0004

Appendix B:

1998 NASA Intern Research Reports

The Effects of Ambient UV Radiation and Temperature on Two Desert Adapted Plants

Alesha Herrera
Rice University - Houston, Texas
Biosphere 2 Center, Summer 1998
Mentor : Dr. Charles Cockell

Introduction

The effects of exclusion of different parts of the UV spectrum on two desert adapted cash crops was studied using four types of UV screens. Ambient, rather than increased levels of UV radiation were implemented in this study. This not only will give a good insight into plant sensitivities to increased UV radiation, but also has an importance relevance to artificial ecosystems, such as Biosphere 2 - a three-acre enclosed ecosystem near Tucson, Arizona. This project was also chosen to further understand the role natural radiation has on crops in desert areas around the world. Both squash and sorghum bicolor were subjected to ambient and reduced level of UV over a 2 month period and the effects on thermal tolerance, photosynthetic yield, photosynthetic rate, leaf area and weight were measured. These plants were chosen for several reasons. Not only are they fast-growing, but they are desert adapted and grow well in this region and many other countries. They are also used as a cash crops in many places, and are therefore both scientifically and economically important.

Materials and Methods

Four different types of UV radiation screens were used in this experiment. OP3 removes both UVA and UVB from the light spectrum reaching the plants. Mylar protects them from UVB only and UV Transparent (UVT) was used on a control group to allow all ambient UV in, yet create the same environment for the plants to grow in. Several experiments were also done using a piece of glass from Biosphere 2, to see how this radiation regime affected the plants. The screens were placed like triangular tents over the plants and both attenuation characteristics and edge effects were measured over the course of the experiment to ensure they were constant.

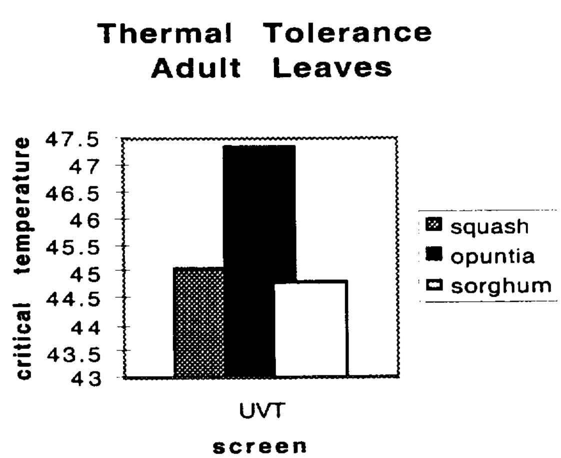
Both squash and sorghum were planted on June 5th and placed in full sunlight in water-filled pools to ensure that no water stress would affect their growth. The plants under all screens were periodically watered with a Miracle Grow solution to prevent nutrient stress. The perimeter of the experiment was fenced off to keep out rodents and other desert animals. The experiment ran for 48 days during which the plants were watered every other day.

Results and Discussion

Thermal Tolerance

The key of this experiment was to study the total effect of UV radiation over the course of germination and early growth of the plants. Since the project was conducted in the middle of the desert, temperature stress and thermal tolerance was a very real concern. Both of these factors were therefore analyzed.

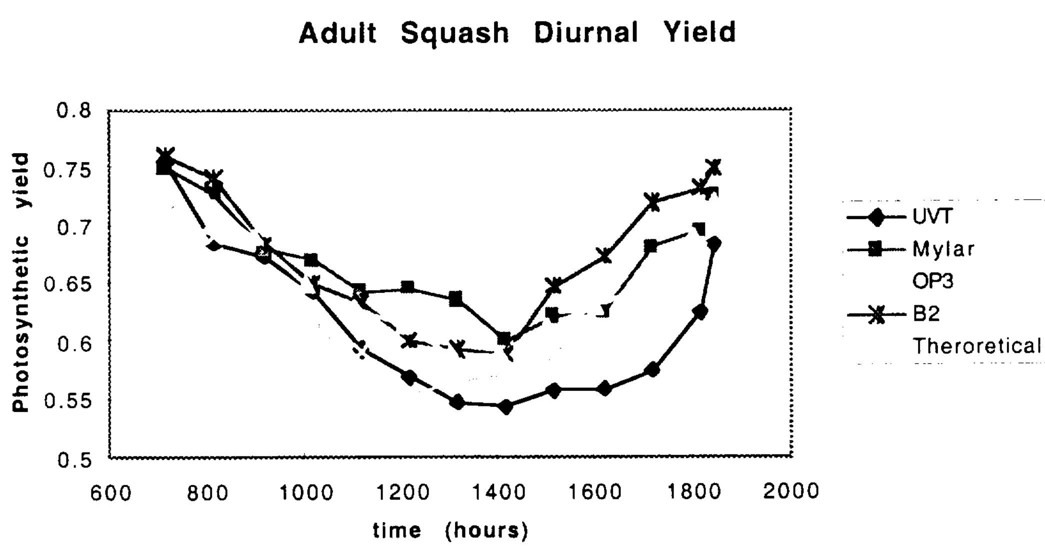
Measuring critical temperature is one way to gain insight about plant reactions to various heat environments. Critical temperature can be calculated by measuring photosynthetic yield across a temperature gradient and determining at what temperature the electron systems within the plant fail. No significant correlation was found between the four screens, but further experimentation showed a significant difference between native and non-native desert plants. The squash and sorghum, which are not native to the Tucson desert area were tested. Their thermal tolerance, along with the thermal tolerance of local Opuntia plants are shown below.



The native desert plants not only have a higher critical temperature, but they are also able to endure hotter temperature regimes for a longer period of time. The critical temperature, or temperature at which, when exceeded, a plant can be expected not to recover, is highest in the native species.

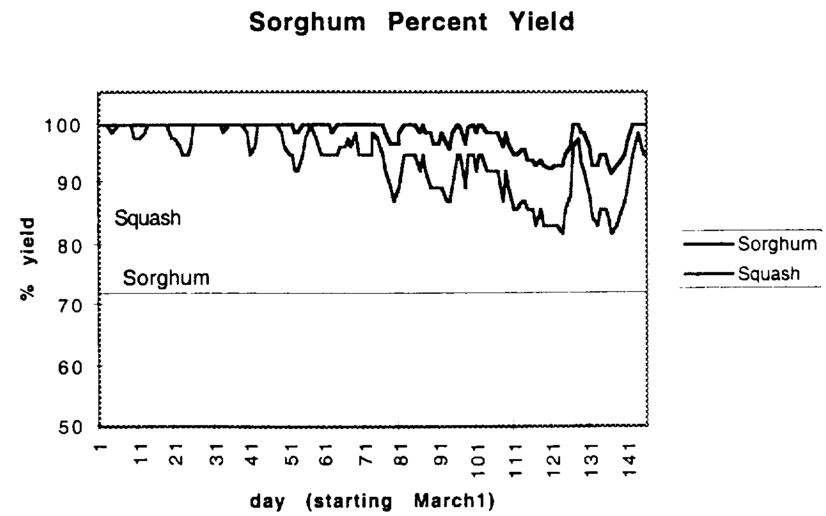
Photosynthetic Yield

Photosynthetic yield is the measure of electron transport reactions in a leaf. Since these reaction tend to vary across different temperatures, yield was measured diurnally to determine the effect that temperature and UV stress has on plant photosystems throughout the day.



The theoretical curve above was generated using temperature data collected throughout the day of the experiment. By determining the theoretical yield based on these temperatures, one can deduce that any additional decreases in yield must be due to UV stress. Differences in diurnal yield due to UV stress were found, with the squash plants shielded from UV exhibiting the greatest overall yield. This experiment also showed that the squash subjected to full ambient UV had a longer recovery time after mid-day temperature stress. It is not apparent how exactly these two factors, UV radiation and temperature, work together as environmental stresses. Further experimentation on this subject is planned for the future.

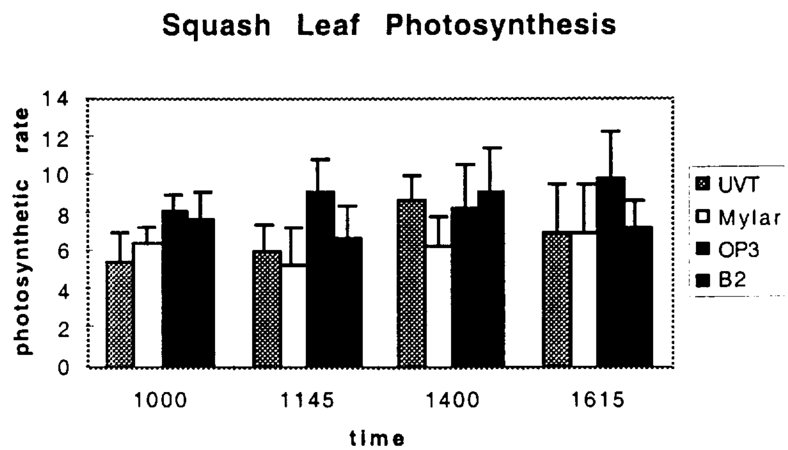
Another product of the photosynthetic yield experiment is shown below.



Maximum yields in the plants occur at moderate temperatures, when there is no thermal stress. The percent yield is calculated in relation to these non-stressed conditions. This plot shows the percent yield achieved throughout the summer of 1998 based on outside ambient temperatures. The two horizontal lines mark the percent yield at critical conditions for both of the plants tested. This graph clearly shows how close squash comes to critical conditions during the hot desert summer. Sorghum bicolor, which has a higher thermal tolerance, is better suited for this weather regime. This type of data can be very helpful in determining the best times for planting and harvesting crops. The data gathered is currently being manipulated for use in other desert areas like Egypt and Libya.

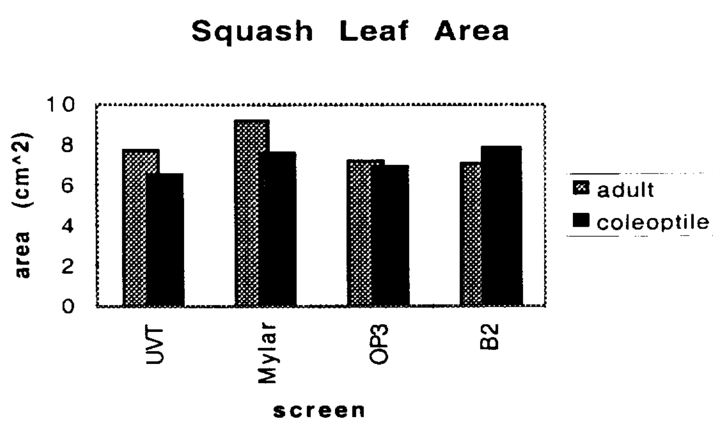
Photosynthetic Rate

Since information about leaf photosynthesis cannot be inferred directly from yield measurements, the next step in the experiment was to measure leaf carbon dioxide uptake.



Though there is no daily pattern evident, the photosynthetic rates were found in most cases to be largest in plants screened from at least one type of UV. This information can be directly related to the growth rate of the plants tested, and biomass results support this data.

Leaf Area

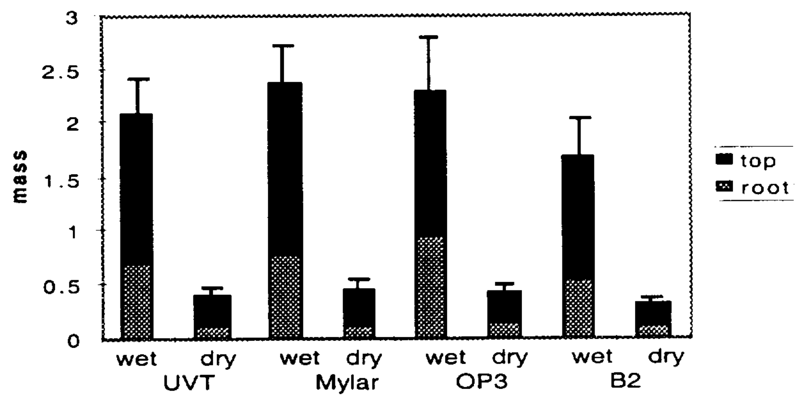


The leaf area in both the coleoptile and adult leaves of the squash plants were measured using a leaf area meter. No significant differences were found.

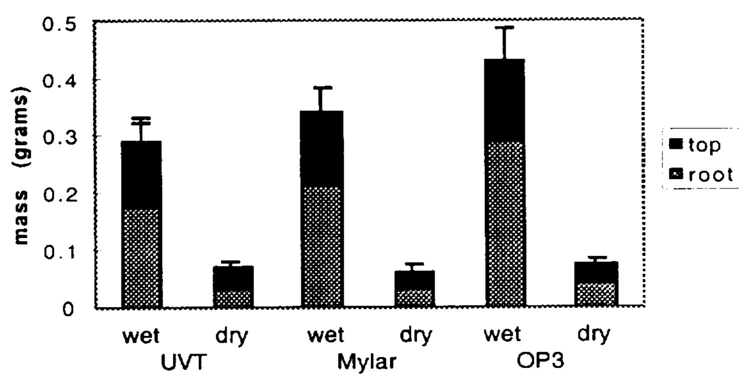
Plant Biomass

Wet as well as dry biomass were measured at the conclusion of the experiment. Both root and above ground portions of the plant were analyzed. In both squash and sorghum a difference in wet mass can be seen between the different screens, though it is more pronounced in the sorghum plants. This may be due to the intense thermal stress that the squash experienced throughout the course of the project. This additional stress may have made UV induced differences less pronounced.

Squash Final Mass



Sorghum Final Mass



Those the effects are not as evident, a similar pattern in dry biomass can be seen in the squash mass data. This is evidence that it is indeed total plant size and mass that differs between the screens and not just water retention.

Education

There is a great need for increased public education and awareness about UV and ozone depletion. The Biosphere 2 Center plays and important role in the education of the public on current global change issues, and this topic should be no exception. A general UV education site has been developed this summer to help the public understand the following topics:

- What is UV Radiation?
- Causes of UV Increase
- Efforts to Decrease Ozone Depletion
- UV Radiation and You
- UV Radiation and Biosphere 2
- Current UV Experiments

This Web site has been designed to give people an understanding of how UV affects everything around us as well as what is being done to protect us from increased UV in the future. It will be displayed as a link from the Biosphere 2 Center's student pages site.

Conclusions

The experiments conducted this summer show that different parts of the Ultraviolet radiation spectrum do indeed have an effect on squash and sorghum plant growth. Especially in the photosynthetic rates and wet biomass can we see the potentially detrimental effect that UV has on these plants. These findings can be extended into an area of great scientific concern at the moment: ultraviolet radiation and the ozone hole. By showing that these plants are sensitive to the relative amounts of UV radiation reaching them, we can predict their negative responses to an increase in UVB, which will occur as the ozone hole continues to grow. Throughout this experiment one can also see the importance of understanding the intricate interactions between the different parts of the UV spectrum when creating an artificial ecosystem. We've also leaned that temperature plays an important role in the plant characteristics discussed, and more work in understanding the UV radiation - temperature synergism is planned for the future.

SOURCES, SINKS

AND

MASS BALANCING ATMOSPHERIC METHANE

AT BIOSPHERE 2

By
Courtney Pegus

Mentors
Joost Van Haren
&
Debra Colodner

Abstract- Methane fluxes from sub-surface permanently water logged soils, semi-moist soils and plant emissions located in the rain-forest biome were measured in an attempt to account for the observed methane gradient during rainforest closures. Methane fluxes from box closures located over sub-surface permanently water logged soils showed a strong positive correlation with time. (R squared =0.998). However, fluxes from semi moist soils located in close proximity from the water logged soils (< 2 meters) showed a weak positive correlation with time (R squared = 0.1082). Flux measurements from all permanently waterlogged soils showed that gas transport between atmosphere and water was faster than microbial methane oxidation. Flux chambers designed to enclose Cyperus alternifolius a plant, which dominated one study region, indicated that these plants actively transport methane.

Introduction

Methane is considered to be a significant greenhouse gas. It is produced in soils (primary production) as the end product of anaerobic decomposition of organic matter and diffuses towards the atmosphere (primary emissions). Studies suggest that approximately 70% of the increase in ambient methane levels over the last 200 years are probably due to an increase in primary emissions (Khalil and Rasmussen, 1984). In the absence of oxygen, methane is very stable; hence the high concentrations in the anoxic soil regions. However, in aerobic conditions it is mineralized to carbon dioxide by methanotrophic bacteria. Soil methane emissions, primarily from natural wetlands, landfills and rice paddies, are estimated to represent about half the annual global methane production. Methane can be transported into the atmosphere via three ways: molecular diffusion, ebullition (degassing) & vascular transport. Rates of methane transportation by molecular diffusion and ebullition are primarily governed by concentration gradients between sub-surface regions and the atmosphere, extensiveness of the aerobic soil region and the relative rates of methanogenic and methanotrophic activity. The relative rates of production and consumption of methane by micro-organisms in turn are governed by, pH, salinity, temperature, distribution of organic matter, oxygenating effect of burrowing animals and many other indirect factors such as algal blooms and seasonal events (Burke et al 1988). Ebullition, (the bubbling of methane) occurs when the partial pressure of the methane bubble exceeds the hydrostatic pressure of the water. In tropical wetlands this mode of transport is especially important as it contributes 20% - 70% of the total methane flux (Bartlett and Harris, 1993). This suggests that the sub-surface topography and the depth at which the methane is produced determine the bubble volume and hence the rate at which it rises when it escapes. Thus, the methane retention capacity of any region may be dependant on the type of litter or vegetative material (i.e. leaf litter dominated by "broad leaves" tend to retain larger methane bubbles than leaf litter dominated by smaller leaves (e.g. Pine needles). Biotic factors such as the presence of submerged roots, which has the effect of increasing the retention capacity of sub-surface regions by acting as matting or "collection pockets" which may increase bubble size and hence the rate at which a bubble can rise through the water. Faster rising bubbles are less likely to interact with methanotrophic regions (Dacey and Klug 1979). Roots also have the ability to increase the aerobic regions of the water column as certain plants (water lilies) actively pump oxygen to their root systems (Dacey et al. 1982).

Transport of methane via vascular plants is dependent on the type of plant growing in the region. Studies done by Chanton et al. demonstrated the methane flux from a bottomland hard wood swamp varied from 270 to 670 mg CH4/ sq. meters / day and was greater in vegetated regions than in non-vegetated regions. In fact (Schutz et al.1991) states that a large fraction of primary emissions are plant-mediated. Many plants adapted to water-logged soils contain (lacunae) which is an extensive network of gas spaces that facilitates the conductance of oxygen to buried roots and rhizomes and methane from sub-surface anaerobic regions directly to the atmosphere (Schutz et al., 1991). Studies suggest that plant mediated transport of methane shields the gas from the methanotrophic zone and hence prevents oxidation from occurring (Potter 1997)

Oxidation of atmospheric methane by well drained soils account for about 10 % of the global methane sink. Studies done on drier savanna and desert soils (hence more aerobic) suggest that these soils act like sinks (Servant et al. 1992). Another important methane sink is the reaction of methane and OH radicals in the atmosphere. $CH_4 + OH$ --- $CH_3 + H_2O$. Ultra Violet radiation plays a key role in the production of the OH radical, which is responsible for the oxidation of methane. However, the rate at which methane is oxidized by this process is still not clear (Hein 1997). Estimates of the global methane balance are currently based on extrapolations from direct flux measurements in source and sink regions and thus involve large uncertainties (Hein 1997).

Experimental Plan and Description of Techniques

Description of Field Site

The experiment was conducted during the summer months (June-July) of 1998 at Biosphere 2 near Oracle, Arizona.

Biosphere 2 provides a unique research site for studying methane as environmental factors such as temperature, relative humidity and other climatic factors can be carefully controlled and monitored. The glass that contains this environment blocks out 100 % of U.V radiation and as a result OH radicals are absent. Thus, the rates of production and consumption can be more accurately accounted for by investigating terrestrial fluxes. Secondly, the entire rainforest biome can be sealed off and the net increase in methane investigated. Thus the accuracy of extrapolating soil fluxes from small soil chambers to entire ecosystems can also be investigated. The three modes of methane transport are present at Biosphere 2. In the flooded plain region, (varzea) ebullition can be seen occurring from a glass wall and previous studies done with box chambers indicated transport via diffusion. Located on one of the study sites on "Cloud Mountain" are dense thickets of Cyperus alternifolius.

Also known as "Umbrella plant" this sedge is a clustering perennial bog plant with ribbed stalks up to 8ft high, bearing a crown of bright green, leaf like bracts around a head of small green flowers. Previous studies done on methane at Biosphere 2 have neglected the effects of these plants, which I suggest, act as "drinking straws" which assist in the transport of methane through the aerobic soil regions. The root system of these plants are quite similar to those studied by Dacey et al. and preliminary observations suggest that the root system acts as "submerged methane pockets" capable of trapping large quantities of methane. The fibrous nature of the stem interior suggests the presence of an extensive network of gas spaces and the methane concentration within these plants were on average six times greater than ambient.

The three field sites chosen were all located in the rainforest biome (Appendices A, B & C) and were all connected by the same water system (Appendix D). Comparisons could be made between methane fluxes from (*site*1) (Appendix E) **vegetated waterlogged soils** (Cloud mountain), (*site* 2) (Appendix E) **un-vegetated waterlogged soils** (varzea) and (*site* 3) (Appendix E) **vegetated semi-moist soils** (Cloud mountain). *Site* 1 (Appendix D) is a semi circular concrete pond located at the top of cloud mountain (Elevation 3874'-6") of varying depths. It is composed mainly of vegetative litter from a monoculture of Cyperus alternifolius. *Site* 2 (Appendix D) is a concrete V-shaped river (Elevation 3835'-10") 42.68 meters long 0.8 meters deep, 1 meter wide composed of a combination of broad leaf tropical litter (Appendix E). *Site* 2 is identical to *site* 1 with the exception of the moisture content present in the soils. *Site* 1 is permanently water logged, whereas *site* 2 is kept semi-moist by misting.

Description of Basic Methodology

Box Chambers

The methane flux between atmosphere and soil was determined in the field using the floating closed chamber method. Open bottom metal boxes of dimensions 6.9 cm*27.5*27.6cm were floated on a Styrofoam frame. Over periods of 15 minutes for up to 4 hours gas samples (10ml) were collected with gas-tight glass syringes and analyzed with a Hewlett Packard 5890 gas chromatograph with a flame ionization detector. Preliminary results depicted huge fluctuations in this method. It became apparent that these fluctuations were a result of a lack of mixing between the methane flux and the air trapped in the chamber and the methodology by which samples were taken. Syringes were "pumped" 10 times to ensure a homogeneous air mixture before the actual sample was drawn. This resulted in pressure perturbations on the water surface, which the box encompassed. Slight perturbations in this system would most likely increase the rate at which ebullition occurred. To reduce this effect a 12volt Elena Computer fan was fitted inside the box to allow proper air mixing and 1 meter of metal tubing attached to the septum. This allowed readings to be taken without any disturbances to the immediate sampling area.

Plant Chambers

To investigate the effects of vascular plant transport, I designed several flux chambers one of which (Courtney Chamber) segmented two stalks of Cyperus alternifolius into three sections -: Roots, stems and leaves. The base of the chamber (where the roots of a clump were planted) contained methanogenic bacteria in waterlogged, anaerobic soil conditions. This part was separated from the rest of the plant by a plastic barrier which was tested for its non-absorbing qualities and the hole which the stem passed through was sealed with Dow Corning high vacuum grease. Air was blown through the top part of the base of the chamber and the methane concentration monitored. The chamber also segmented the leaves from the stem and these concentrations also monitored.

An 8Ft. plant chamber was also designed to investigate the effects of Cyperus alternifolius on methane fluxes in the field. This chamber was suspended from the space frame and made of the same leak proof plastic used to segment the first chamber. Two12volt Elina Computer fan were fitted inside the chamber to allow air circulation and 5 ft of extended septum tubing used so that readings could be taken with minimal disturbance.

Results and Discussion

By comparing the flux concentrations of the upper plant parts in the segmented "Courtney Chamber" we noted a strong positive correlation with time (graph 1) for plant stems and a negative correlation for the vented base. This suggests that the Cyperus alternifolius actively pumped methane from subsurface regions to the upper stems. The leaf cylinder also showed a strong positive correlation with time (R sq. = 0.77 which suggests that the entire upper plant is involved in gas exchange. This may give an explanation for the methane fluctuations during 1998 rainforest closures (Graph 3). Internal gas samples taken on different plants found along the Varzea indicated the high internal methane concentration for Cyperus alternifolius (Graph 4). This demonstrates the importance of examining the effects of Cyperus and other water plants when investigating mass movement and mass balancing methane.

Other Sources

The Varzea showed a strong positive correlation with distance for methane concentration. (Graph 5). This may be explained by the source of the river being a highly oxygenated waterfall region whereas the end of the river is a rich organic sump. On average the methane flux from the Varzea was on order of 8 times higher than the ambient methane concentration (Graph 6). The strong positive correlation with time suggests that the Varzea suggest that it is another significant methane source.

Box Fluxes

Although there was significant variation between the methane fluxes on different dates of the same site (graph 7, 8 & 9) production on vegetated water logged conditions was the highest of the sites examined. (Graph 10 &11) Graphs of site 3 and ambient concentration suggest that site 3 (Graph 11) acted as both a source and a sink. Site 2 indicated a higher production rate than ambient. (Graph 10) This suggests that besides the presence of vegetation, permanently water logged soils are significantly important for high methane production.

Conclusion

In my attempt to balance and account for the increase in methane flux during rainforest closures, I discovered several sources. Of the three sites examined, two sites (Site1 & 2) turned out to be significant methane sources (Graph 12). The fluctuations of Site 3 suggested that the percentage saturation of the soil determined whether that site was a source or a sink

The evidence gathered on the effects of Cyperus alternifolius strongly suggests that the total flux (mg/sq. cm/min) should changed to (mg/cubic cm./ min) as these plants can be considered to be vertical "methane flux columns" per square cm, hence the notation mg/cubic cm./min.

The effect of these plants definitely brings new parameters to light when investigating methane flux. In past studies on light were not taken to be a parameter in the same regards as temperature. I believe that there is a strong correlation between methane flux and light intensity (time of day).

My hypothesis therefore is that the methane flux during the day will be greater than nighttime fluxes as plants photosynthesize during the day and respire at night. Fluxes without the presence of Cyperus alternifolius will therefore show no difference during night and day but changes will take place in plant chamber boxes.

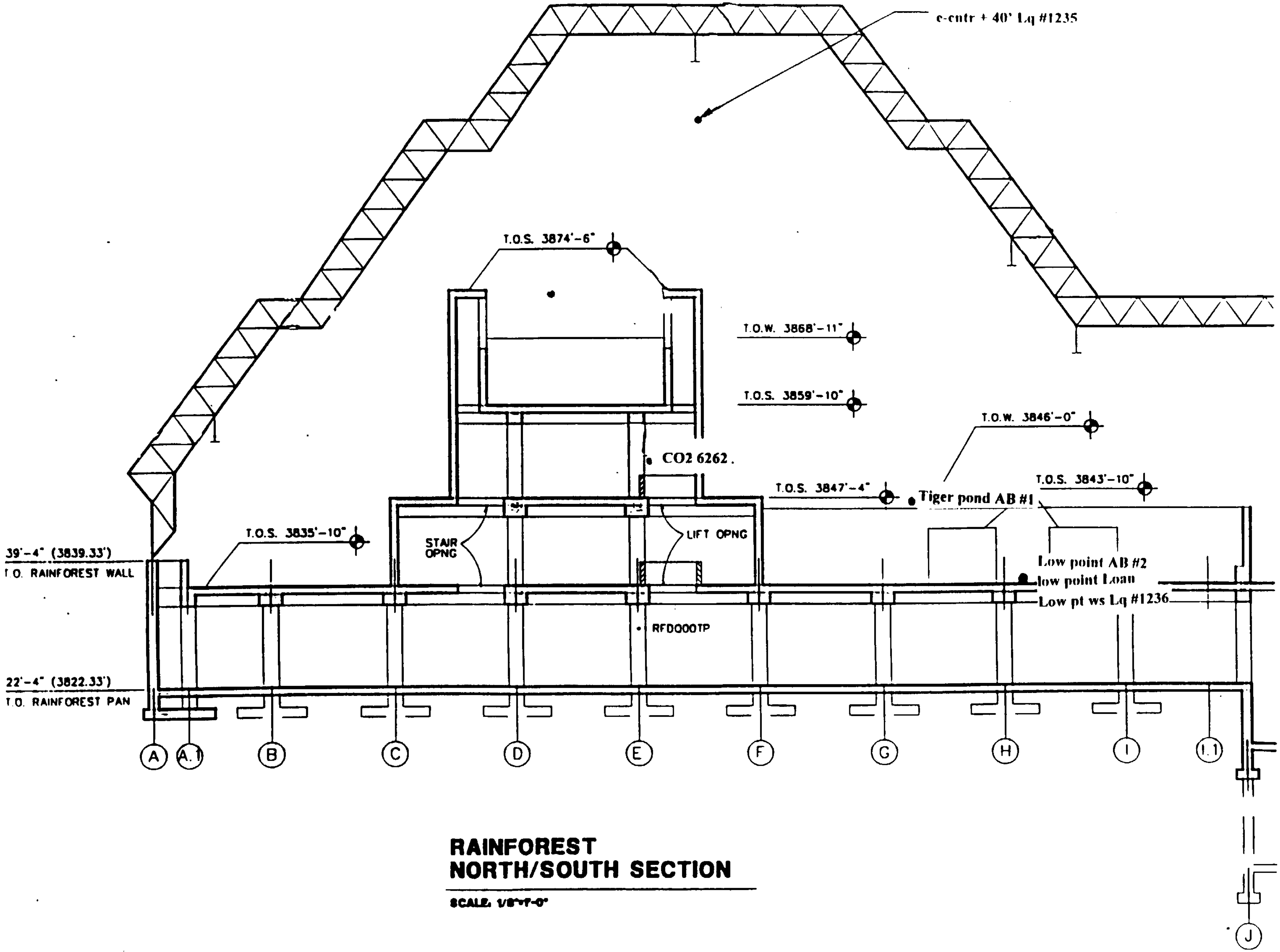
Problems

One major difficulty was the daily variation of standard concentrations as it made it virtually impossible to recheck previous samples

Secondly, due to time constraints a chamber that was designed to investigate the methane fluxes from plants in the field was never implemented. Leaf bags gave no tangible results because of the sensitivity of these plants. The flux chamber gave an indication that under high anoxic conditions these plants do indeed transport methane. However, the plant's performance under different sub-surface methane concentrations was never tested. The litter content in the chamber was different to the type that the plant grew in on top of the mountain; neither was attempts made to keep atmospheric conditions similar to that of Cloud Mountain. The unique design of the chamber allows repetitive reading to be taken (Graph 13). However, the chamber can be improved by introducing a circulation system and temperature control.

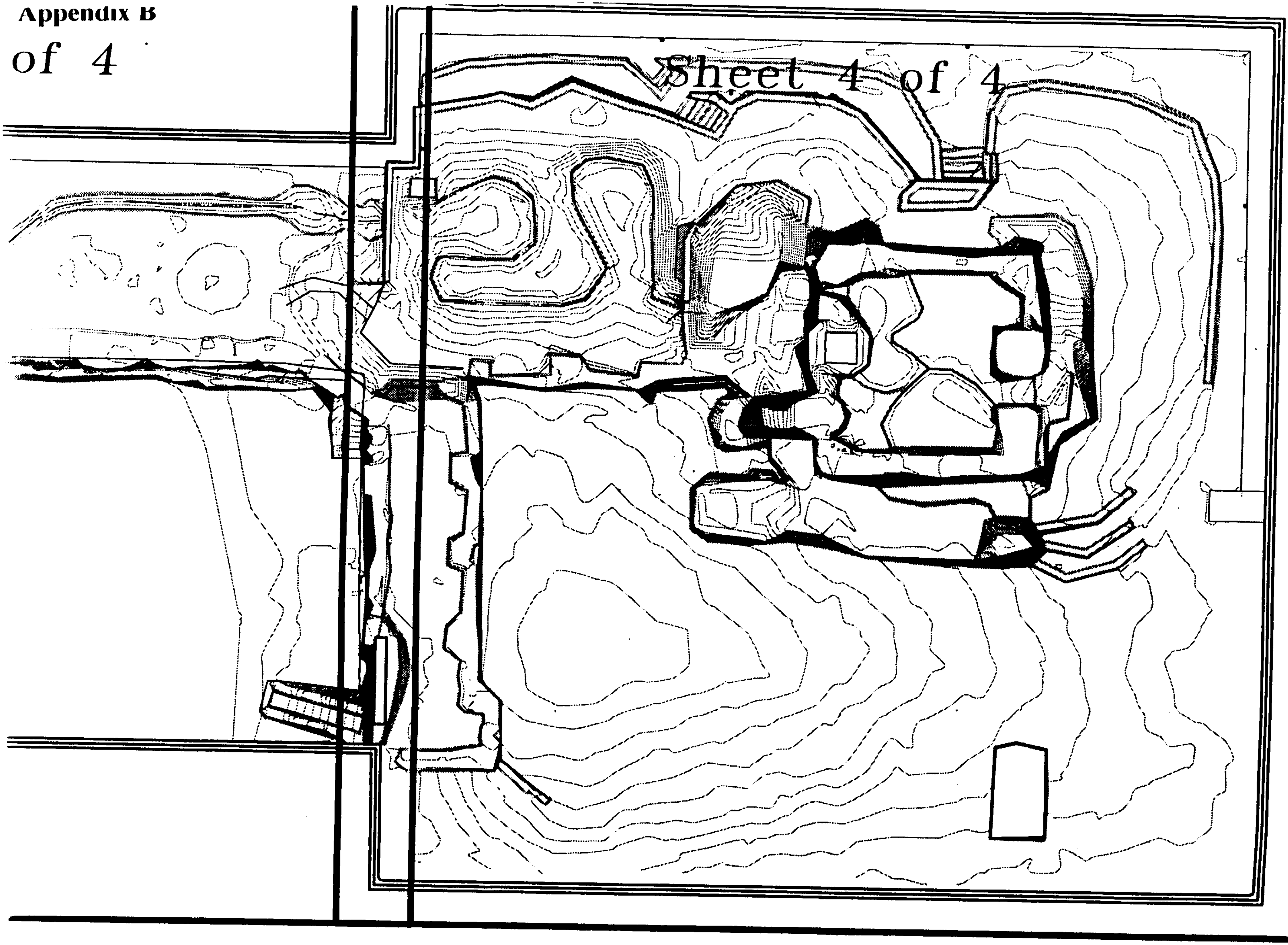
Finally, readings of sources and sinks should be taken in close time periods since the production and possibly consumption are so highly variable.

Appendix A

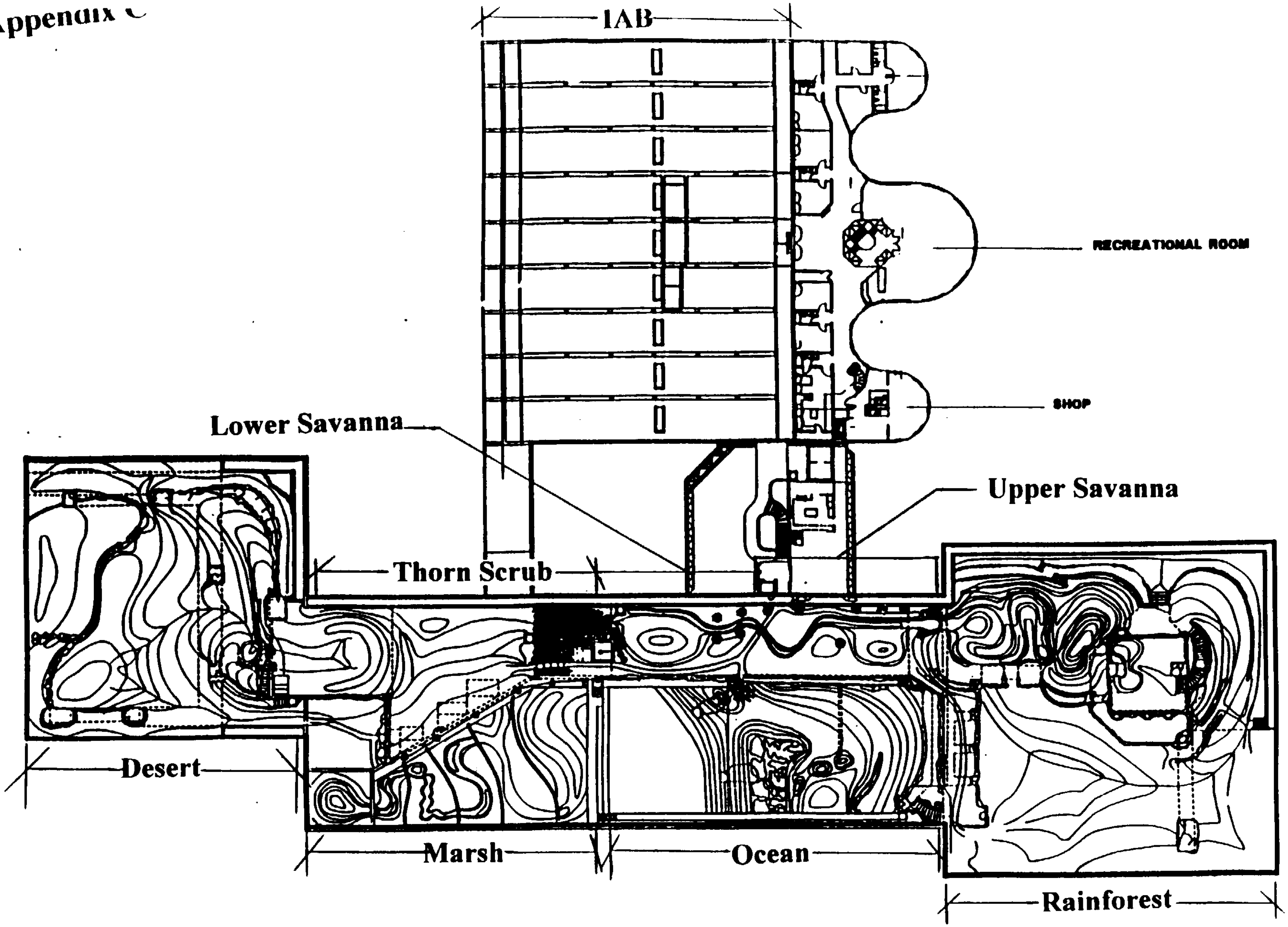


**RAINFOREST
NORTH/SOUTH SECTION**

SCALE: 1/8"=1'-0"

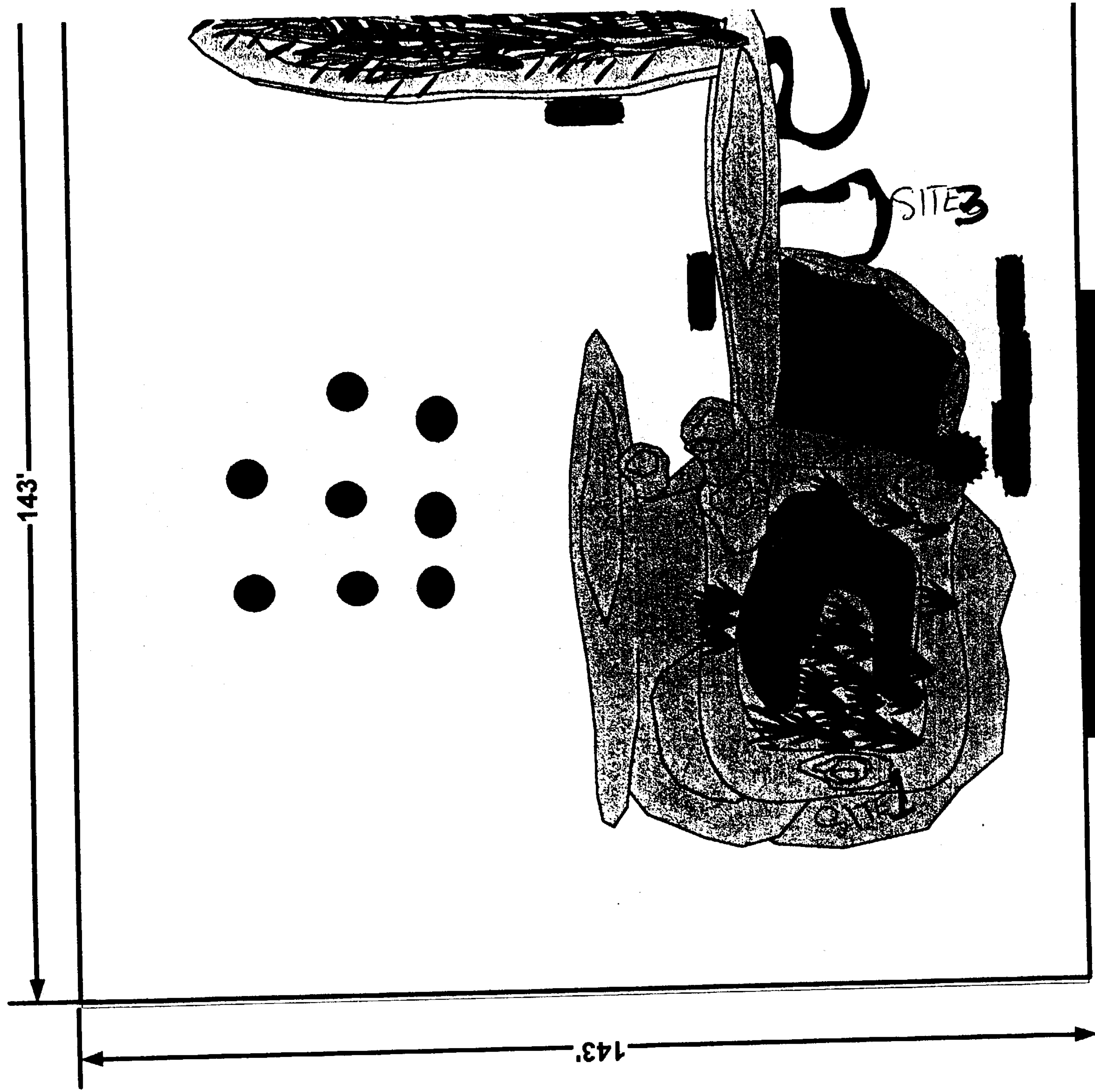

Sheet 4 of 4

Appendix C



IAB
RECREATIONAL ROOM
SHOP
Lower Savanna
Upper Savanna
Thorn Scrub
Desert
Marsh
Ocean
Rainforest

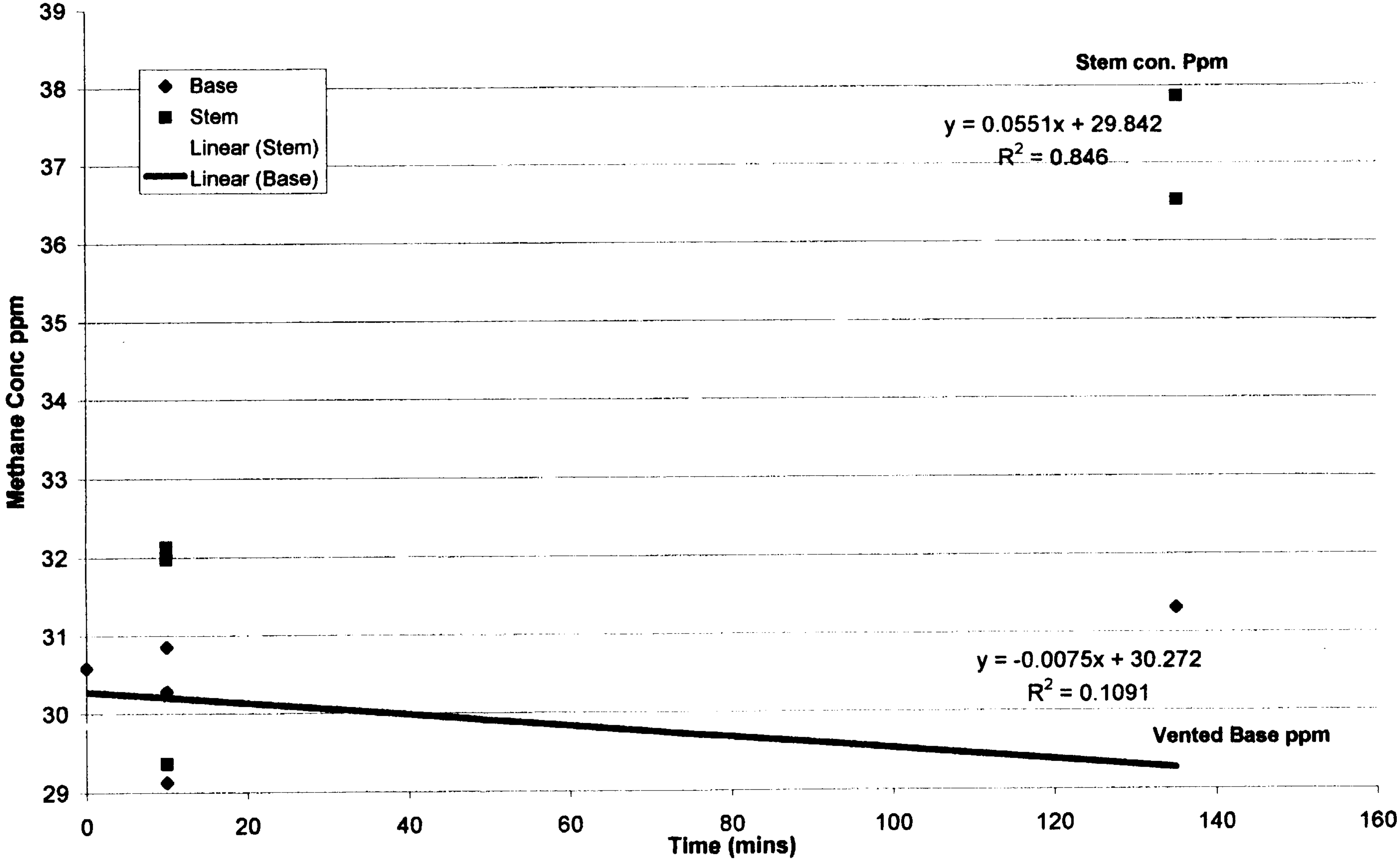
Appendix D



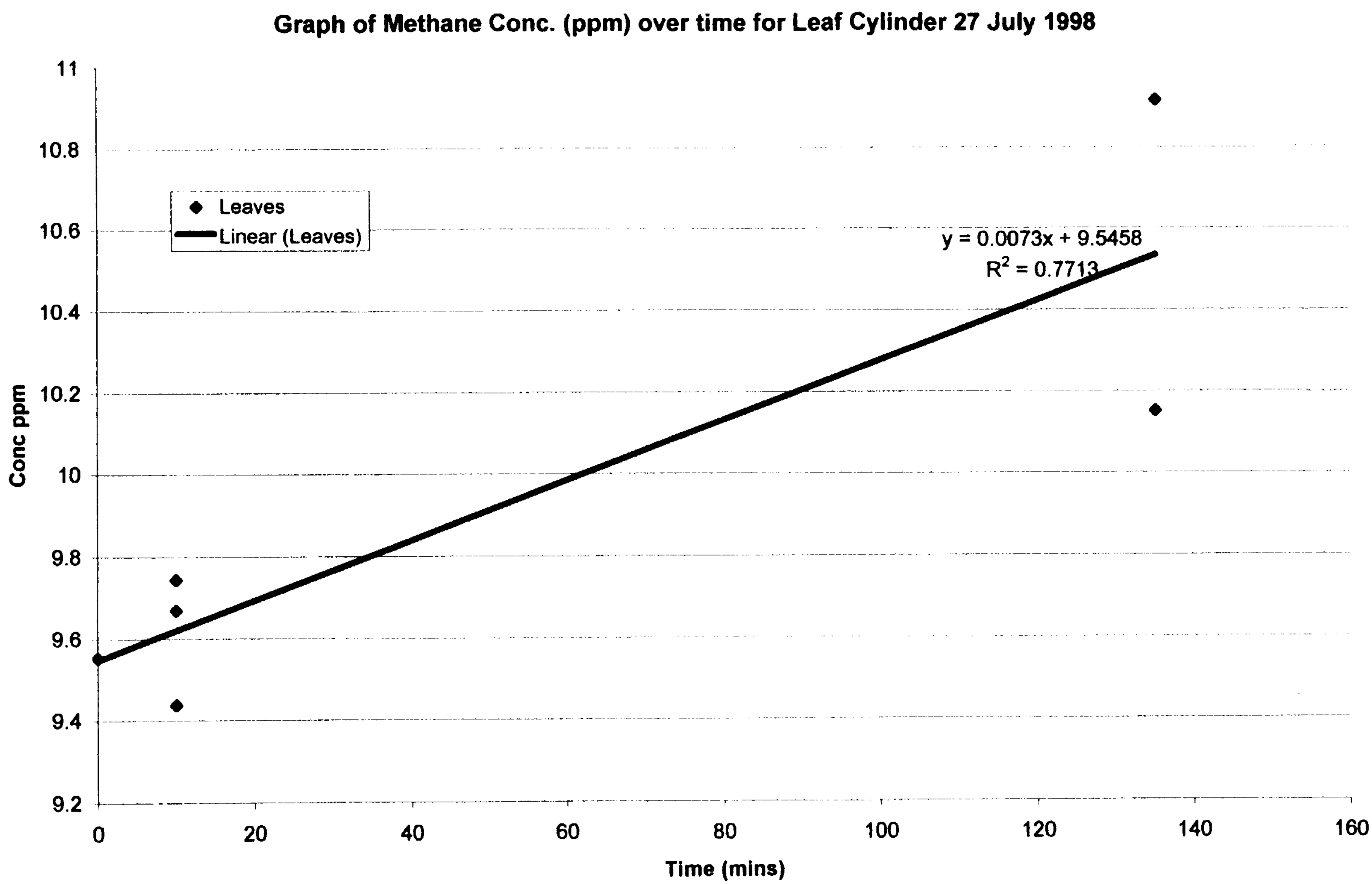
Appendix E

GRAPH 1

Comparisson of Methane Conc. between (sealed and vented) Base chamber and (sealed and Closed) Stem chamber 27 July 1998

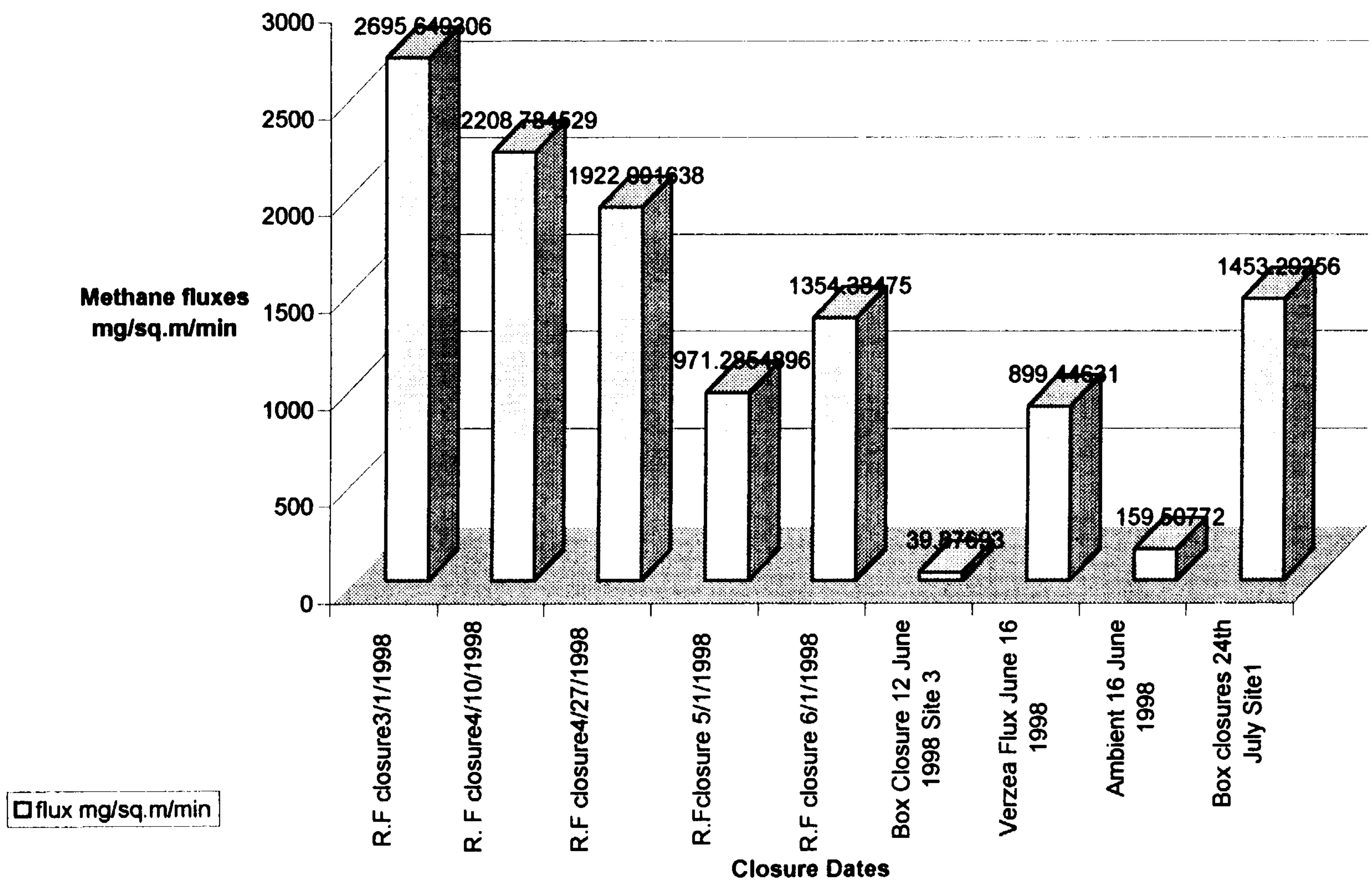


GRAPH 2


Graph of Methane Conc. (ppm) over time for Leaf Cylinder 27 July 1998
Leaves
Linear (Leaves)
y = 0.0073x + 9.5458
R^2 = 0.7713
Conc ppm
Time (mins)
11
10.8
10.6
10.4
10.2
10
9.8
9.6
9.4
9.2
0
20
40
60
80
100
120
140
160

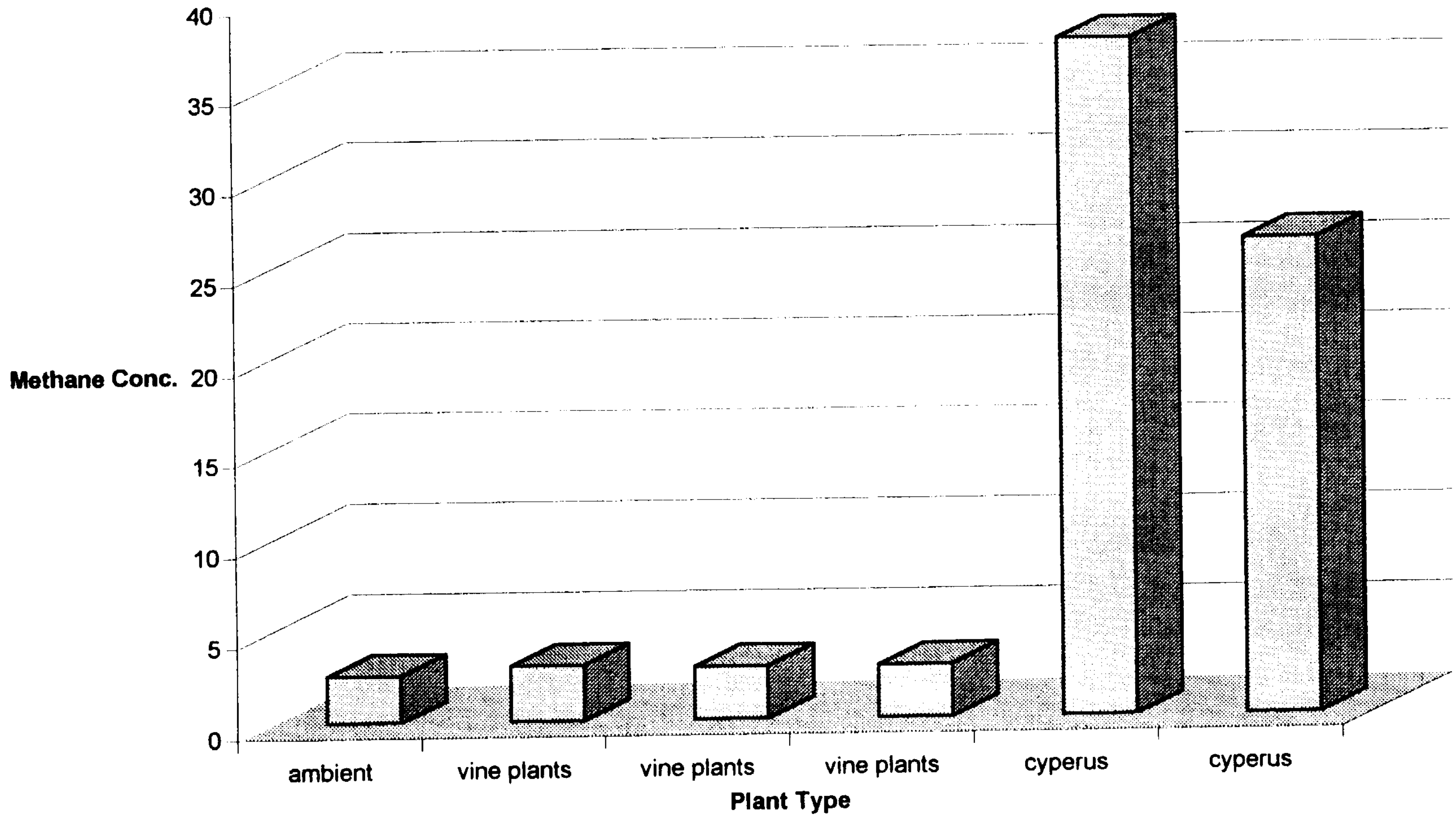
GRAPH 3

Comparisson of flux in mg/sq.m/min for Rainforest Biome Closures and Box Fluxes

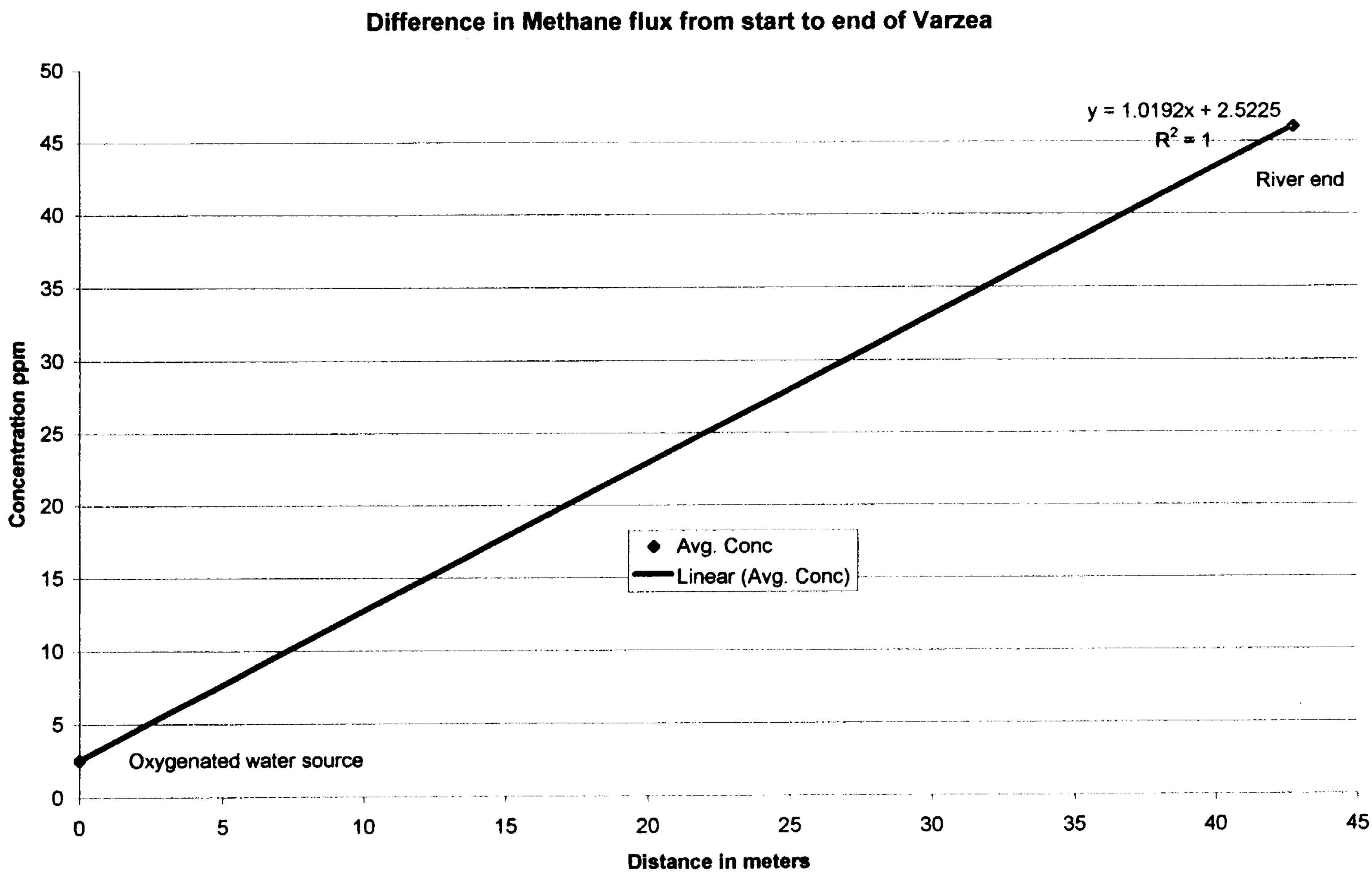


GRAPH 4

Graph showing Internal air samples of plants along Site 2

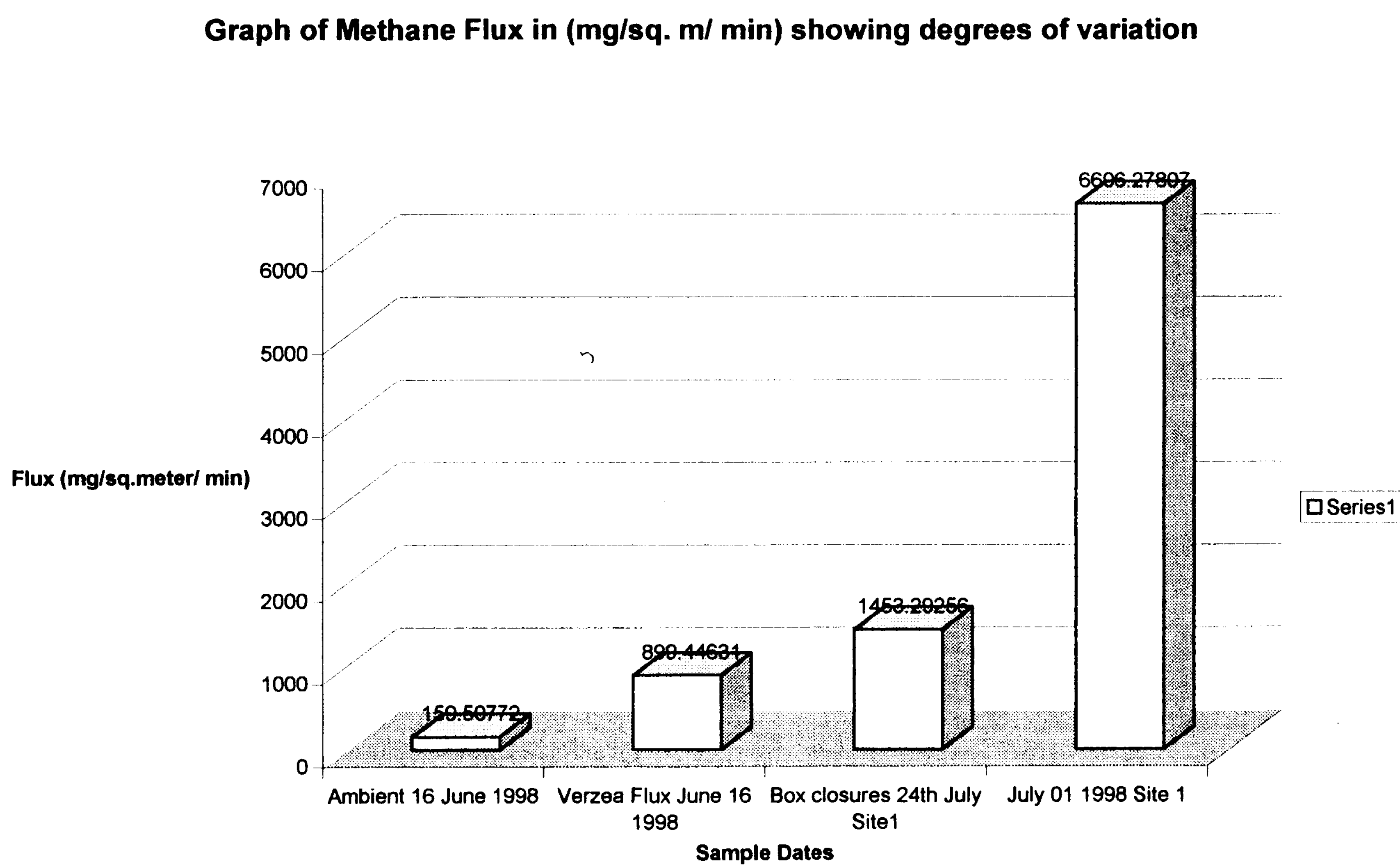


GRAPH 5



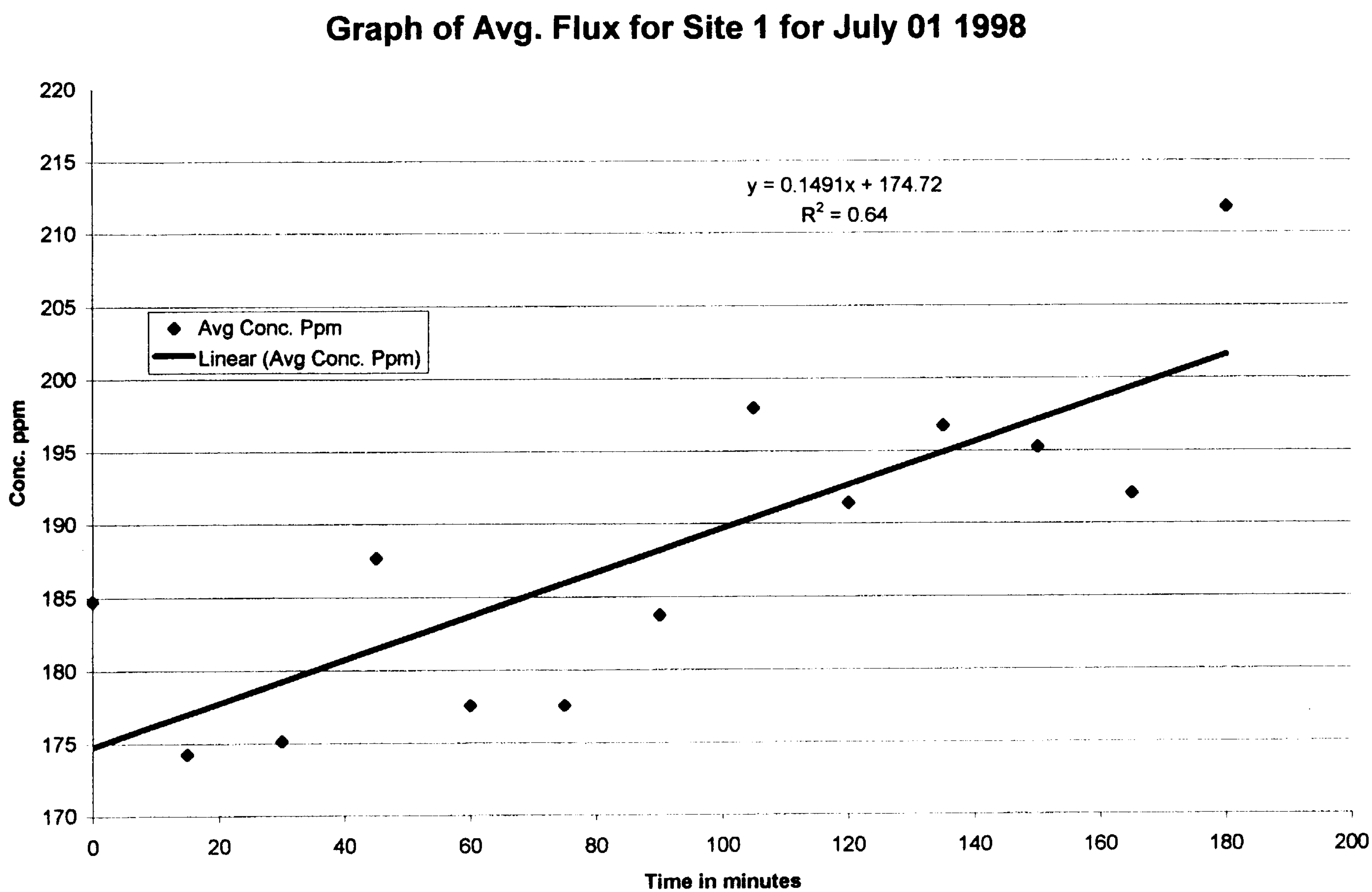
Difference in Methane flux from start to end of Varzea
Concentration ppm
Distance in meters
0
5
10
15
20
25
30
35
40
45
50
y = 1.0192x + 2.5225
R² = 1
River end
Oxygenated water source
Avg. Conc
Linear (Avg. Conc)

GRAPH 6



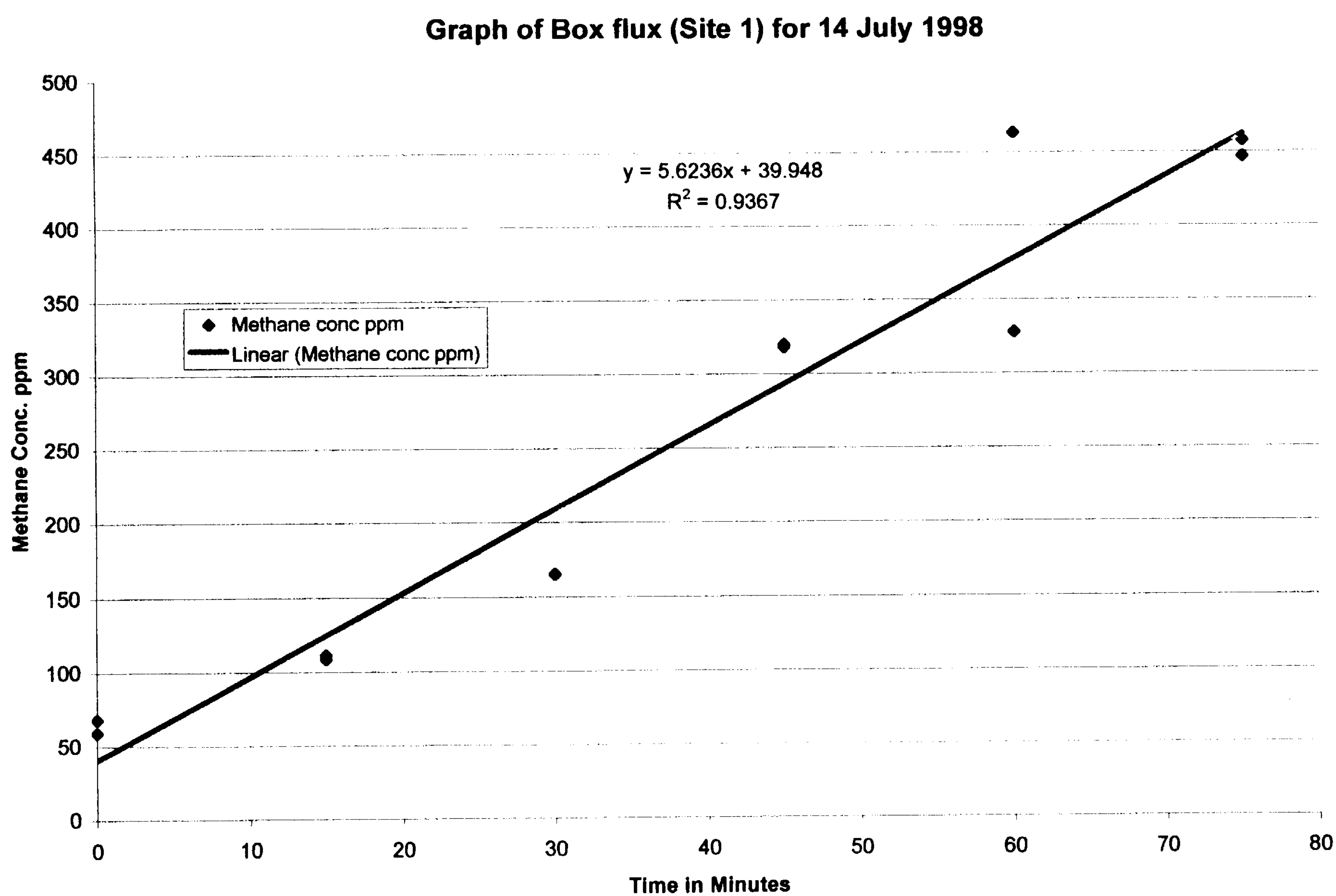
Graph of Methane Flux in (mg/sq. m/ min) showing degrees of variation
Flux (mg/sq.meter/ min)
7000
6000
5000
4000
3000
2000
1000
0
150.50772
899.44631
1453.29256
6606.27807
Ambient 16 June 1998
Verzea Flux June 16 1998
Box closures 24th July Site1
July 01 1998 Site 1
Sample Dates
Series1

GRAPH 7



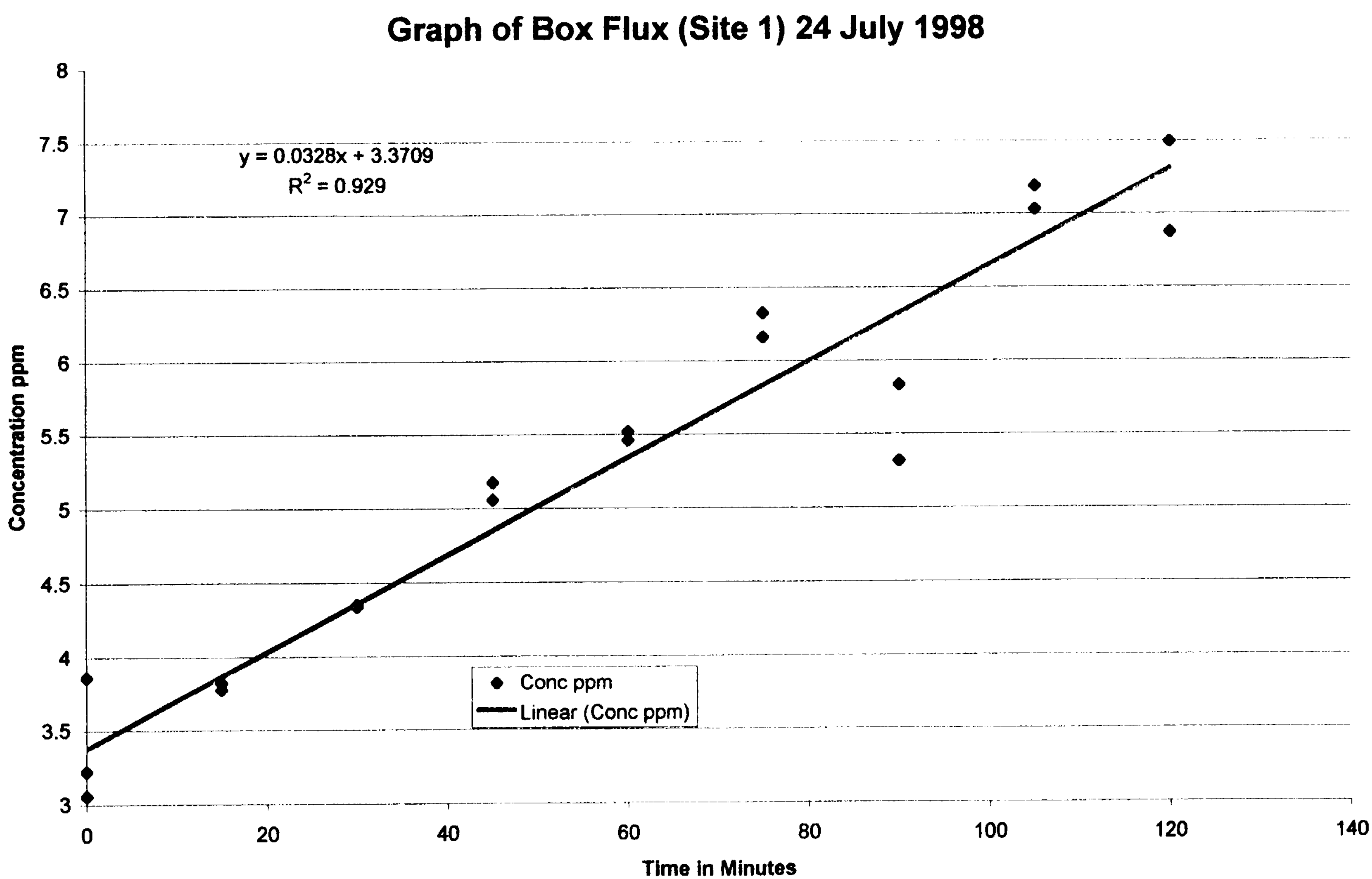
Graph of Avg. Flux for Site 1 for July 01 1998
y = 0.1491x + 174.72
R2 = 0.64
Avg Conc. Ppm
Linear (Avg Conc. Ppm)
Conc. ppm
220
215
210
205
200
195
190
185
180
175
170
0
20
40
60
80
100
120
140
160
180
200
Time in minutes

GRAPH 8



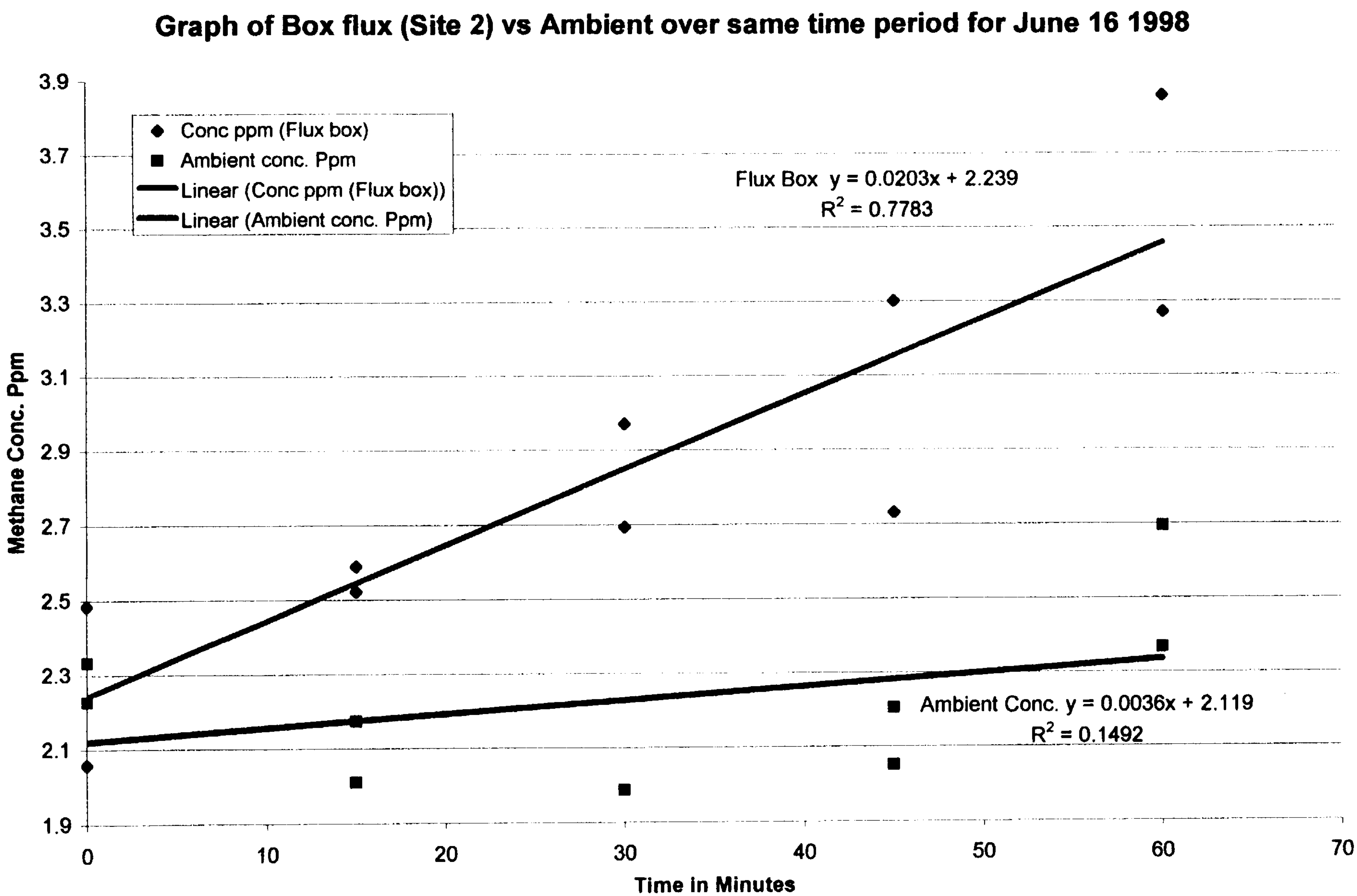
Graph of Box flux (Site 1) for 14 July 1998
Methane conc ppm
Linear (Methane conc ppm)
y = 5.6236x + 39.948
R2 = 0.9367
Methane Conc. ppm
Time in Minutes
0
50
100
150
200
250
300
350
400
450
500
0
10
20
30
40
50
60
70
80

GRAPH 9

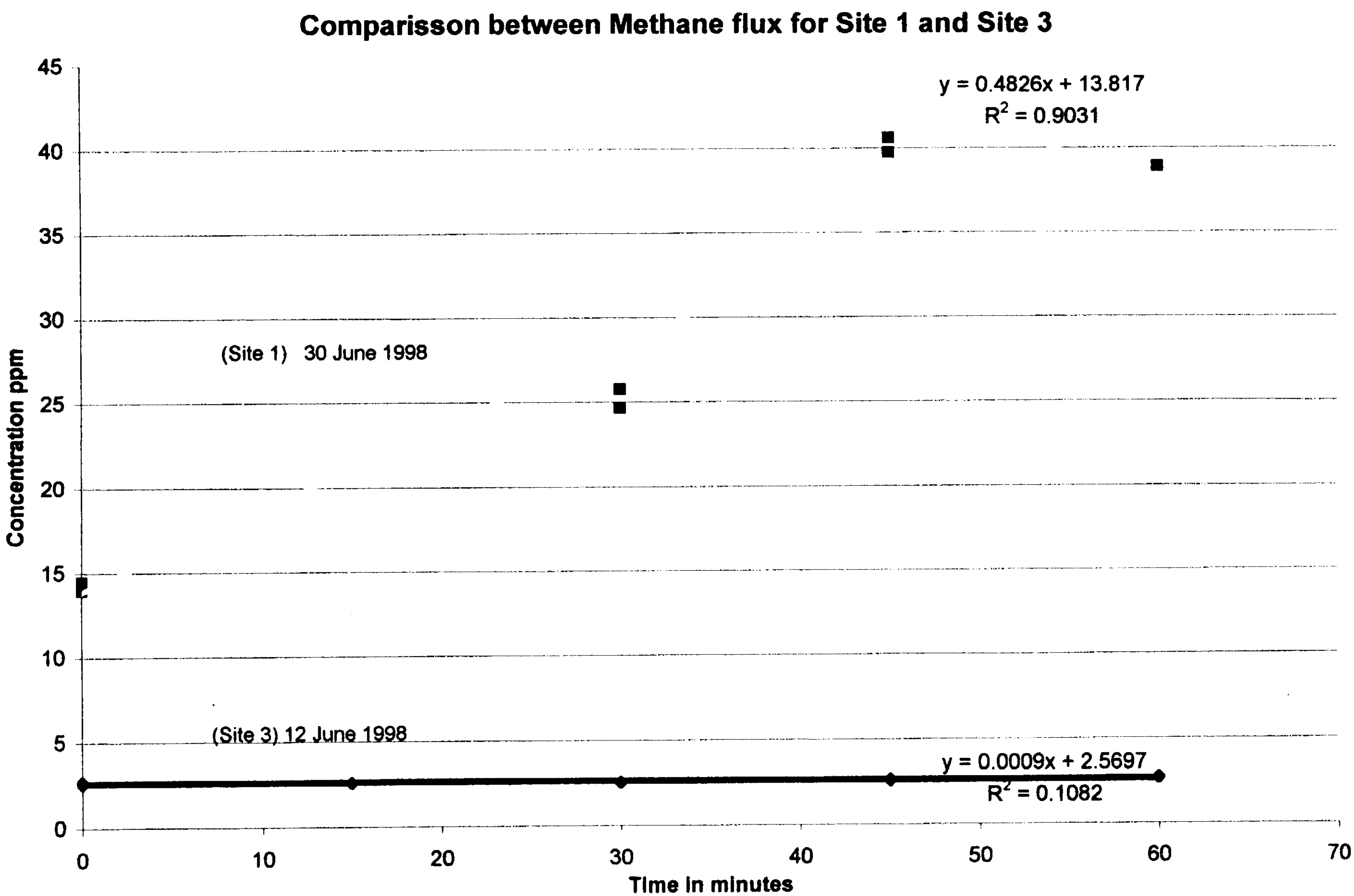


Graph of Box Flux (Site 1) 24 July 1998
y = 0.0328x + 3.3709
R2 = 0.929
Conc ppm
Linear (Conc ppm)
Concentration ppm
Time in Minutes
8
7.5
7
6.5
6
5.5
5
4.5
4
3.5
3
0
20
40
60
80
100
120
140

GRAPH 10

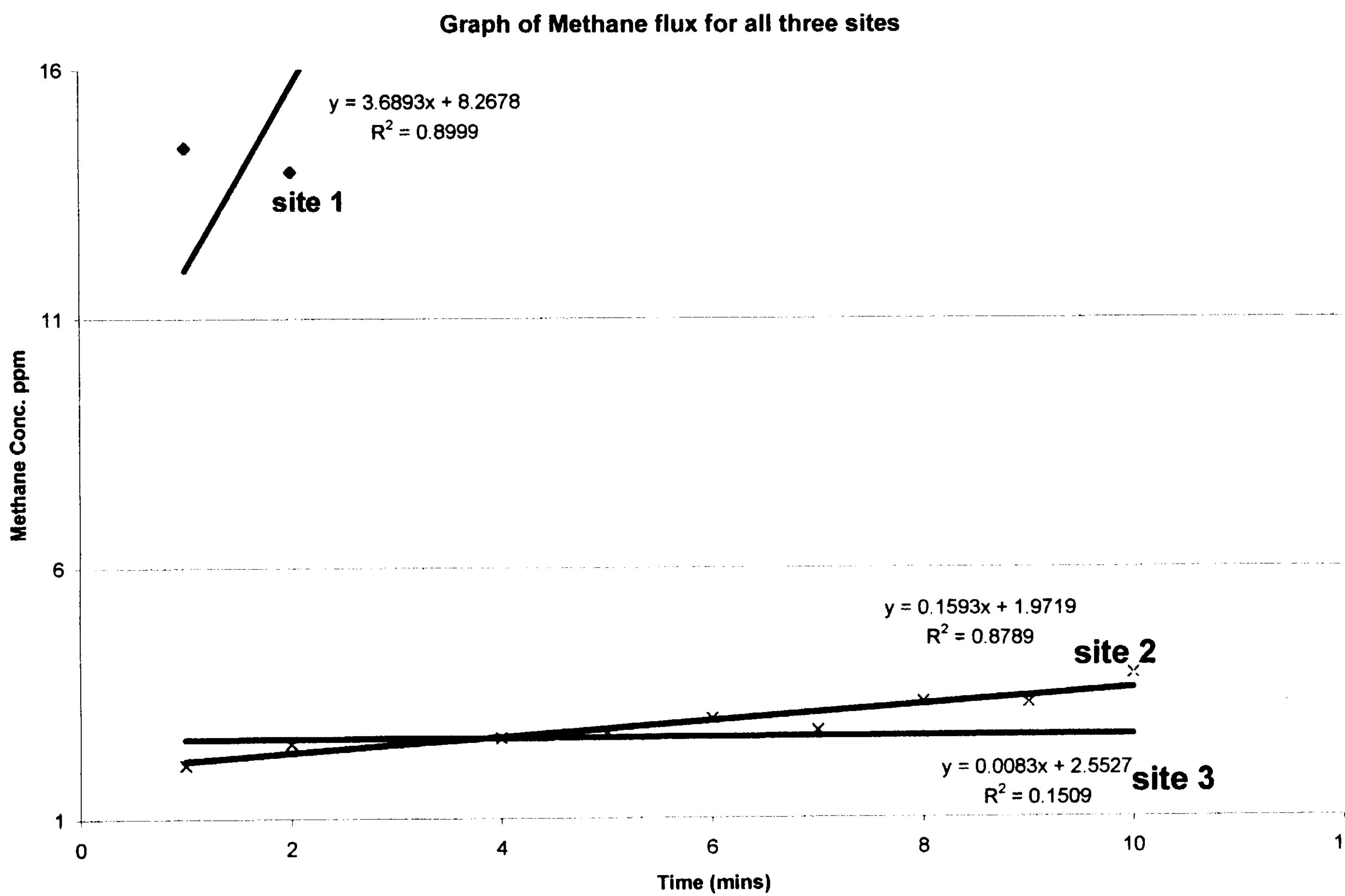

Graph of Box flux (Site 2) vs Ambient over same time period for June 16 1998
Conc ppm (Flux box)
Ambient conc. Ppm
Linear (Conc ppm (Flux box))
Linear (Ambient conc. Ppm)
Flux Box y = 0.0203x + 2.239
R2 = 0.7783
Ambient Conc. y = 0.0036x + 2.119
R2 = 0.1492
Methane Conc. Ppm
3.9
3.7
3.5
3.3
3.1
2.9
2.7
2.5
2.3
2.1
1.9
0
10
20
30
40
50
60
70
Time in Minutes

GRAPH 11

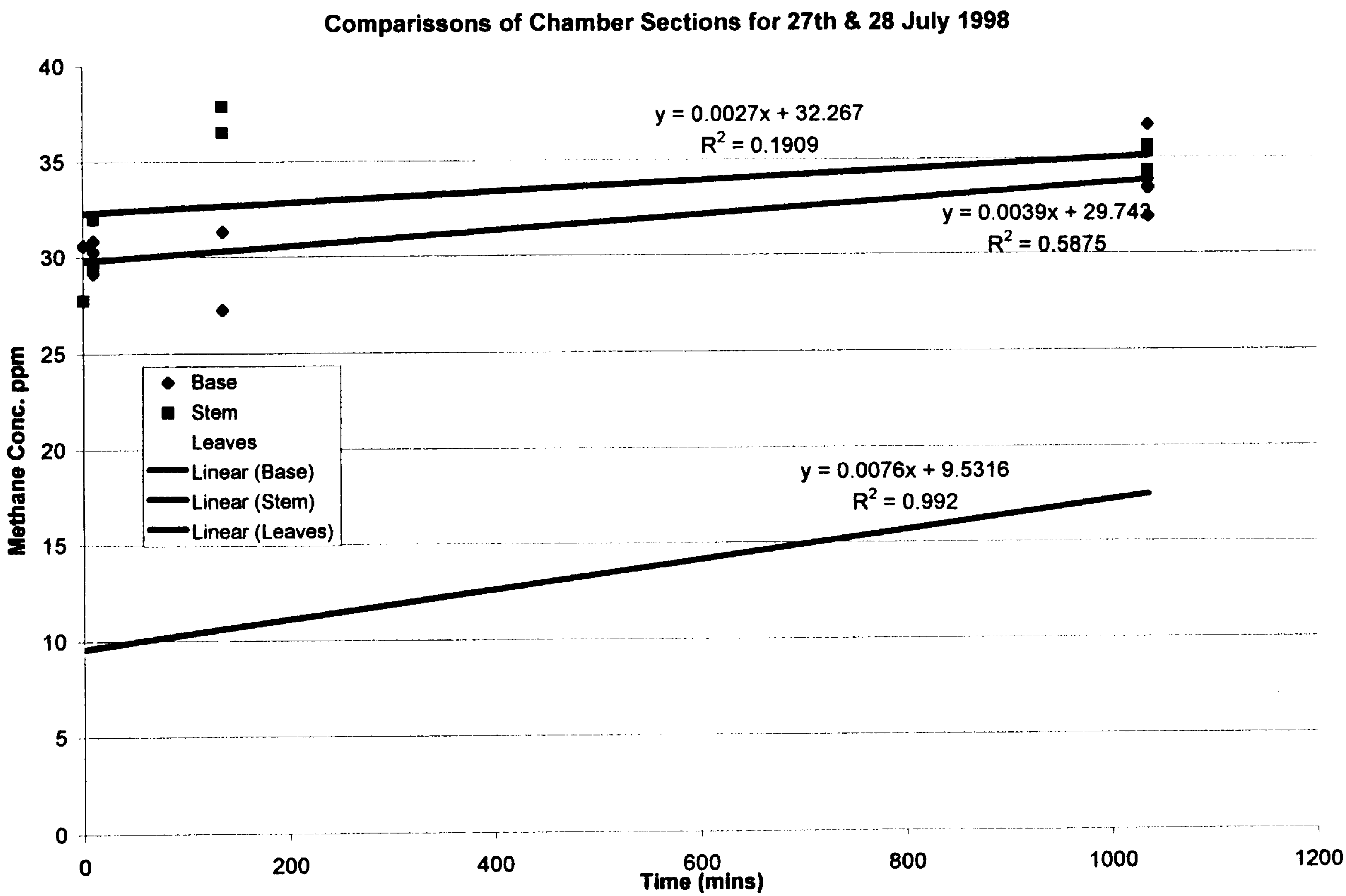


Comparisson between Methane flux for Site 1 and Site 3
y = 0.4826x + 13.817
R2 = 0.9031
(Site 1) 30 June 1998
(Site 3) 12 June 1998
y = 0.0009x + 2.5697
R2 = 0.1082
Concentration ppm
Time in minutes
0
5
10
15
20
25
30
35
40
45
0
10
20
30
40
50
60
70

GRAPH 12


Graph of Methane flux for all three sites
16
11
6
1
Methane Conc. ppm
y = 3.6893x + 8.2678
R2 = 0.8999
site 1
y = 0.1593x + 1.9719
R2 = 0.8789
site 2
y = 0.0083x + 2.5527
R2 = 0.1509
site 3
0
2
4
6
8
10
12
Time (mins)

GRAPH 13



Comparissons of Chamber Sections for 27th & 28 July 1998
Methane Conc. ppm
Time (mins)
0
5
10
15
20
25
30
35
40
0
200
400
600
800
1000
1200
Base
Stem
Leaves
Linear (Base)
Linear (Stem)
Linear (Leaves)
y = 0.0027x + 32.267
R2 = 0.1909
y = 0.0039x + 29.742
R2 = 0.5875
y = 0.0076x + 9.5316
R2 = 0.992

Flux calculations

Flux = [(total moles of chamber) * (slope of methane flux line) * (molecular wt. of methane)] / Area which chamber encloses

1 liter = 1000 cubic cm =1000ml

to find out the no. of moles in a box: 1 mole occupies 22.4 liters

in a mole there are 6.022 * 10 Exp. 23) molecules

we know that 1-liter = 0.001 cubic meters... Thus 22.4 liters = 0.0224 cubic meter

1 mole -------- 0.0224 cubic meters

?????--------- volume of box

thus volume of box in moles = volume of box/22.4 liters since temperature is taken to be ideal ::

total moles within box =

Volume of box *273/ (0.0224 *(273 + temp)) Now the factor 273/(273 + temp) corrects for the gas not being at std. Temperature

slope of curve gives the rate at which methane is coming from the surface over time. ppm/ time... usually ppm/min

Remember methane CH_4 ...We have Carbon + 4 Hydrogen. Molar mass Carbon=12g/mole & 4 Hydrogens @ 4g/mole. So we have 16g/mole

molwt. Molecular wt. Of methane **16g/mole** or **16000mg/mole** or **0.016kg/mole**

FLUX BOX (FLOATING BOX) REFERS TO THE METAL BOX CHAMBERS USED IN THE EXPERIMENT

Air temperature =29.1 degrees Celsius

Volume of box = 6.9 cm*27.5*27.6cm = 5237.1 cm cubic

1cubic cm = 0.000001cubic m

Volume of cork which protrudes into box = 21.362 cm cubic

Volume of air space for "flux box" = (5237.1)-(21.362)=5215.738 cubic cm

Volume of box in M=0.00521cubic m

Volume of box in liters = 5.21liters

Area of Box=759 sq. cm

Area of floating box=0.0759 sq. meters

Thus flux for dates... FLUX WILL DEPEND ON THE SLOPE OF THAT DATE

Flux

Box chamber

flux = **(totmol*slope*molwt)/area**

Units of methane flux :: total moles = total moles within chamber = Volume of chamber*(273K)/(0.0224 cubic mete

/mole)*(273+air temp.)

Thus we have total moles .... totmol = (0.00521*273)/[(0.0224)*(302.1)] = 0.210 moles

Slope of curve gives the rate at which methane is coming from the surface over time. PPM/ time...

usually ppm/min

molwt. Molecular wt. Of methane **16g/mole** or **16000mg/mole** or **0.016kg/mole**

Applying values to equation :: We have **flux = (totmol*slope*molwt)/area**

{[(0.00521*273)/(0.0224)*(302.1)]*slope*0.016}/0.0759 kg/meter sq./day

Total moles in box = 0.210. Thus we have **{0.210 * 0.016kg/mole * slope}/ 0.0759** sq. meters

Final equation ={(0.00336 * slope)/0.0759} =**0.044*slope** Bear in mind that units are **kg/meter sq./min**

Thus flux for box chamber in mg/meter sq. /day = **{[(0.00521*273)/(0.0224)*(302.1)]*slope*16000}/0.0759**

Thus we have [(**0.210*16000**)*(**slope**)]/**0.0759** = (3386.5*slope)/0.0759 **mg/meter sq./min**

Final equation for all box flux =44307.7*slope **mg/meter sq./min**

Methane gradient calculations

ppm/24hrs=ppm/60x24...=ppm/min

1 part per million =1 micro mole /mole

1ppb=1 part 1,000,000,000

1 part per 1,000 million =1 micro mole/1000moles

1part per billion = 1 micromole/1000 moles

Flux

Rainforest Biome at Biosphere2

Volume of rainforest =26700 cubic meters 26,700,000 liters

Area of rainforest =2000 sq. meters

1 liter = 1000 cubic cm

1 cubic meter =1,000,000 cubic cm

1 cubic meter =1,000 liters, so 1 liter =0.001cubic meters

Average daily temperature of rainforest =27.778C

molwt. Molecular wt. Of methane **16g/mole** or **16000mg/mole** or **0.016kg/mole**

Units of methane flux ::total moles = total moles within rainforest =

Volume of Rainforest*(273K)/(0.0224 cubic meters /mole)*(273+air temp.)

flux = **((26700cubic m* 273)*(slope)*(0.016kg/mole))/(2000sq.m)*(0.0224 cubic meter/mole)*(273+27C)**

{[26700*273)/(0.0224)*(300)]*slope*0.016}/2000....=**(1084687.5*slope*0.016)/2000** kg/meter sq./min

Final equation =8.6775* slope Bear in mind that units are **kg/meter sq./min**

Final equation = 8677500* slope Bear in mind that units are **mg/meter sq./min**

To change flux measurements from **mg/meter sq. /day** to **mg/meter sq. / 1440 min**

To change flux measurement from **mg/meter sq./ day** to **mg/ meter sq. /86400 seconds**

Consider this :: many papers refer to flux as **molecules / cm. sq./ sec**

Thus we have 6.022 * 10 Exp.23 molecules per mole

For methane Molecular weight = 16000 mg per mole
Thus 16000mg per 6.022*10 Exp. 23 molecules

1 mg per $\frac{(6.022*10 \text{ Exp. } 23)}{16000}$ molecules

Thus 1 mg of Methane = (6.022*10 Exp. 23)/ 16000 = (3.763 *10 Exp. 19) molecules

Therefore **mg/ meter sq./day to molecules / cm. sq. / sec**
(3.763*10 Exp. 19) **Molecules / meter sq./ day** = (3.763*10 Exp. 19) **Molecules/ 10000 sq. cm / day** =

(3.763*10 Exp. 19)**Molecules / 10000 sq. cm/ 86400 sec.**

Making 500ppm stds.

Evacuate 6 liter bottle and filled with nitrogen up to 20psi.
Dimensions of bottle. Circumference = 72 cm.
Thus circumference $=\pi*r*2$…… thus $72 = \pi * D$
$D=70.9/\pi = 22.6$ cm
Inner Radius = 11.29 cm
Volume of cylinder $= 4/3 * \pi * R^3 = 4/3 * \pi * (11.29)^3$
Volume of cylinder = 6027.96 cubic cm =6028 cubic cm.
Now PV=nRT
To change PSI – Atmospheric pressure
PSI* 0.0680460.
Thus 20 PSI = 20*0.0680460=1.36 Atm.
Volume 6302 cubic cm.
Pressure $= 1.36 * 1.01325 * 10^5$ N/m^2 =137895 N/m^2
Volume = 6028*10(-6) cubic meters
Volume = 6.028 * 10(-3) cubic meters
Molar mass of nitrogen = 14.0067 g/mole
Temperature = 20 degree C = 293K
Now 1 mole of an ideal gas occupies a volume of 22.414 liters @ 1 atm. pressure.
Thus R = 8.314 $\frac{\textbf{Kpa -L}}{\textbf{Mol-K}}$

PV= nRT
Thus, n = PV/RT

$$\frac{\textbf{137895N/sq. m * 6.028*10(-3) cubic meters}}{\textbf{8.314 * 293}}$$

Thus in cylinder filled with 20PSI nitrogen we have 0.341 moles.

Now 1ppm = 1 micro mole / mole
500ppm = 500 micro mole / mole
500 ---------1
? --------- 0.341
500*0.341= 170.5 micromoles of methane
Atmospheric pressure = 888 millibars
Thus volume of methane needed for injection

$$= \frac{\textbf{8.341*\{170.5/ 10(exp.6)\} *\{293\}}}{\textbf{88760}}$$

=0.000004694 cubic meters methane
=4.69*10(-6) cubic meters
=4.69*10(-3) liters
=4.69 ml
Thus for a std of 500 ppm methane we need to inject 4.69 ml of methane in a 6 liter cylinder filled with nitrogen @ 20 psi.

Courtney's Chamber Calculations

The Courtney Chamber is sealed and segmented in four segments Base of Chamber, Stem Base, Stem Tube and Leaf Cylinder

Base of Chamber
Height of Air Space = 11cm
Circumference 132.5
132.5=2*(pie)*r
r=21.08 cm
Area =1396 sq.cm.
Volume of Base= 15356.2 cubic cm

Stem Base
Circumference = 85.5 cm
Height 6.5 cm
85.5 =2*(pie)*r
r= 13.607
Area = 581.73 sq.cm
Volume = 3781.25 cubic cm
Circumference of base pipe = 32.7 cm
Area = 85.09 sq. cm
Height =4.0 cm
Volume = 340.36cubic cm
Total Volume=4121.61 cubic cm

Stem Tube
Length= 48.5cm
Inner Radius=2.5cm
Area=19.634sq. Cm
Volume=952.29 cubic cm

Leaf Cylinder = 10 liters

Mass Balance Calculations

Information For Dimensions of "Courtney Chamber"

1 liter 1000 cubic cm

Volume of base of chamber = 15356.2 cubic cm = 15.3562 liters

Volume of stem Base = 4121.61 cubic cm = 4.12161 liters

Volume of Stem Tube = 0.95229 liters

Total Stem Volume = 5.0739 liters

Volume of Leaf Cylinder = 10 Liters

Flux from plant chamber sections

Base of chamber = 15.3562 liters

Using Equation for Flux = (Tot. moles* Slope*mol.wt.)/area

Avg. Chamber Temperature. = 27 degrees C

Flux = {(15.3562*273)/(22.4)*(302.1)}*slope*16000}/1.396

Thus flux for Base =7100*slope = FLUX mg/sq.cm./min

Total Stem Tube Volume = (Stem Base + Stem Tube) = 5.0739 liters

Using Equation for Flux = (Tot. moles* Slope*mol.wt.)/area of plant stem

Avg. Chamber Temperature. = 27 degrees C

We make calculations for area in terms of stem area as that is the area flux will be emitted from (The stem of the plant)

Avg. stem Diameter =0.6 cm

Radius of stem = 0.3 cm

Circumference of stem = 1.884 cm

Length of stem in tube = 55cm

Chart of methane Concentrations and Fluxes (mg/sq. cm. /min) for chamber segments

Time	Base	Stem	Leaves	Base Flux	Stem Flux	Leaves
15:20	30.5834	27.724	9.5526	-53.25	1.740	0.028382
15:30	30.8502	31.9754	9.744			
15:30	29.1218	32.132	9.6686			
15:30	30.2818	29.3596	9.4366			
17:45	31.3084	36.5197	10.9156			
17:45	27.2368	37.8624	10.15			
32:45:00	33.3616	35.6004	17.574			
32:45:00	36.7256	34.0025	17.3188			
32:45:00	31.8942	35.2814	17.98			
32:45:00	33.4602	34.3012	16.7852			

Thus Total flux that come from each sq. cm of Cyperus alternifolius (leaves & Stem) every minute = 1.740 mg + 0.028 =1.768 mg./minute

Consider this Circumference

If we estimate the area of the water logged vegetated region on the mountain top to be 28 sq. meters

Assuming the Average Height of the Cyperus is 200cm =2m

Then flux from plant = 200*1.768 = 353.74 mg/min for ever plant

We estimate that eight plant stems fit in one cm.

Thus, horizontal flux from these (vertical plant columns) =2122.44 mg/cm/min

Now cloud mountain = 28 sq. meters

We have 1 meter = 10,000 sq. meters

Thus area of cloud mountain = 280,000 sq. cm

In 1 minute we have **594283200 mg** of methane for **most productive site**.

However from Historical Data we see that many parts in the rainforest act as a methane sink. Applying our flux equation to these values we get

Chart showing Historical data (Fall 1997) for different box chamber sampling in the Rainforest Biome

FALL 1997 Data	slope	Flux mg/sq. m/min	Average slope	Avg. Flux mg/sq.m/min
RF1 (10/10)	-0.00381	-33095.7	-0.01107	-96086.7
RF2 (10/10)	-0.00278	-24147.8	0.011593	100598.7
RF 1S (10/21)	-0.00733	-63564.6		
RF2 (10/21)	-0.0064	-55530.5		
RF1 (10/31)	0.00735	63782.4		
RF2 (11/11)	0.003173	27531.97		
RF1 (11/7)	-0.00728	-63208.8		
RF2 (11/7)	0.017602	152745.1		

Chart showing Box fluxes (mg/sq. cm/min) for Site 1 sampling

Ambient 16 June 1998	159.50772
Box closures 24th July Site1	1453.29256
Box closure 6/30/1998 Site1	21382.89602
July 01 1998 Site 1	6606.27807
Box values for 14th July 1998(Site 1)	249168.7817
16 July 1998 Box closure Site 1	200137.8809

If we compare these values to the net rainforest flux

Table of 1998 Rainforest closures showing net methane concentrations

Flux Dates	March 1998	April'10 1998	April 27 1998	May 1998	June 1998
grad ppm/hr	0.018638889	0.015272495	0.013289553	0.006716	0.009365
grad ppm/min	0.000310648	0.000254542	0.000221493	0.000112	0.000156
flux mg/sq.m/min	2695.649306	2208.784529	1922.001638	971.2855	1354.385

At a glance we have on average	**Net Flux**	**+1830.4 mg/ sq. m/min**
	Net Cyperus production	**+2122.44 mg/cm/min**
	Net Sink	**-96086.7 mg/cm/min**
	Net Flux from Varzea	**+899.44361 mg/cm/min**

Assuming that Net sink is representative of these Fluxes and that it is indeed correct. The next step will be to determine accurately the areas of rainforest that are Net Sources and Net sinks over *Delta T.* (say 1 minute) These values show that there is a net sink in the rainforest that is not accounted for.

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